Consulting Port and Coastal Engineers

# PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE REHABILITATION

**PRE-FEASIBILITY STUDY REPORT**

FEL 2 STUDY

REV. 02

26 March 2019

TRANSNET NATIONAL PORTS AUTHORITY
Port Elizabeth, South Africa

TRANSNET

national ports authority

PRDW
Consulting Port and Coastal Engineers

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## ACRONYMS

| | |
|---|---|
| **BH** | Bore hole |
| **BS/EN** | British standards/European norm |
| **CD** | Chart datum |
| **c/c** | Centre to centre |
| **DUR** | Design utilization ratio |
| **EIA** | Environmental impact assessment |
| **FEL** | Front-end-loading |
| **FOS** | Factor of safety |
| **GPS** | Global positioning system |
| **HAT** | Highest astronomical tide |
| **kN** | kiloNewton |
| **kNm** | kiloNewton metre |
| **kPa** | kiloPascal |
| **LAT** | Lowest astronomical tide |
| **m** | metre |
| **MBS** | Multi-beam survey |
| **MCA** | Multi-criteria analysis |
| **MS** | Microsoft |
| **SLS** | Serviceability limit states |
| **t** | Metric ton |
| **ULS** | Ultimate limit states |
| **ϕ** | diameter |

# EXECUTIVE SUMMARY

## Terms of reference

The Old Tug Jetty sheet pile wall, located in the Port of Port Elizabeth, comprises steel interlocking 'U' sheet pile sections together with dead man anchors and a concrete capping beam. The jetty wall was constructed in the mid 1970's and extends approximately 246.2 m with an advertised berth depth of approximately -4 m CD.

The sheet piles have corroded significantly with large holes visible in the tidal zone. These holes have caused leaching of backfill material resulting in the subsidence of the back of quay area.

PRDW have been appointed by Transnet National Ports Authority (TNPA) to conduct a pre-feasibility (FEL 2) study for the rehabilitation of the Old Tug Jetty sheet pile wall.

## Condition assessment

From the available information, it was concluded that:

- The current deterioration of the sheet pile wall is ongoing and will get progressively worse;
- Given the advanced state of deterioration the ability of the structure to fulfil its functional requirement is uncertain;
- The progressive weakening of the steel sheet piles because of corrosion could result in a sudden failure if the holes in the piles grow unchecked;
- Doing nothing would eventually result in the abandoning or condemning of the quay due to safety concerns;
- The option of cladding the existing wall to rehabilitate it is fatally flawed since steel deterioration will continue resulting in uncertainty regarding the remaining service life; therefore
- Replacement is the only practical solution that would provide certainty with regards to the future life span of the facility.

## Recommended rehabilitation option

Based on the current condition of the structure and the results from the optioneering and multi-criteria analysis, a counterfort wall and deck on pile hybrid is recommended as the preferred option. This option comprises 2 phases. Phase 1 entails the construction of a counterfort wall with berth depth of -5.2 m CD.

Thereafter, if there is sufficient demand for a deeper berth, the structure can be upgraded by implementing phase 2. Phase 2 expansion entails the construction of an adjoining deck on pile structure partially supported by the counterfort wall with a design berth depth of -6.5 m CD.

The primary factors governing the selection of the counterfort wall and deck on pile hybrid over other structures were constructability, modest construction schedule, maintainability and provision for future increase in berth depth and structural loading.

The estimated construction duration and cost for the counterfort wall and deck on pile hybrid is summarised in Table 1. These estimates are based on the assumptions set out in Sections 10, 11 of this study and the multi-criteria analysis (see Annexure B).

**Table 1: FEL 2 construction cost and duration summary**

| Phase | Pre-feasibility study (FEL 2) estimates | |
|---|---|---|
| | Project cost | Construction duration |
| Phase 1: Counterfort wall | R 157 million | 12-15 months |
| Phase 2: Deck on pile | R47 million | 9-10 months |

## Framework for FEL 3 study

Based on the findings of this FEL 2 study and the condition of the existing structure it is recommended that this project move into the FEL 3 stage. Limited site information was available for the FEL 2 study and there are still several uncertainties that need to be addressed in the next phase (FEL 3) of this project. These uncertainties include, and are not limited to, the structural integrity of the sheet piles, dead man anchors, the depth of the sheet pile toe, condition of the rock fill in front of the existing sheet pile wall and finally the geotechnical conditions.

To progress this project further a number of site investigations are required, assumptions in this FEL 2 study need to be verified and detailed design work needs to be carried out (FEL 3) before the construction stage (FEL 4) can commence.

The estimated study duration and costs are summarised in Table 2 below. These estimates are based on the assumptions set out in Section 11 of this study. A detailed breakdown of the cost and duration can be found in Section 11.3 and 11.4.

**Table 2: FEL 3 study cost and duration summary**

| Phase | Feasibility study (FEL 3) estimates | |
|---|---|---|
| | Study cost | Study duration |
| Phase 1: Counterfort wall | R 9.65 million | 22 months |
| Phase 2: Deck on pile | R 4.50 million | 17 months |

It should be noted that the study duration is dictated by the duration of the environmental impact assessment. The FEL 3 engineering study is 9 months of phase 1 and 5½ months for phase 2.

## Conclusion and recommendations

Based on the findings of this FEL 2 study and the condition of the existing structure it is recommended that the Old Tug Jetty sheet pile wall be rehabilitated as soon as possible.

However, should the rehabilitation not proceed due to a lack of immediate funding or other issues, it is recommended that the Old Tug Jetty sheet pile wall be surveyed and monitored at least on a bi-annual basis going forward. If excessive movement of the wall is observed, the structure should be decommissioned until it has been rehabilitated.

**TRANSNET NATIONAL PORTS AUTHORITY**

PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE REHABILITATION

PRE-FEASIBILITY STUDY REPORT

PRE-FEASIBILITY STUDY (FEL 2)

# 1. INTRODUCTION

## 1.1 Project background

PRDW have been appointed by Transnet National Ports Authority (TNPA) to conduct a pre-feasibility (FEL 2) study for the rehabilitation of the Old Tug Jetty sheet pile wall. The Old Tug Jetty sheet pile wall is located within the Port of Port Elizabeth, refer to Figure 1-1. The site extents are 246 m with an advertised berth depth of -4 m CD. The jetty wall was constructed in the mid 1970's and comprises steel interlocking 'U' sheet pile sections together with dead man anchors and a concrete capping beam.


**Figure 1-1: Old Tug Jetty site extents**

As can be seen in Figure 1-2 below, the sheet piles have corroded significantly with large holes visible in the tidal zone. These holes have caused leaching of backfill material resulting in the subsidence of the back of quay area. TNPA has undertaken numerous repair campaigns involving filling of holes with soilcrete. However, the continued deterioration of the sheet pile wall has resulted in an unsustainable maintenance regime.

**Figure 1-2: Extent of sheet pile corrosion**

The quay wall is currently being used for the berthing of fishing vessels and trawlers. The northern extent of the back of quay area is used for the transhipment of cargo and supplies, while the southern extent is used for boat maintenance.

## 1.2 Current study

The purpose of this study is to determine the most suitable solution to rehabilitate the Old Tug Jetty sheet pile wall to mitigate the risks associated with its current condition.

The risks are, and not limited to, the following:

- Further loss of backfill material which could result in partial collapse of back of quay area;
- Failure of the sheet pile wall resulting in partial or complete failure of the structure;
- Loss of berthing space;
- Adverse impact on port operations;
- Damage to property; and
- Human injury or loss of life;

This report documents the work that has been undertaken by PRDW to date, namely:

- Review of available information and compilation of the Basis of Design (refer to Annexure A) along with an interpretative geotechnical report;
- Conceptual designs and review of options for rehabilitation of sheet pile wall, and selection of the preferred option using a pre-screening assessment and multi-criteria analysis (refer to Annexure B);
- Preliminary design of the selected structure, including drawings and construction cost estimate; and
- Feasibility study (FEL 3) recommendations and project controls with cost estimate and schedule.

## 1.3 Report structure

The Basis of Design including site information and functional requirements are presented in Annexure A, and the optioneering and multi-criteria analysis is presented in Annexure B. Their content will not be repeated herein.

The structural description of the preferred solution is described in Section 2 with Section 3 presenting the preliminary design methodology. Sections 4 and 5 discusses the design loads and load combinations respectively. The counterfort and deck on pile design is addressed in Sections 6 and 7 with health, safety and environmental design considerations in Section 8. Sections 9 and 10 addresses constructability and capital cost estimation for the preferred solution. Section 11 presents the feasibility study (FEL 3) framework with the conclusion and recommendations following in Section 12.

## 1.4 Units

All units are SI unless otherwise denoted.

# 2. STRUCTURAL DESCRIPTION

This section presents the structural description for the preferred rehabilitation option.

## 2.1 Selection of the preferred rehabilitation option

Based on the outcomes from the optioneering and multi-criteria analysis, a counterfort wall and deck on pile hybrid structure was selected as the preferred rehabilitation option for the Old Tug Jetty sheet pile wall. This option comprises of 2 phases.

Phase 1 entails the construction of a counterfort wall with a berth depth of -5.2 m CD. Thereafter, if there is sufficient demand for a deeper berth, the structure can be upgraded by implementing phase 2. Phase 2 expansion entails the construction of an adjoining deck on pile structure partially supported by the counterfort wall with a design berth depth of -6.5 m CD.

The primary factors governing the selection of the counterfort wall and deck on pile hybrid over other structures were constructability, modest construction schedule, maintainability and provision for future increase in berth depth and structural loading.

## 2.2 Counterfort wall and deck on pile structure

The counterfort deck on pile structure comprises of 2 phases and the proposed extents of each phase is illustrated in Figure 2-1 below. Detailed drawings of the proposed solution can be found in Annexure C.


**Figure 2-1: Phase construction of preferred solution**

The phase 1 counterfort wall is 259.3 m long with a maximum cope line offset of 6 m from the existing, tapering as it approaches the boat ramps at each end. The cope level is at +4 m CD with the berth depth varying from -5.2 m CD along the north western face sloping up and tying into the extents of the boat ramps.

The existing sheet pile wall will be abandoned and buried and the back of quay area will be remediated. The construction process consists of dredging marine sediment and the excavation of a thin layer of existing rock fill in front of the sheet pile wall. The risk of excavating in front of the existing sheet pile wall would need to be assessed as part of the next project phase. Thereafter, a filter fabric will be laid on top of the rock fill and along the vertical extents of the sheet pile wall. A stone bed is then placed on top of the filter fabric to create a level bed for the precast counterfort units. The counterfort wall is then seated on the stone bed and scour rock placed on top of its toe. Thereafter, the wall will be backfilled with quarry run and the concrete and civil work completed. Finally, the quay furniture will be installed. Figure 2-2 illustrates the typical cross section of the counterfort wall. The full images depicting the typical sections can be found in Annexure C.

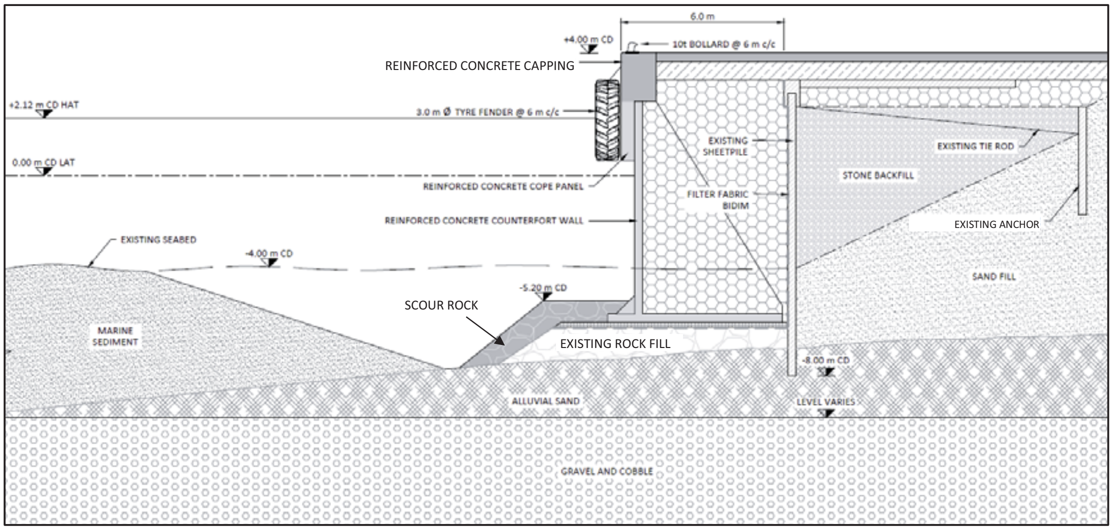


**Figure 2-2: Phase 1 typical section**

If there is sufficient demand for a deeper berth, the structure can be upgraded by implementing phase 2. Phase 2 of the project entails the construction of a deck on pile structure in front of the counterfort wall. The deck on pile jetty is 87.3 m long with further cope line offset of 5.8 m. The cope level is at +4 m CD with a berth depth of -6.5 m CD. The deck on pile length is limited to the extents illustrated in Figure 2-1 because it is not possible to achieve the -6.5 m CD berth depth along the approaches to the slipways as the seabed needs to rise to suit the boat ramp geometry.

The construction process would commence with the dredging of marine sediment. Then the existing quay furniture on the counterfort wall affected by the deck on pile structure would be removed. Thereafter, steel tubular pile casings would be driven at the toe of the existing rock fill, excavated out to toe level and then the reinforced concrete pile cast inside. Precast pile caps would then be seated on top of the pile. Abutments will be constructed into the counterfort units which will house the precast beams and provide lateral support to the deck on pile structure. After placing precast beams, cope panels and planks the elements are stitched together with in-situ reinforced concrete. Finally, the quay furniture would be installed. Figure 2-3 illustrates the typical cross section of the counterfort wall and deck on pile structure.

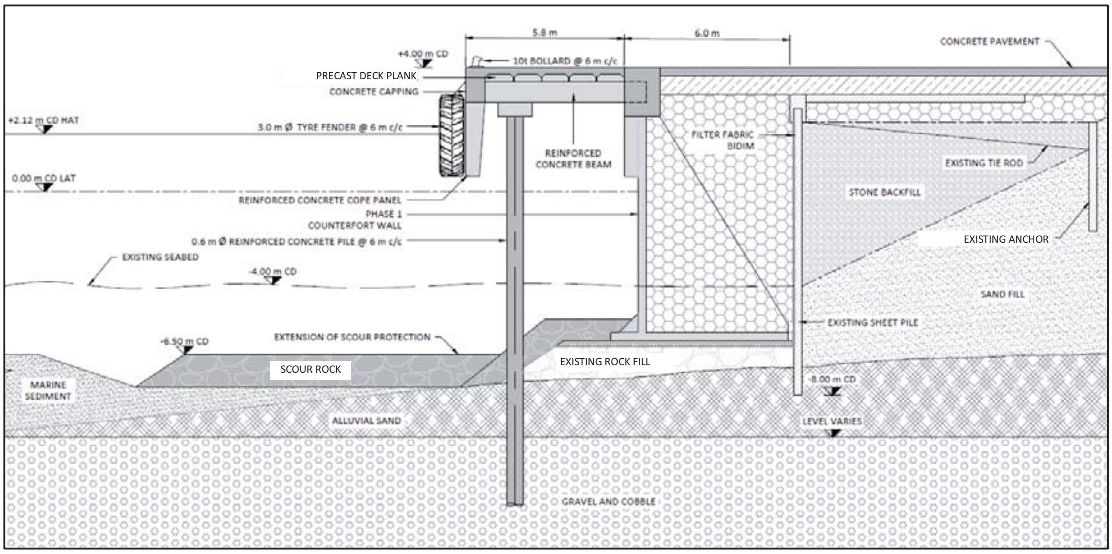


**Figure 2-3: Phase 2 typical section**

## 2.3 Quay furniture

### 2.3.1 Fenders

The berthing loads and fender spacing have been determined in accordance with BS 6349 for the design vessels listed in the Basis of Design (see Annexure A for more information). The chosen fenders are 3 m diameter earthmover tyres spaced of 6 m c/c. Fender type and spacing has been specified based on berthing arrangements of similar facilities in South Africa. The fender size was selected based on its energy absorption capacity to resist the design berthing load.

### 2.3.2 Bollards

A bollard size of 10 t has been selected in accordance with BS 6349 for the design vessels listed in the Basis of Design (see Annexure A for more information). A bollard spacing of 6 m c/c has been selected taking into consideration the recommendations of the TNPA Port Engineering Handbook (2015) and its specification in similar facilities.

### 2.3.3 Safety ladders

Safety ladders are provided at 30 m spacing along the structure in accordance with BS 6349 recommendations. The bottom rung of the ladders will be a minimum of 1 m below LAT, and the fixing of the ladder will be designed for easy replacement. The ladders and grab rails will be designed so that mooring ropes will not snag on them.

### 2.3.4 Life-saving equipment

Life-saving equipment in the form of a 762 mm diameter lifebuoy fitted with 30 m of buoyant line, as required by BS 6349, stored in a covered cabinet and supported on a freestanding upright pole, are provided along the structure.

The lifebuoys will be annular ring lifebuoys and a highly visible orange colour in accordance with the International Convention for the Safety of Life at Sea (SOLAS) and the International Lifesaving Appliance (LSA) code. Lifebuoys are provided at 100 m spacing along the quay.

### 2.3.5 Quayside service requirements

Provision for buried potable water, firefighting, electricity ducts and manholes along the counterfort quay wall has been provided.

In addition, provisions for a concrete pavement between the new quay structure and the back of quay buildings with surface runoff drained towards the landward side has been provided.

# 3. PRELIMINARY DESIGN METHODOLOGY

The preliminary design for the counterfort wall and deck on pile hybrid followed the summarised process listed below:

- Define structure's functional requirements:
  - Required service life
  - Design constraints
  - Determine design vessels
  - Determine operational requirements
- Finalise structural arrangement and geometric constraints:
  - Dependant on site conditions such design water level, founding conditions and design vessel characteristics.
- Determination of governing design criteria.
- Determining critical design checks to be undertaken.
- Compilation of critical design load cases (actions) and combinations.
- Undertaking preliminary member sizing by hand calculations.
- Undertaking modelling to refine preliminary design.
- Finalising preliminary design according to design criteria.

# 4. DESIGN LOADS

This section presents the imposed loads considered in the design of the marine structures. The terms load and action have been used interchangeably.

## 4.1 Permanent loads

The self-weight of the structure has been considered under permanent loads. Permanent loads were determined using the following material densities:

- Structural steel 77.0 kN/m$^3$
- Reinforced concrete 25.0 kN/m$^3$
- Plain concrete 24.0 kN/m$^3$
- Seawater 10.025 kN/m$^3$

## 4.2 Variable persistent loads

### 4.2.1 General surcharge load

A surcharge load of 20 kPa has been used to account for traffic, cargo and material handling equipment as per Section 3.13.13.2 of the TNPA Port Engineering Handbook (2015) recommendations.

### 4.2.2 Berthing loads

The berthing analysis has been undertaken in accordance with BS 6349-4:2014. The berthing energy has been calculated for the design vessel, taking into consideration the berthing conditions, berthing velocity, berthing angle, and the method of approach and departure from the berth. Thereafter, the design berthing energy was corrected using the appropriate design correction factors for temperature, angle berthing, velocity and manufacturing tolerances.

Table 4-1 presents the design berthing energy and resulting berthing load assuming 3 m diameter earthmover tyres are used as fenders. The detailed calculations can be found in Annexure F.

**Table 4-1: Berthing energy and rated reactions for design vessels berthing at 6°**

| Design vessel | Corrected design berthing energy | Design berthing load |
|---|---|---|
| | ($E_{D\ corrected}$) | ($R_{D\ corrected}$) |
| | kNm | kN |
| Krotoa | 193 | 1000 |

### 4.2.3 Mooring load

Bollards will be spaced at 6 m c/c along the length of the structure with bollard sizing specified as 10 t, as per Section 3.13.3 of the TNPA Port Engineering Handbook (2015) recommendation for vessels of a displacement up to 2000 t.

### 4.2.4 Mobile crane load

A mobile crane is used for boat maintenance and repair. A 50 t mobile crane with an outrigger point load of 250 kN was assumed. The crane size was limited by the available back of quay area and inferred from loading as per Section 3.13.10.5 of the TNPA (2015) Port Engineering Handbook.

### 4.2.5 Tidal lag

A tidal lag of 0.5 m has been assumed in accordance with the recommendation of the Portnet Port Engineers Handbook (1994) apply at the back of the counterfort wall to account for the expected phreatic surface differential between the back of wall and free water level as a result of tide cycles.

## 4.3 Variable transient loads

The following variable transient loads have not been considered in the preliminary design:

- Construction loads: premature to include at this phase in the project.
- Seismic loads: according to SANS 10160 – Part 4: 2010 the nominal peak ground acceleration in the region of Port Elizabeth, based on the seismic hazard map, is 0.025g. The seismicity is therefore deemed as benign and will not be included as part of this study.

# 5. LOAD COMBINATIONS

## 5.1 Loads, material and combination partial factors

The design loads/actions detailed above have been factored by the partial and combination factors presented in Table 5-1 below. These factors correspond to set B partial factors presented in BS 6349-2:2010, Table A.1.

**Table 5-1: Partial factors**

| Action description | | Geotechnical action partial factors | | | |
|---|---|---|---|---|---|
| | | Combination 1 | | Combination 2 | |
| | | Unfavourable | Favourable | Unfavourable | Favourable |
| Persistent and variable actions | Permanent actions ($\gamma_G$) | 1.35 | 1.00 | 1.00 | 1.00 |
| | Variable actions ($\gamma_Q$) | 1.50 | 0.00 | 1.30 | 0.00 |
| | Water load ($\gamma_W$) | 1.35 | 0.00 | 1.00 | 0.00 |
| Seismic and accidental actions | Permanent actions ($\gamma_G$) | 1.00 | 1.00 | 1.00 | 1.00 |
| | Variable actions ($\gamma_Q$) | 1.00 | 0.00 | 1.00 | 0.00 |
| | Water load ($\gamma_W$) | 1.00 | 0.00 | 1.00 | 0.00 |
| **Soil parameter descriptions** | | **Soil parameter partial factors** | | | |
| | | **Combination 1** | | **Combination 2** | |
| Persistent and variable actions | Internal angle friction ($\gamma_{\phi'}$) | 1.00 | | 1.25 | |
| | Effective cohesion ($\gamma_c$) | 1.00 | | 1.25 | |
| | Undrained shear strength ($\gamma_{cu}$) | 1.00 | | 1.40 | |
| | Poisson's ratio ($\gamma_v$) | 1.00 | | 1.00 | |
| Seismic and accidental actions | Internal angle friction ($\gamma_{\phi'}$) | 1.00 | | 1.00 | |
| | Effective cohesion ($\gamma_c$) | 1.00 | | 1.00 | |
| | Undrained shear strength ($\gamma_{cu}$) | 1.00 | | 1.00 | |
| | Poisson's ratio ($\gamma_v$) | 1.00 | | 1.00 | |
| **Action description** | | **Structural action partial factors** | | | |
| | | **Unfavourable** | | **Favourable** | |
| Permanent actions ($\gamma_G$) | | 1.35 | | 1.00 | |
| Variable persistent actions ($\gamma_Q$) | Cargo loads | 1.50 | | 0.00 | |
| | Traffic loads | 1.35 | | 0.00 | |
| | Crane loads | 1.35 | | 0.00 | |
| | Wind loads | 1.40 | | 0.00 | |

| | | | |
|---|---|---|---|
| | Temperature | 1.30 | 0.00 |
| | Hydrostatic pressure | 1.40 | 0.00 |
| | Wave loading | 1.40 | 0.00 |
| | Vessel berthing loads | 1.20 | 0.00 |
| | Mooring loads | 1.40 | 0.00 |
| | Forces from ship propulsion | 1.50 | 0.00 |
| **Action combination description** | | **Action combination partial factors** | |
| Characteristic combination value ($\psi_0$) | | 0.70 | |
| Frequent value ($\psi_1$) | | 0.50 | |
| Quasi-permanent value ($\psi_2$) | | 0.30 | |

The formulae in Table 5-2 for ultimate and serviceability limit states have been used to generate the load combinations.

**Table 5-2: Formulae for combination of loads**

| Design situation | Limit state | Permanent actions | Leading variable action | Secondary variable actions | Seismic action |
|---|---|---|---|---|---|
| **Ultimate Limit States (ULS)** | | | | | |
| Persistent and transient | Unfavourable | $\sum \gamma_{Gj,sup} G_{kj,sup}$ | $+ \gamma_{Q,1} Q_{k,1}$ | $+ \sum \gamma_{Q,i} \psi_{0,i} Q_{ki}$ | - |
| | Favourable | $\sum \gamma_{Gj,inf} G_{kj,inf}$ | $+ \gamma_{Q,1} Q_{k,1}$ | $+ \sum \gamma_{Q,i} \psi_{0,i} Q_{ki}$ | - |
| **Serviceability Limit States (SLS)** | | | | | |
| Characteristic | Unfavourable | $\sum G_{kj,sup}$ | $+ Q_{k,1}$ | $+ \sum \psi_{0,i} Q_{ki}$ | - |
| | Favourable | $\sum G_{kj,inf}$ | $+ Q_{k,1}$ | $+ \sum \psi_{0,i} Q_{ki}$ | - |
| Frequent | Unfavourable | $\sum G_{kj,sup}$ | $+ \psi_{1,1} Q_{k,1}$ | $+ \sum \psi_{2,i} Q_{ki}$ | - |
| | Favourable | $\sum G_{kj,inf}$ | $+ \psi_{1,1} Q_{k,1}$ | $+ \sum \psi_{2,i} Q_{ki}$ | - |
| Quasi-permanent | Unfavourable | $\sum G_{kj,sup}$ | - | $+ \sum \psi_{2,i} Q_{ki}$ | - |
| | Favourable | $\sum G_{kj,inf}$ | - | $+ \sum \psi_{2,i} Q_{ki}$ | - |

# 6. COUNTERFORT WALL DESIGN

## 6.1 Functional requirements

The phase 1 counterfort wall has been designed to be robust to achieve a service life of 50 years with minimal maintenance. The sizing of the counterfort has been dictated by the need to limit water area reclaimed to minimise effects on port operations. To assist with constructability, counterfort units will be precast off site and placed into position. There are two large open sites on TNPA property within 150 m from the Old Tug Jetty that could possibly be utilized as a casting yard.

## 6.2 Design criteria

The design of the counterfort wall has been be executed within the framework of the Eurocode design standards, British Maritime Standards BS 6349 suite and a number of complementary and interrelated quality standards, design guidelines and codes of practices presented in the basis of design (refer to Annexure A).

The counterfort wall has been preliminarily sized according to the ultimate limit states criteria for global stability. The wall has been assessed for the following modes of failure according to BS EN 1997-1:2004 design approach 1:

- Overturning – Limit equilibrium method
- Sliding – Limit equilibrium method
- Slip – Morgenstern-Price Method
- Bearing – Brinch Hansen method

If the capacity of the counterfort wall to resist the above modes of failure is greater than the effects from the critical factored load combinations, then the structure is deemed to be sufficiently stable. Results are presented in terms of their design utilization ratios with results less than 1 indicating stability.

## 6.3 Method of analysis

The sizing of the counterfort wall was conceptually developed by hand calculations utilizing industry sizing norms. The following global stability modes of failure were then verified using Fine Geo 5© Prefab Wall (2017) and Slope Stability (2018) software:

- Overturning
- Sliding
- Slip

Bearing capacity has been assessed using a verified, PRDW in house developed MS Excel© spreadsheet.

## 6.4 Design assumptions

The critical design assumptions are as follows:

- The counterfort wall will be backfilled with quarry run.
- Material properties utilized in design according to Basis of Design document (refer to Annexure A).
- Counterfort wall modelled using virtual back wall theory.
- An average effective angle of internal friction for the mobilized soil mass of 38° was assumed to account of various soil horizons for the bearing assessment. This needs to be confirmed by outcomes of the site investigations as part of the FEL 3 study.

- The counterfort wall has been designed for the critical case where the retained height is at its maximum of 9.2 m. The remaining shallower sections of the wall have been sized using the same height to width ratio as the 9.2 m high wall.

## 6.5 Critical load combinations and stability results

The critical load combinations have been determined by applying the design loads listed in Section 4 in various realistic combinations at HAT and LAT that produce the largest design utilization ratio. The critical load combination and corresponding design utilization ratio for the each of the modes of failure is presented in Table 6-1 below. These results are based on the assessment undertaken for the maximum counterfort wall retained height for both project phases.

**Table 6-1: Counterfort wall critical load combinations and results**

| Project phase no. | Critical load combination | | | | Mode of failure | BS EN 1997-1:2004 Design approach 1 combo no. | Design utilization ratio |
|---|---|---|---|---|---|---|---|
| | Leading variable action | Secondary variable actions | Tide level | Tidal lag | | | |
| 1 | Traffic | Mooring | HAT | 0.5 m | Sliding | Combination 2 | 0.45 |
| 1 | Mooring | Traffic | HAT | 0.5 m | Overturning | Combination 1 | 0.43 |
| 1 | Mooring | Traffic | LAT | 0.5 m | Slip | Combination 2 | 0.77 |
| 2 | Traffic | Mooring | HAT | 0.5 m | Bearing | Combination 2 | 0.97 |

Based on the preliminary design for the maximum retained height of 9.2 m, the counterfort units need to be 6.5 m wide and 8.6 m high. The remaining height being made up by the capping beam.

# 7. DECK ON PILE DESIGN

## 7.1 Functional requirements

The phase 2 deck on pile structure has been designed utilizing only reinforced concrete members to achieve a service life of 50 years with minimal maintenance. The arrangement of the deck on pile structure has been dictated by the need to limit water area reclaimed to minimise effects on port operations.

To assist with constructability, as many structural elements as possible will be precast off site and placed into position. Precast elements will include pile caps, beams, deck planks and cope panels. The precast units will be stitched together with in-situ reinforced concrete casts to create a monolithic structure.

Piles were also designed as reinforced concrete elements. To assist with constructability, RC piles will be formed by first driving a sacrificial steel tubular casing to depth, excavating out the inside of the pile, inserting a rebar cage and thereafter filling with concrete.

The deck on pile will tie into the existing counterfort structure by constructing an abutment to house the deck on pile precast beams spanning between the counterfort and the piles. The abutments provide lateral support and transfers all lateral loads from the deck on pile to the counterfort structure.

## 7.2 Design criteria

The design of the deck on pile structure has been be executed within the framework of the Eurocode design standards, British Maritime Standards BS 6349 suite and a number of complementary and interrelated quality standards, design guidelines and codes of practices presented in the Basis of Design (refer to Annexure A).

The deck on pile structure has been conceptually developed to transfer all lateral loads such as berthing and mooring to the counterfort wall. This globally stabilizes the structure negating the need for a global structural model at the preliminary design phase.

The deck on pile structural elements have been preliminarily sized according the ultimate limit state and serviceability limit state criteria. The following design checks have been carried on the deck on pile structural elements according to BS EN 1992-1-2:2004:

- Slab – ULS bending and shear checks and SLS crack width checks
- Beam – ULS bending and shear checks and SLS crack width checks
- Cope panel – ULS bending and shear checks
- Pile – ULS axial load check

If the capacity of the structural elements to resist the critical factored load combination is greater, then the structure is deemed to be sufficiently stable.

In addition, the pile bearing capacity assessment has been undertaken in accordance with Tomlinson 5th Edition (2008) using the safe working stress method.

## 7.3 Method of analysis

The sizing of elements was conceptually developed by hand calculations utilizing industry sizing norms. Thereafter, the sizing of the following elements was verified using approved PRDW in house developed MS Excel© spreadsheets:

- Slab
- Beam
- Cope panel

- Pile foundation design

Finally, the pile structural axial load check was undertaken using Prokon© Structural Analysis (2018) software.

## 7.4 Design assumptions

The critical design assumptions are as follows:

- All structural connections were assumed to be pinned.
- Material properties utilized in the design were according to the Basis of Design (refer to Annexure A).
- Traffic surcharge and mobile crane outrigger loads cannot occur at the same location at the same time.

## 7.5 Critical load combinations and member sizing

The critical load combinations have been determined by applying the design loads listed in Section 4 in various realistic combinations to produce the largest design utilization ratio. The critical load combination, design criteria and required preliminary design element sizes are presented in Table 7-1 below.

**Table 7-1: Deck on pile structural element design results**

| Structural element | Required element dimensions | Critical design criteria | Critical load combination |
|---|---|---|---|
| Slab | 500 mm thick | ULS – bending | Mobile crane outrigger load (only) |
| Beam | 1200 mm wide and 1300 mm high | SLS – crack width | Traffic surcharge load (only) |
| Cope panel | 700 mm thick | SLS – crack width | Berthing load (only) |
| Pile | 600 mm ϕ | ULS – axial load | Mobile crane outrigger load (only) |

Regarding the required pile embedment, the critical load combination was the mobile crane load (only), requiring a minimum embedment depth of 8.5 m

# 8. HEALTH, SAFETY AND ENVIRONMENTAL DESIGN CONSIDERATIONS

## 8.1 Environmental design considerations

The focus of the design effort has been to limit the extent of any temporary works, limit the extent of dredging and limit the new cope line offset ahead of the existing wall. This will limit the loss of water area and minimise the impact on port operations.

## 8.2 Health and safety design considerations

### 8.2.1 Construction safety

The proposed design can be constructed using standard marine methods and does not expose the contractor's personnel to any elevated safety risk. A major focus of the design effort has been to limit diver related activities which is a high-risk work in low visibility environments.

Marine construction by nature is hazardous and for this reason is it important that a marine contractor with suitable experience and with a good HSE track record is contracted to undertake the construction.

### 8.2.2 Operational safety

The following considerations have been made in the design:

- **Safety ladders** – Emergency ladders designed to the general recommendations of BS 6349-2:2010 are required for safety, allowing for a person who is in the water to climb safely on to a structure. Ladders have been provided according to the recommended guideline of 30 m c/c. The bottom rung of the ladder is located 1 m below LAT to facilitate ease of access for persons in the water. In addition, the ladder top handhold is recessed, and no stringers extend above the cope level to prevent snagging on mooring lines.
- **Intermediate hang holds** – Intermediate hang holds between ladders are provided through the use of tyre fenders.
- **Lifesaving equipment** – Lifesaving equipment in the form of a 762 mm diameter life buoy fitted with 30 m buoyant line as required by BS 6349-2:2010 are provided at 100 m spacing along the back of the quay.

## 9. CONSTRUCTIBILITY

To achieve the project execution objectives of:

- Minimising the capital cost of the rehabilitation construction.
- Reduction of the overall construction programme.
- Maximising durability of the completed works.
- Allowing execution to be undertaken at appropriate levels of risk.
- Minimising construction and permanent impact on port operations.

The proposed design solution needs to be subjected to a high-level constructability review. This review needs to identify any risk areas and ensure that they are mitigated through engineering development in FEL 3 or early communications with the construction contractor.

Only the preferred solution is detailed below.

### 9.1 Project site

The project site is located within the Port of Port Elizabeth boundary. Access to the site will need to be through the Baakens River entrance on Lower Valley Road.

There is limited backup area and open space for contractor laydown areas and stockyards. However, there is the potential to utilise the open field close to the site. The locations for contractor site offices and yards needs to be addressed in FEL 3.

**Figure 9-1: Site layout**

### 9.2 Use of the existing wall

One of the major cost drivers on marine construction sites is the mobilisation of specialist marine floating plant and equipment. Although the existing wall is deteriorating the opportunity to use it as a construction platform is a significant cost saver. Similarly, the phase 1 counterfort wall can also be utilised as a platform when constructing the deck on pile in phase 2. The contractor will need to be made aware of any loading and other limitations to the backup area behind the sheet pile wall for phase 1 and the back area behind the counterfort wall for phase 2.

## 9.3 Proposed construction sequence

The following is a proposed sequence for the construction. Construction will be split into two phases as described below. The exact sequence will need to be defined in FEL 3 study.

**Phase 1** – Counterfort wall

- Decommission of Old Tug Jetty sheet pile wall
- Site establishment
- Procurement of materials
- Dredge to appropriate level and remove top layer of rock fill
- Place filter fabric on top of rock fill and along vertical extents of the existing sheet pile wall
- Place stone bed layer
- Cast counterfort units in a casting yard
- Remove all the existing quay furniture and demolish existing structures that obstruct the new works
- Place counterfort units
- Install scour rock on top of counterfort toe
- Backfill counterfort with quarry run
- Place filter fabric on top of quarry run backfill
- Undertake pavement layer works
- Install civil services
- Cast concrete capping beam and cope panel
- Install quay furniture
- Paving to final levels and services fit out
- Commissioning

**Phase 2** – Deck on pile structure

- Partial decommission of Old Tug Jetty counterfort wall
- Site establishment
- Procurement of materials – steel pile casing assumed to be imported
- Dredge to appropriate level
- Remove all the existing quay furniture – store for reuse on the new structure
- Pile installation
  - Install guide frame with required temporary support
  - Drive tubular pile casing to level
  - Excavate out pile using auger, grab and airlift
  - Insert reinforcing cage into pile
  - Tremie concrete to fill pile
- Install scour protection
- Prepare counterfort capping beam to receive deck on pile primary beam
- Place and grout into position precast pile cap
- Deck installation

- Place precast primary beam seated on counterfort wall and pile cap
  - Place precast slab planks between primary beams
  - Hang and brace precast cope panel in position using a construction frame
  - Pour in-situ concrete to stitch precast elements together and form capping beam and deck slab
- Install quay furniture
- Commissioning

The following photographs have been included for reference.

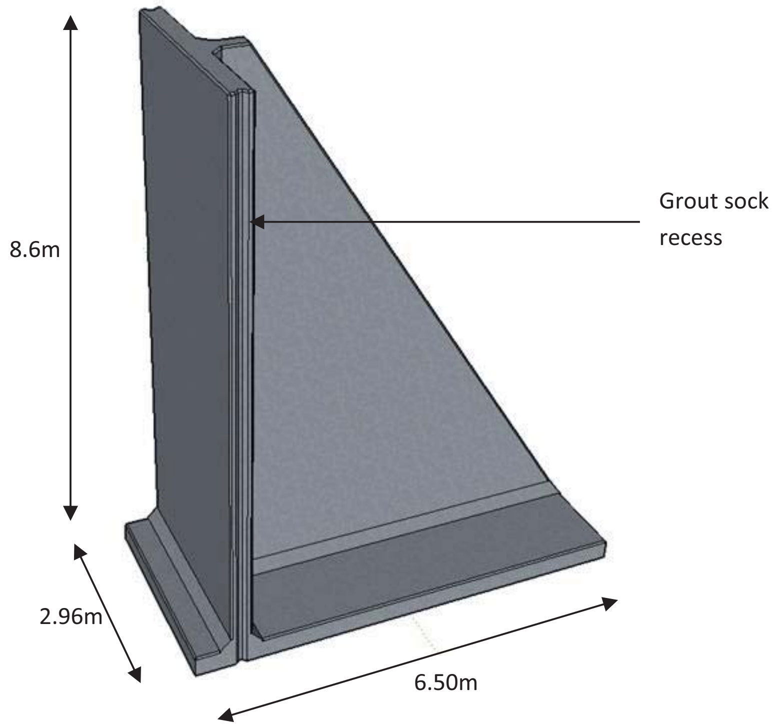


**Figure 9-2: Precast counterfort wall unit**

**Figure 9-3: Concrete capping beam – South Africa, Saldanha Bay, General Maintenance Quay 2015**

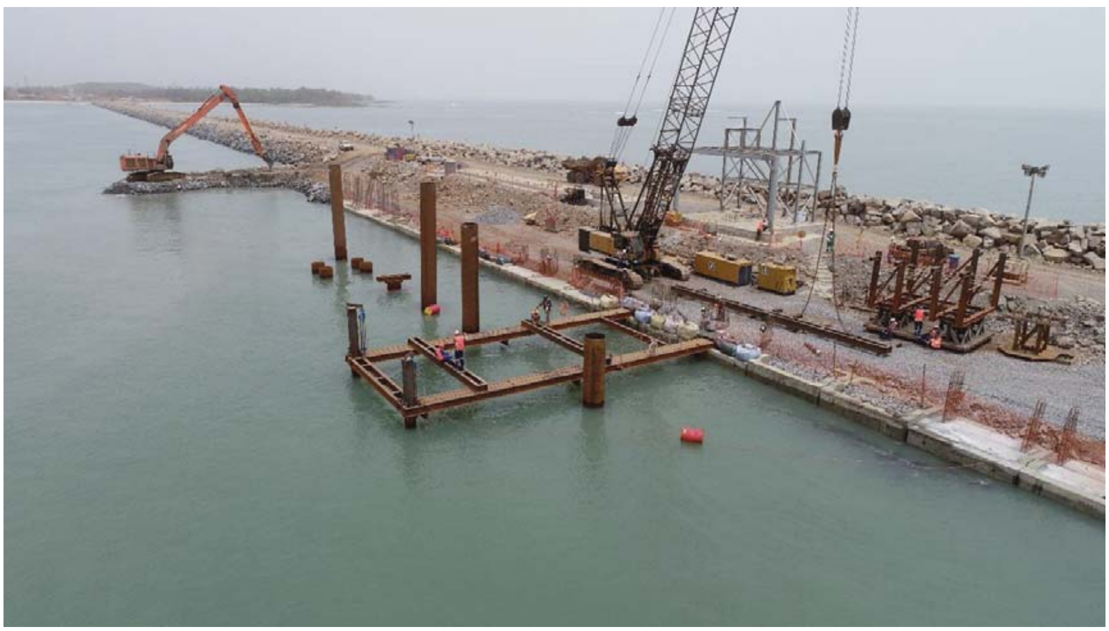

**Figure 9-4: Piling frame – Guinea, Cape Verga, Bauxite Export Port 2018**

## 9.4 High level constructability review

The proposed construction methods are common marine construction practice and there are several local contractors who have sufficient capability to execute the works.

The main risks associated with construction is the potential for delays due to unforeseen geotechnical conditions when constructing the deck on pile structure. It is important that adequate geotechnical investigation work is undertaken at the FEL 3 stage to mitigate this risk. The casting time for the counterfort units should also be taken into account to avoid delays in construction.

# 10. COST ESTIMATE

## 10.1 Capital cost basis

The capital cost estimate for the rehabilitation of the Old Tug Jetty sheet pile wall have been prepared considering the layouts and basic engineering information presented in this report. The costing for the two phases have been kept separate for the instance where the phases are not constructed simultaneously. Additional considerations include:

- The estimate class for the option is set at an AACE Class 4 / FEL 2 level with an agreed level of accuracy of -30 % to +50 %
- The estimates have been derived using a combination of measured preliminary quantities and corresponding current or escalated unit rates largely based upon PRDW's internal rates database supported by indicative market related pricing information. Built-up rates and prices have been used where no relevant rates or prices were available.

The estimate is subject to the following assumptions and exclusions:

Assumptions:

- Cost base dated as at January 2019
- Exchange rate (Dollar) - $ 1.00: R 13.90
- Exchange rate (Euro) - 1.00 €: R 15.90
- Exchange rate (Pound) - 1.00 £: R 17.90
- Contractor has unrestricted access to the berth and use of existing quay during construction
- Existing founding material is suitable for the proposed structure
- All construction for phase 1 will be completed using marine equipment
- All construction for phase 2 will be complete using land-based equipment
- All fill and scour material are to be imported from a commercial source within 30 km radius from the construction site
- Dredged material to be disposed onshore dewatered and taken to a landfill site
- Counterfort units can be loaded from an existing quay

Exclusions:

- Landside facilities i.e. buildings, structures and services
- Allowance for purchase/lease of land and third-party compensation due to disruption or relocation
- Allowance for compensation to third parties
- Allowance for market adjustment due to local and international demand, availability of skills, resources and materials
- Allowance for rate of exchange adjustments
- Allowance for owner's costs
- Allowance for pre-tender and post contract escalation
- Allowance in respect of post contract contingencies (10% recommended)
- Value Added Tax or other South African or Foreign taxes, royalties and duties

## 10.2 Preliminary and general cost allowance

An allowance for the contractor's preliminary and general (P&G) costs has been included as part of the direct capital cost estimate of each cost element. Each P&G allowance has been included as a percentage of the total value of construction work for that particular cost element. The P&G allowances are set at between 30% and 40% and vary depending on the nature of the work.

## 10.3 Design development allowance

For this report issue, a design development allowance of 10%, has been included to cover design and pricing uncertainties due to the level of design information available at this stage of the project. The design development allowance is included in the base capital cost estimate as a percentage of the total value of construction work, including P&G's. This allowance does not include provision for post contract project wide contingencies. It is recommended that an additional 15% of the final capital cost be included in the project budget for this purpose.

## 10.4 Professional fees allowance

In addition to the P&G and design development percentage allowances, a professional fee allowance between 7% and 13% has been included in order to cover design fees. The percentage allowance is based on the fee scale principals recommended by the Engineering Council of South Africa (ECSA) as published in Government Gazette No. 38324 on 12 December 2014 which varies depending on the nature and scale of the work. The professional fee allowance is included in the direct capital cost estimate as a percentage of the total value of construction work, including P&G, design development allowances. This allowance excludes provision for construction supervision, project management fees and owners' costs.

## 10.5 Site investigate allowance

An allowance for site investigations has been included, separate to the design professional fees. This allowance covers the cost of drilling boreholes, to determine the existing ground conditions and surveys.

## 10.6 Construction supervision allowance

A construction supervision allowance has been included to provide for the oversight and supervision costs during the construction phases of the project. The construction supervision cost allowance is based on an estimated construction duration of 14 and 10 months for Phase 1 and 2 respectively. It also covers those costs required to bring the project to a financial and contractual closure.

## 10.7 Environmental and local authority approval allowance

An allowance for environmental impact assessment including an environmental management plan has been included. This is based on a high-level cost estimate provided by an environmental specialist. In addition, it includes costs associated with local or other authority approvals.

## 10.8 Capital cost summary

The estimated capital costs, subject to the assumptions and exclusions as listed above, are summarised in Table 10-1 below. A detailed breakdown of the capital cost estimate is included as Annexure D of this report.

Table 10-1: Capital cost estimate for rehabilitation of Old Tug Jetty

| Description | Phase 1: Counterfort wall | Phase 2: Deck on pile structure |
|---|---|---|
| Direct capital costs | R 140 470 000 | R 38 840 000 |
| Site investigation allowance | R 2 650 000 | R 220 000 |
| Construction supervision allowance | R 13 000 000 | R 7 000 000 |
| Environmental, EIA, EMP and Local Authority Approval Allowance | R 1 000 000 | R 1 000 000 |
| **Estimated capital cost** | **R 157 120 000** | **R 47 060 000** |

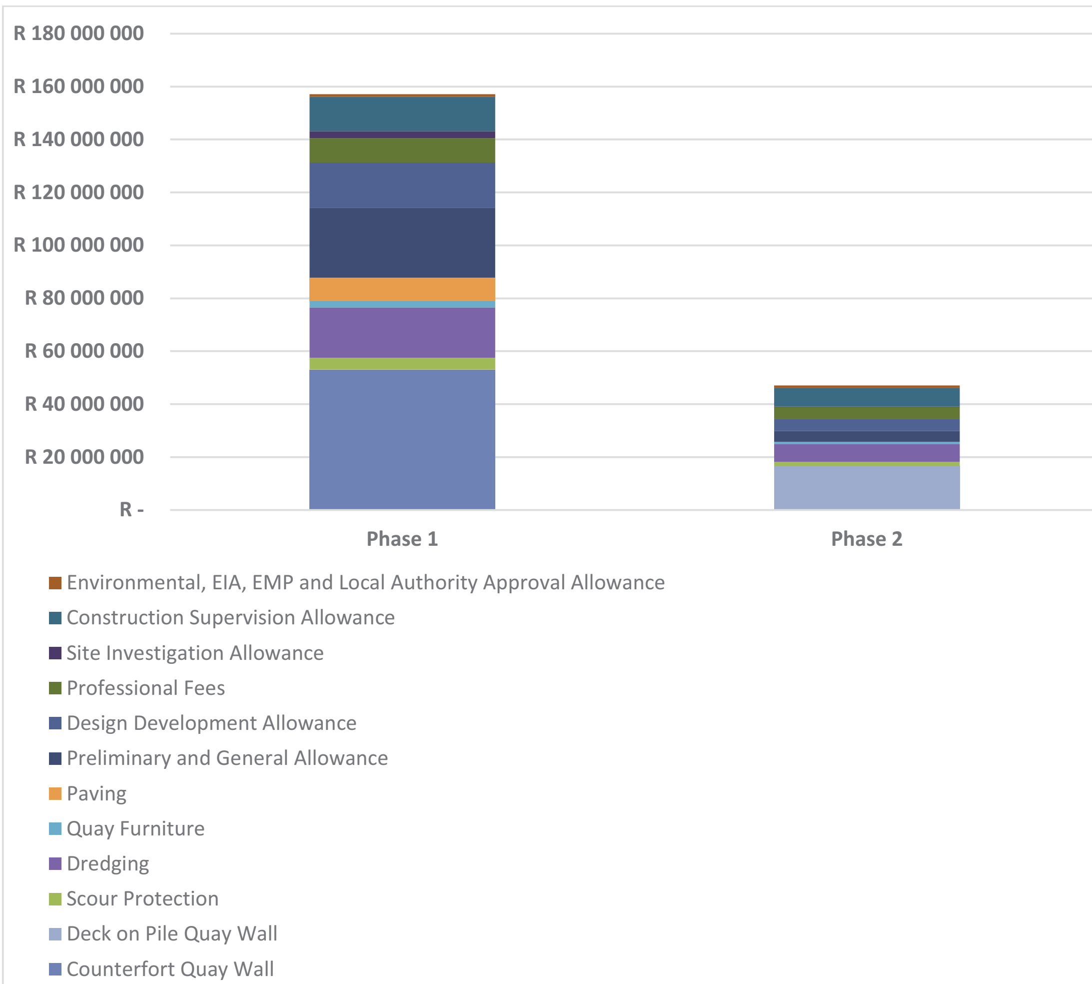


**Figure 10-1: Capital cost estimate breakdown for the rehabilitation of the Old Tug Jetty sheet pile wall**

In the event that the Client decides to undertake both Phase 1 and Phase 2 simultaneously, the estimated capital cost is R 195 960 000. This estimate is based on the Phase 1 capital cost estimate plus the Phase 2 direct capital cost as listed in Table 10-1 above (refer to Annexure D for breakdown).

# 11. FRAMEWORK FOR FEL 3

Based on the findings of this FEL 2 study and the condition of the existing structure it is recommended that this project move into the FEL 3 stage. Limited site information was available for the FEL 2 study and there are still several uncertainties that need to be addressed in the next phase (FEL 3) of this project.

A number of site investigations are required to progress this project further, assumptions in this FEL 2 study need to be verified and detailed design work needs to be carried out (FEL 3) before the construction stage (FEL 4) can commence.

This section presents the FEL 3 study frame work for the Phase 1 and Phase 2 rehabilitation of the Old Tug Jetty sheet pile wall.

## 11.1 FEL 3 project scope recommendations for phase 1 counterfort wall

It is envisaged that the FEL 3 scope of work will consist of the primary activities described below.

### 11.1.1 FEL 3 Study

#### 11.1.1.1 Project management and coordination

- Meet the client to develop and discuss the Basis of Design
- Formalise scope of project and agreements with TNPA
- Kick-off meeting, monthly progress meetings, workshops, gate review meeting
- General project administration

#### 11.1.1.2 Detailed (FEL 3) Engineering

- Prepare a design basis for the client’s approval
- Front-end engineering design - 100% engineering:
  - Stability assessment of the existing wall
  - Development of preferred rehabilitation solution
  - Dredging and scour protection
  - Navigation study
  - Coastal process study
- Safety in design
- Risk assessment (HSE)
- Capital cost estimate (15% accuracy)
- Project schedule – Level 4 break down
- FEL 3 Design report

#### 11.1.1.3 Tender documentation and procurement

- Prepare the scope of works, specifications, bill of quantities, pricing instructions, tender drawings and site information for the tender documents

#### 11.1.1.4 Input into studies, reports and documents prepared by others

- Input into the TNPA project execution plan (PEP)
- Technical input into the environmental impact assessment (EIA)

- FEL 3 gate review meeting
- Attend a risk assessment workshop

#### 11.1.1.5 FEL 3 Deliverables

- Site investigation report
- Design basis
- Design report
  - FEL 3 design – 100% engineering
  - Capital cost estimate (15% accuracy)
  - Project schedule
  - Risk assessment
  - Constructability assessment
- Tender documentation (works information, specifications, bill of quantities, pricing assumptions, site information, tender drawings, quality management plan, HSE specification)

### 11.1.2 Site investigations

- The following site information is required:
  - Multi beam hydrographic survey to verify the current bathymetry
  - Marine (x5) and landside (x3) boreholes, jet probes (x48) and laboratory testing to determine geotechnical conditions
  - Detailed inspection of the quayside services (water, power and storm water) including a topographic survey
  - Trial pits (x4) required to sample back fill material, expose existing tie rods and anchor walls to determine existing structural condition
  - Dive survey to document extent of steel sheet pile corrosion and to sample existing scour rock
  - Determination of existing sheet pile embedment depth by means of geophysical techniques if as-built drawings are not available
- Scope out the required site investigations mentioned above. This is to include preparing the works information, schedules of quantities, drawings and site information
- Recommend suitable contractors for the site investigations and participate in the selection of a preferred contractor
- Monitor the progress and quality of site investigations
- Geotechnical interpretive report based on all available geotechnical information, by a suitably qualified geotechnical engineer
- Site investigation report

### 11.1.3 EIA study

- Environmental impact assessment (EIA) to be undertaken by a suitably qualified environmental specialist.

## 11.2 FEL 3 project scope recommendations for phase 2 deck on pile

It is envisaged that the FEL 3 scope of work for phase 2 will be identical to phase 1 apart from the site investigation requirements and coastal process study.

The following site investigations will be required:

- Multi beam hydrographic survey to verify the current bathymetry
- Geotechnical interpretive report based on all available geotechnical information, by a suitably qualified geotechnical engineer
- Site investigation report based on all available site information

## 11.3 FEL 3 study programme

The FEL 3 study schedule for phase 1 and phase 2 has been undertaken using MS Project© and is cost and resource loaded. It is envisaged that the FEL 3 study durations (excluding the EIA and local authority approvals) for the phase 1 counterfort wall and the phase 2 deck on pile will be approximately 9 months and 5½ months respectively. The durations including the EIA process are approximately 22 months and 17 months for phase 1 and 2, respectively. Refer to Annexure E for the detailed Phase 1 & 2 programmes.

The critical programme assumptions are:

- Full scoping and EIA's are required for both phases and separate EIA's will be carried out for each FEL 3 phase;
- The duration to carry out a full EIA is 15 months. This includes 2 months for time risk allowances; and
- Site investigations and interpretive reporting will take approximately 5 months. A portion of the FEL 3 designs can be started prior to completing the site investigations.

The FEL 3 study schedule for the proposed rehabilitation of the Old Tug Jetty sheet pile wall for phase 1 and phase 2 is summarised in Figure 11-1 and Figure 11-2 below.

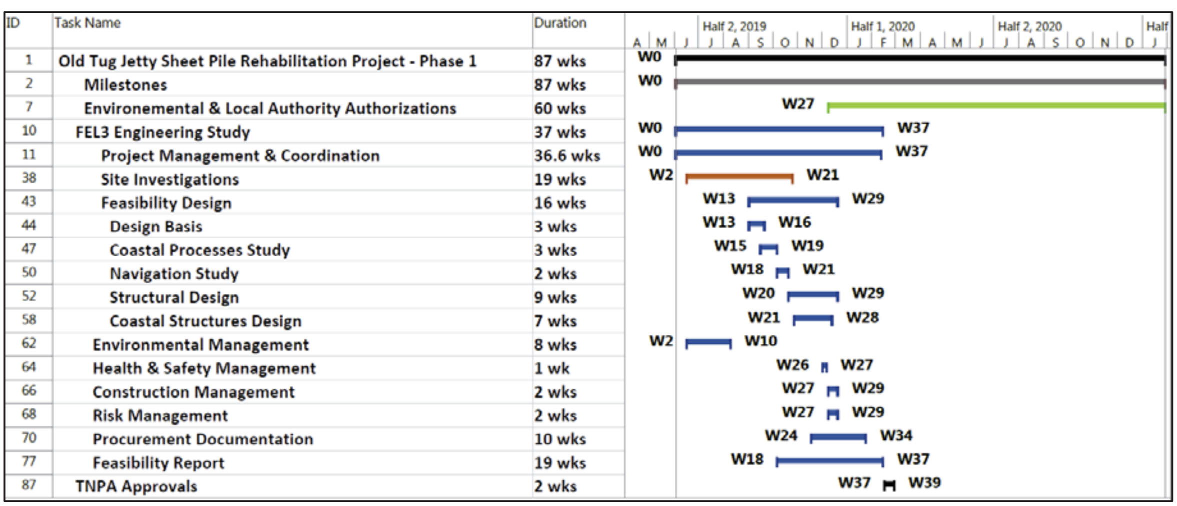


**Figure 11-1: Phase 1 counterfort wall summarised FEL 3 study schedule**

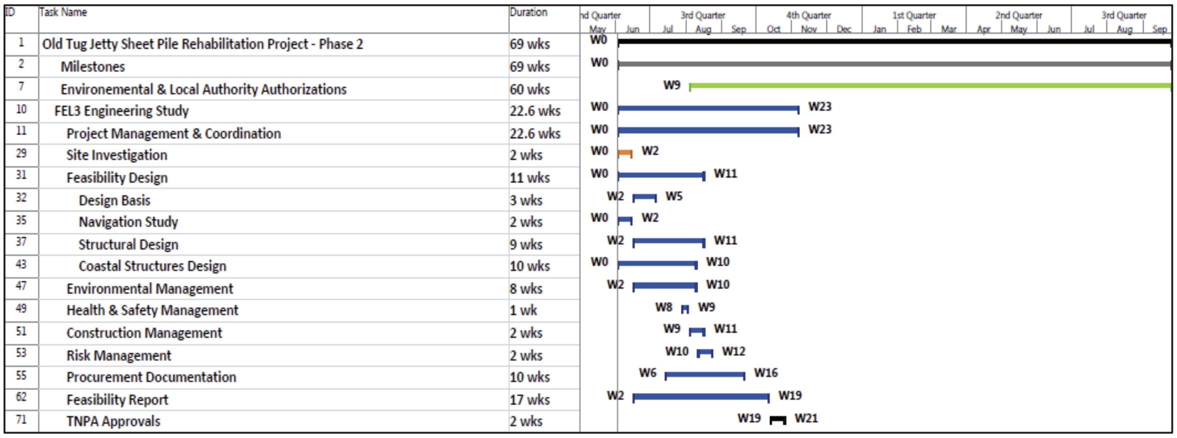


**Figure 11-2: Phase 2 deck on pile summarised FEL 3 study schedule**

## 11.4 FEL 3 study budget

The fee estimates shown below are provided as a budgeting guide only. The fees shown have been based on time cost allowance using the ECSA fee scales for engineering work of this nature and adapted to match the TNPA PLP staging. However, the final engineering fee will be based on competitive bidding process and may deviate substantially from what is presented. This allowance however is dependent on the level of support TNPA require and may reduce or increase as required. It is recommended that TNPA allow a project contingency in addition to cover any unforeseen additional costs.

**Table 11-1: FEL 3 study budget**

| Activity | Phase 1 counterfort wall | Phase 2 deck on pile |
|---|---|---|
| | Cost | Cost |
| **FEL 3 study** | R 6 000 000 | R 3 280 000 |
| **Site investigations - allowance** | R 2 650 000 | R 220 000 |
| **Full environmental impact assessment incl. allowance for local authority or other approval** | R 1 000 000 | R 1 000 000 |
| **Total** | R 9 650 000 | R 4 500 000 |

In the event that the Client decides to undertake both Phase 1 and Phase 2 simultaneously, the estimated FEL 3 study budget is R 12 930 000. This estimate is based on the Phase 1 total study cost plus the Phase 2 FEL 3 study cost as listed in Table 11-1.

# 12. CONCLUSIONS AND RECOMMENDATIONS

Old Tug Jetty sheet pile wall has corroded significantly with large holes visible in the tidal zone. These holes have caused leaching of backfill material resulting in the subsidence of the back of quay area. TNPA has undertaken multiple repair campaigns with no long-term success.

Therefore, PRDW have been appointed by Transnet National Ports Authority (TNPA) to conduct a pre-feasibility (FEL 2) study for the rehabilitation of the Old Tug Jetty sheet pile wall.

## 12.1 Conclusions

Based on the available information, it was concluded that:

- The current deterioration of the sheet pile wall is ongoing and will get progressively worse;
- Given the advanced state of deterioration the ability of the structure to fulfil its functional requirement is uncertain;
- The progressive weakening of the steel sheet piles because of corrosion could result in a sudden failure if the holes in the piles grow unchecked;
- Doing nothing would eventually result in the abandoning or condemning of the quay due to safety concerns;
- The option of cladding the existing wall to rehabilitate it is fatally flawed since steel deterioration will continue resulting in uncertainty regarding the remaining service life; therefore
- Replacement is the only practical solution that would provide certainty with regards to the future life span of the facility.

Based on the outcomes from the optioneering and multi-criteria analysis, a counterfort wall and deck on pile hybrid structure was selected as the preferred rehabilitation option for the Old Tug Jetty sheet pile wall. This option comprises of 2 phases.

Phase 1 entails the construction of a counterfort wall with a berth depth of -5.2 m CD. Thereafter, if there is sufficient demand for a deeper berth, the structure can be upgraded by implementing phase 2. Phase 2 expansion entails the construction of an adjoining deck on pile structure partially supported by the counterfort wall with a design berth depth of -6.5 m CD.

The primary factors governing the selection of the counterfort wall and deck on pile hybrid over other structures were constructability, modest construction schedule, maintainability and provision for future increase in berth depth and structural loading.

## 12.2 Recommendations

Based on the findings of this FEL 2 study and the condition of the existing structure it is recommended that the Old Tug Jetty sheet pile wall be rehabilitated as soon as possible.

However, should the rehabilitation not proceed due to a lack of immediate funding or other issues, it is recommended that the Old Tug Jetty sheet pile wall be surveyed and monitored at least on a bi-annual basis going forward. If excessive movement of the wall is observed, the structure should be decommissioned until it has been rehabilitated.

**ANNEXURE A |** BASIS OF DESIGN

PRDW
Consulting Port and Coastal Engineers

# PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE REHABILITATION

**BASIS OF DESIGN**

FEL 2 STUDY

REV.03

26 March 2019

TRANSNET NATIONAL PORTS AUTHORITY
Port of Port Elizabeth, South Africa

TRANSNET
national ports authority

PRDW

Consulting Port and Coastal Engineers

# PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE REHABILITATION

**BASIS OF DESIGN**

PRE-FEASIBILITY STUDY (FEL 2)

S2001-109-DB-ST-001-R3

26 March 2019

| REV. | TYPE | DATE | EXECUTED | CHECK | APPROVED | CLIENT | DESCRIPTION / COMMENTS |
|---|---|---|---|---|---|---|---|
| 00 | C | 05/12/2018 | JPR/YH | PES | AEL | | |
| 01 | C | 30/01/2019 | JPR/YH | PES | AEL | | ADDRESSING CLIENT'S COMMENTS |
| 02 | C | 14/02/2019 | YH | PES | AEL | | ADDRESSING CLIENT'S COMMENTS |
| 03 | D | 26/03/2019 | JPR/YH | PES PES | AEL | | ADDRESSING CLIENT'S COMMENTS |

TYPE OF ISSUE: (A) Draft (B) To bid or proposal (C) For Approval (D) Approved (E) Void

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Port of Port Elizabeth, South Africa

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national ports authority


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PRDW
Consulting Port and Coastal Engineers

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# 1. INTRODUCTION

## 1.1 Project background

PRDW have been appointed by Transnet National Ports Authority (TNPA) to conduct a pre-feasibility (FEL 2) study for the rehabilitation of the Old Tug Jetty sheet pile wall. The Old Tug Jetty sheet pile wall is located within the Port of Port Elizabeth, refer to Figure 1-1. The site extents are approximately 246.2m with an advertised berth depth of approximately -4m CD. The sheet pile wall was constructed in the mid 1970's and comprises of steel interlocking 'U' sheet pile sections together with dead man anchors and a concrete capping beam.

The sheet piles have corroded significantly with large voids visible in the tidal zone. These voids have caused leaching of backfill material resulting in the subsidence of the back of quay area. TNPA has undertaken numerous repair campaigns involving filling of holes with soilcrete. However, the continued deterioration of the sheet pile wall has resulted in an unsustainable maintenance regime.

The purpose of this study is to determine the most suitable solution to rehabilitate the Old Tug Jetty sheet pile wall to mitigate the risks associated with its current condition.

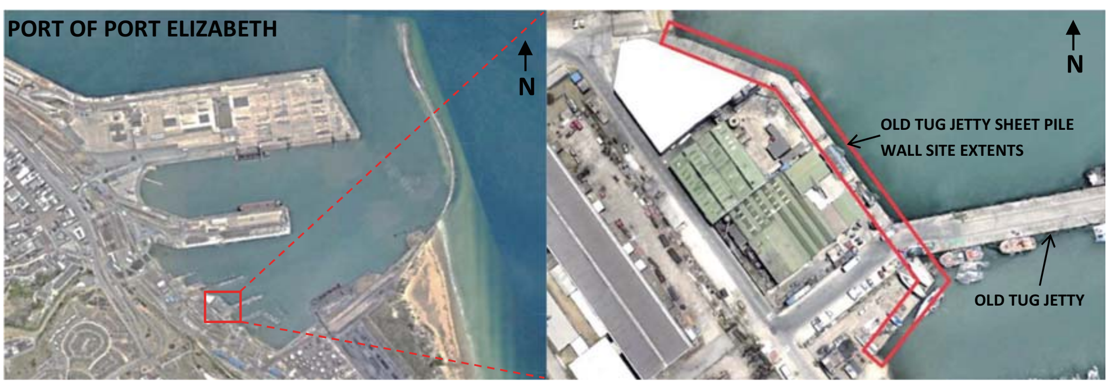


**Figure 1-1: Old Tug Jetty site extents**

The quay wall is currently being used for the berthing of fishing vessels and trawlers. The northern extent of the back of quay area is used for the transhipment of cargo and supplies, while the southern extent is used for boat maintenance (for yachts).

## 1.2 Purpose of design basis

This document stipulates the basis on which the pre-feasibility study of the Old Tug Jetty sheet pile wall will be undertaken. It identifies the design requirements and summarises all the salient information pertaining to PRDW's scope of work. This document will remain live throughout this study and will be updated if and when required.

## 1.3 Scope of work

The breakdown of the scope of work for the pre-feasibility study of the Old Tug Jetty Sheetpile Rehabilitation is as follows:

- Review of available information and compile Basis of Design;
- Compile pre-feasibility report which includes:
  - Basis of Design
  - Interpretative geotechnical report – as per tender methodology, the report has been completed by Jeffares & Green as part of the Lead-in jetty construction
  - Conceptual designs
  - Multi-criteria analysis (MCA)
  - Recommendation on preferred solution
  - Preliminary design
  - Drawings
  - Feasibility study (FEL 3) recommendations and project controls
  - Construction cost estimate.

## 1.4 Report structure

Section 2 of this report presents the site conditions which includes the environmental and geotechnical conditions. Section 3 summarises the functional requirements of the jetty, with the structure layout considered being covered in Section 4. The design criteria for the structure is described in Section 5. Section 6 gives the guidelines, codes of practice and other external references that will be utilized during the study.

# 2. SITE CONDITIONS

## 2.1 Project datum and coordinate system

All vertical levels will be relative to Chart Datum (CD) which is 0.836m below Land Levelling Datum (LLD).

The reference coordinate system to be used will be:

- Geodetic Datum: Hartbeeshoek94
- Ellipsoid: WGS 84
- Projection: UTM 27 (Zone 35)
- Central Meridian: 25

## 2.2 Tide levels

The tide levels shown in Table 2-1 have been sourced from the South African Navy Hydrographic Office (SANHO, 2018). The levels are referenced to Chart Datum (CD), defined as 0.836m below Land Levelling Datum (LLD).

**Table 2-1: Predicted tide levels for Port Elizabeth**

| Tide level | Abbreviation | Water level [m CD] |
|---|---|---|
| Highest Astronomical Tide | HAT | + 2.12 |
| Mean High Water Springs | MHWS | + 1.86 |
| Mean High Water Neaps | MHWN | + 1.29 |
| Mean Level | ML | + 1.04 |
| Mean Low Water Neaps | MLWN | + 0.79 |
| Mean Low Water Springs | MLWS | + 0.21 |
| Lowest Astronomical Tide | LAT | 0.00 |

## 2.3 Design still water level

The calculated water level is summarised in Table 2-2 and includes for sea level rise.

**Table 2-2: Design maximum still water level**

| Item | Symbol | Unit | 1:100 year event | Reference/Comment |
|---|---|---|---|---|
| Mean High Water Spring | MHWS | m CD | 1.86 | (SANHO, 2018) |
| Storm Surge | SS | m | 0.99 | Tidal residuals 95% upper confidence level |
| Sea Level Rise (2070) | SLR | m | 0.55 | (IPCC, 2014) |
| Design maximum still water level | | m CD | 3.40 | |

## 2.4 Wind

Wind data measured at the Port of Ngqura is available for the period of 1998 to 2015. The wind conditions at the Port of Ngqura are considered representative as it is located 20km northeast of Port Elizabeth and will be used for this study. Figure 2-1 presents a wind rose based on wind data compiled by CSIR as measured at the Port of Ngqura.

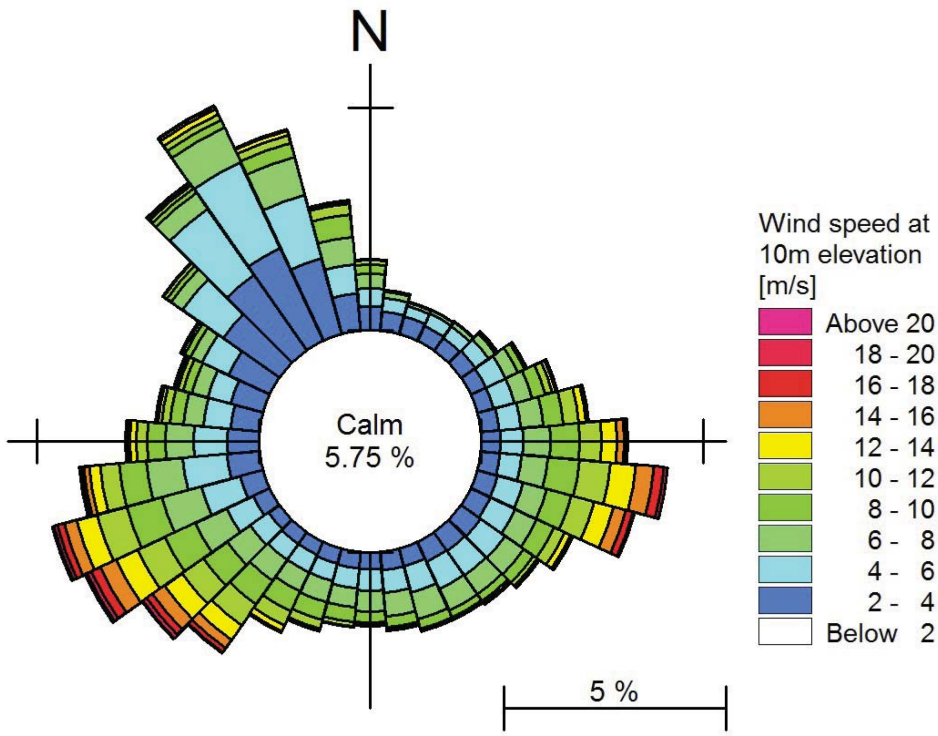


**Figure 2-1: Wind rose from measured wind data taken at the Port of Ngqura**

## 2.5 Waves and currents

The wave climate at the Old Tug Jetty was found to be dominated by locally generated wind-waves associated with dominant north easterly-winds. The location of the Old Tug Jetty (situated on the lee of the main breakwater) results in the facility being sheltered from wind-waves associated with winds from other directions as well as swell waves penetrating into Algoa Bay.

For this study, currents and waves in the vicinity of the Old Tug Jetty have been assumed to be insignificant due to its sheltered location in the harbour.

## 2.6 Temperature

The following temperature range, based on isotherm maps provided in SANS 10160 - Part 7, will be applied to the structure:

- Min shade air temperature: -4.5°C
- Max shade air temperature: 44.8°C (1:50 year)

## 2.7 Seismicity

Nominal peak ground acceleration in the region of Port Elizabeth, based on the seismic hazard map provided in SANS 10160 - Part 4:2010, is 0.025g. Therefore, the seismicity is benign and will not be assessed as part of this study.

## 2.8 Site information

Available site information consists of the following documents:

- As-built drawings (PEH51V0888-01, PEH51V1109-01 and PEH51V1110-01)
- Geotechnical drilling investigation at the Port of Port Elizabeth – Lead-in Jetties: Prepared by Jeffares & Green
- Old Tug Jetty Wharf Assessment Report: Prepared by Buchule Engineers (Pty) Ltd
- TNPA annual asset inspection photos (2018) and diving videos (2017)
- Single beam bathymetric surveys: Undertaken by Transnet Dredging Services

## 2.9 Bathymetry

A single-beam survey of the seabed is annually carried out by Transnet Dredging Services. The following sounding was done in November 2018 and is shown in Figure 2-2 below.


**Figure 2-2: Bathymetry of basin**

## 2.10 Summary of geotechnical information

In 2015, Jeffares & Green (Pty) Ltd conducted a geotechnical investigation in the Port of Port Elizabeth. The investigation was undertaken for the construction of the proposed 40 ton slipway as well as for the construction of the two Lead-in jetties. The geotechnical investigation comprised of a drilling campaign consisting of 12 rotary drilled boreholes cores, 6 along the proposed slipway and 6 cores along the two Lead-in jetties. The investigation used rotary core drilling to depths between -21.96m CD to -25.56m CD.

The boreholes along the Lead-in jetties are the closest available to the Old Tug Jetty and are considered to give a good indication of the likely geotechnical conditions for the purposes of this pre-feasibility study.

Boreholes 3, 5 and 6 are the closest to the Old Tug Jetty and considered the most relevant and will provide sufficient information for the required level of design. Figure 2-3 shows the location of the selected boreholes.


**Figure 2-3: Lead-in jetty borehole locations**

According to Jeffares & Green, alluvium/fill dominated all boreholes and is mainly comprised of sub-angular to rounded gravel, cobbles and minor boulders of quartzitic sandstone and gravelly sand. The boreholes indicate the absence of hard rock and the harbour area is significantly inconsistent in its horizontal and vertical profile, showing wide variability in strata levels. Founding in gravel and cobbles may, however, be problematic as variable settlement may occur. It is thus recommended that if a piling option is considered, a specific driving set be maintained, to which the piling installation must adhere to.

Based on the material descriptions from the selected three borehole logs and as-built drawings, their typical design material properties have been defined in Table 2-3 below.

**Table 2-3: Soil properties**

| Material description | Saturated density $\Upsilon_{sat}$ [kN/m³] | Bulk density $\Upsilon_{bulk}$ [kN/m³] | Effective internal friction Angle φ' [°] | Cohesion c' [kN/m²] | Reference |
|---|---|---|---|---|---|
| Marine sediment/Loose sand/Silty sand | 18.5 | 17.5 | 30 | - | Arcelor Piling Handbook 8th Edition |
| Sand fill/Medium dense sand | 19.0 | 18.5 | 32 | - | |
| Gravel backfill | 20.0 | 19.0 | 38 | - | |
| Quarry run | 19.5 | 18.5 | 45 | - | |
| Scour rock | 20.5 | 19.5 | 45 | - | |
| Alluvial gravel and cobbles | 20.0 | 19.0 | 35 | - | |
| Pavement layer work (assumed to be highly compacted gravel) | 21.0 | 20 | 45 | - | |
| Existing rock fill (assumed to be weathered quarry run) | 19.5 | 18.5 | 40 | - | |

It is recommended that for the following project phase (FEL 3 study), a more detailed geotechnical investigation along the Old Tug Jetty should be undertaken to confirm the soil properties.

# 3. FUNCTIONAL REQUIREMENTS

## 3.1 Design life

The design service life for the rehabilitation Old Tug Jetty sheet pile wall is 50 years as per design working life category 4 of the TNPA Port Engineering handbook (Transnet National Ports Authority, 2015). The design will focus on maximum operational flexibility and safety with an emphasis on the fishing industry.

## 3.2 Design constraints

The following design constraints will be considered:

1. Method and duration of construction:

   Rehabilitation options should minimise operation downtime of the fishing industry and boat repair facility, also taking into consideration the waterside impact on port operations.

2. Integration of surrounding infrastructure:

   The integration of the new structure with existing structures will be a key design consideration. The lack of as-built information for the existing structures may result in unforeseen risks related to structural capacity and stability and impact on adjacent infrastructure. This may also result in conservative designs to mitigate potential risks.

   The rehabilitation of the sheet pile wall shall commence at the northern boat ramp, proceeding in front (seaside) of the existing wall, underneath the Old Tug Jetty and conclude at the southern boat ramp.

3. Limited back of quay area:

   Rehabilitation options should take into account the limited back of quay area due to existing infrastructure.

4. Future increase in berth depth

   The adjoining Old Tug Jetty has an advertised berth depth of -6.5m CD therefore, the proposed rehabilitation option for the Old Tug Jetty sheet pile should also cater for this berth depth.

If additional design constraints are identified, they will be included in the pre-feasibility design report.

## 3.3 Cope level

The current cope level is at +3.0m CD. However, the anticipated design still water level for the service life of the structure is +3.4m CD (refer to Table 2-2). Therefore, the cope level of the rehabilitation Old Tug Jetty sheet pile wall needs to be increased. The recommended cope level for the FEL 2 study is +4.0m CD. This will need to be confirmed as part of a coastal process study undertaken during the FEL 3 project phase.

## 3.4 Berth depth

The advertised berth depth for the Old Tug Jetty sheet pile wall is -4.0m CD while the adjoining jetty berth depth is -6.5m CD. The proposed rehabilitation option should be designed to a berth depth of -6.5m CD.

## 3.5 Quay furniture

Quay furniture requirements will be determined as part of this study.

## 3.6 Quayside service requirements

The design will make provision for potable water and electricity. Firefighting water pipes will be buried in the fill, with manholes for the hydrants along the cope.

In addition, provisions will be made for a concrete pavement between the new quay structure and the back of quay buildings with surface runoff drained towards the landward side.

## 3.7 Design vessel parameters

The Client has provided the 2018 vessel register which contains limited specifications for the vessel sizes that will be utilizing this facility. The design berthing load in generally governed by the largest vessel which is the *Adamant*. The vessel specifications for the *Adamant* will therefore be inferred from a vessel of similar length and type operating out of Saldanha Bay, namely, the *Krotoa*. The design vessel specifications are shown in Table 3-1.

**Table 3-1: Design vessel specifications**

| Parameter | Assumed | Available vessel information as provided by TNPA | | |
|---|---|---|---|---|
| | Krotoa | Adamant (Largest vessel) | Zanette (Smallest vessel) | Black Jack (Shortest vessel) |
| Gross register tonnage | 1111 | 974 | 25 | - |
| Displacement ($m^3$) | 1399 | - | - | - |
| Length overall (m) | 47.5 | 61.0 | - | 6.1 |
| Length between perp. (m) | 42.0 | - | - | - |
| Beam (m) | 11.9 | - | - | - |
| Laden draft (m) | 5.7 | - | - | - |

## 4. EXISTING STRUCTURE

### 4.1 Old Tug Jetty layout

The Old Tug Jetty back-up area can be divided into two sections based on operations. The northern side is mainly used for the berthing of fishing boats and trawlers, with the back of quay area used for the transhipment of cargo and supplies. The southern side is used for the staging of boats for maintenance and repair. A fixed 4-ton crane is used for vessel handling, along with an occasional mobile crane. Figure 4-1 to Figure 4-3 below presents the layout and operation of the Old Tug Jetty Sheetpile.


**Figure 4-1: Old Tug Jetty Sheetpile layout**

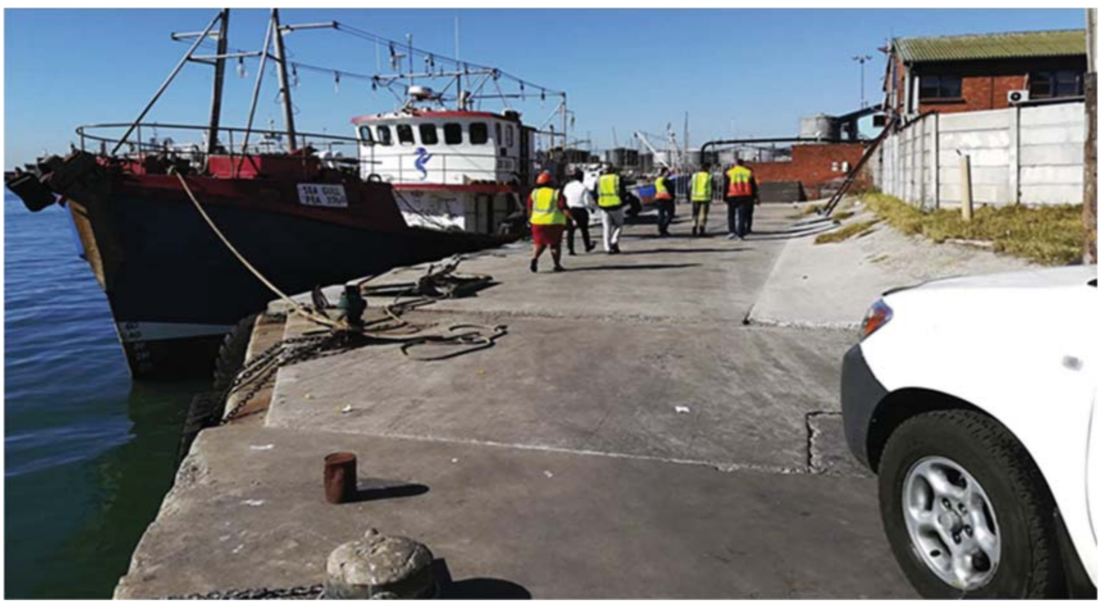

**Figure 4-2: Northern side of Old Tug Jetty Sheetpile**

**Figure 4-3: Southern side of Old Tug Jetty Sheetpile**

## 4.2 Structure condition

Buchule Engineers (Pty) Ltd was appointed by TNPA to conduct an assessment of the wet assets in the Port of Port Elizabeth. The assessment included visual inspections undertaken on land and by boat, and where deemed necessary diving inspections were also conducted.

The seaside visual and diving inspection of the sheet pile wall found numerous holes in the sheet piles where backfill material is leaching out. This has resulted in the subsidence of the back of quay area.

An additional 200mm concrete slab has been added behind the wall, which was not part of the original design, because of present usage needs. This has added load on to a structure that is already in a poor condition.

Fendering consists of varying size tyres installed by the terminal operators at ad-hoc locations along the jetty. Bollards are typically severely corroded and informal methods of mooring are being used.

From the available information, it was concluded that:

- The current deterioration of the sheet pile wall is ongoing and will get progressively worse;
- given the advanced state of deterioration the ability of the structure to fulfil its functional requirement is uncertain;
- the progressive weakening of the steel sheet piles because of corrosion could result in a sudden failure if the holes in the piles grow unchecked;
- doing nothing would eventually result in the abandoning or condemning of the quay due to safety concerns;
- the option of cladding the existing wall to rehabilitate it is fatally flawed since steel deterioration will continue; and
- replacement is the only practical solution that would provide certainty with regards to the future life span of the facility.

# 5. DESIGN CRITERIA

## 5.1 Durability and serviceability requirements

The durability and serviceability design criteria for the rehabilitation of the Old Tug Jetty sheet pile wall is described below.

### 5.1.1 Concrete works

Concrete structural elements will be designed using the concrete criteria listed in Table 5-1 below.

**Table 5-1: Concrete criteria**

| Descriptions | Criteria | Reference | Comments |
|---|---|---|---|
| Min cube strength – reinforced concrete ($f_{cu}$) | 45MPa @ 28 days | - | High density concrete |
| Min cube strength – plain concrete ($f_{cu}$) | 35MPa @ 28 days | - | - |
| Min nominal concrete cover | 65 mm | - | Mix design dependant.<br>May be higher in extreme zones |
| Crack width limit | 0.3 mm | BS EN 1992-2:2005 (T 7.101N) | Serviceability frequent load combination of actions |

### 5.1.2 Steel criteria

The corrosion rates listed in Table 5-2 will be used in the design of steel elements as per BS 6349-1:2000.

**Table 5-2: Typical rates of corrosion for structural steels in temperate climates**

| Exposure zone | Corrosion rate mm/side/year | |
|---|---|---|
| | Mean | Upper limit |
| Atmospheric zone:<br>- Above splash zone and where direct wave or spray impingement is Infrequent. | 0.04 | 0.10 |
| Splash zone:<br>- Above mean high-water to a height depending on mean wave height and exposure to wind. | 0.08 | 0.17 |
| Tidal zone:<br>- Between mean high-water and mean low-water spring level. | 0.04 | 0.10 |
| Continuous seawater immersion zone:<br>- From 0.5m below LAT to seabed level | 0.04 | 0.13 |
| Below seabed level or in contact with soil | | 0.015 max |

### 5.1.3 Deflection criteria

**Table 5-3: Serviceability deflection criteria**

| Parameter | Criteria | Reference | Comments |
|---|---|---|---|
| Lateral deflection | The lessor of H/300 or 100mm | BS 6349-2:2010 (Table 1) | Serviceability frequent load combination of actions |
| Longitudinal deflection | The lessor of H/300 or 100mm | BS 6349-2:2010 (Table 1) | |
| Vertical deflection | Span/250 | BS EN 1992-1-1:2004 (Clause 7.4.1-4) | |

## 5.2 Design loads

**Table 5-4: Design load parameters**

| Item | | Load description | Reference / Comments | Value | Unit |
|---|---|---|---|---|---|
| 01 | Dead loads | Steel | SANS 10160-2 (Table A.5) | 78.0 | kN/m³ |
| | | Reinforced concrete | SANS 10160-2 (Table A.1) | 25.0 | kN/m³ |
| | | Plain concrete | SANS 10160-2 (Table A.1) | 24.0 | kN/m³ |
| | | Seawater | TNPA PEH Clause 5.4.6.3 | 10.025 | kN/m³ |
| 02 | Live loads | Bollard load | BS 6349-4 Section 3 | To be determined as part of the study | |
| | | Fender load | BS 6349-4 Section 2 | | |
| | | Surcharge (traffic and storage) | TNPA PEH Clause 3.13.13.2 | 20 | kN/m² |
| | | 50t mobile crane (Crane size limited by available back-up area) | TNPA PEH Clause 3.13.10.5 | 250 | kN |
| | | Construction load | BS 6349-2 Clause 2.3.7 | 10 | kPa |
| 03 | Environmental loads | Hydrostatic loads (tidal lag) | BS 6349-1 & Portnet PEH Clause 2.7.3.3 | To be determined depending on the structure type and configuration | |
| | | Temperature range | SANS 10160-7 Figure 1 and 2 | -4.5 to 44.8 | °C |

## 6. GUIDELINES AND CODES OF PRACTICE

The study will be executed within the framework of a number of complementary and interrelated quality standards, design guidelines and codes of practices presented below.

### 6.1 ISO 9000 Series

All design work will be undertaken within the PRDW Quality Management System that has been set out in terms of ISO 9001.

### 6.2 British Standards

- BS 6349-1 Maritime Works - Code of practice for general criteria
- BS 6349-2 Maritime Works - Code of practice for the design of quay walls, jetties and dolphins
- BS 6349-4 Maritime Works - Code of practice for design of fendering and mooring systems
- BS 8004 Code of Practice for Foundations
- BS 1377-1 Soils for Civil Engineering Purposes

### 6.3 European Standards

- BS EN 1990 Basis of Structural Design
- BS EN 1991 Actions on Structures
- BS EN 1992 Design of Concrete Structures
- BS EN 1993 Design of Steel Structures
- BS EN 1997 Geotechnical Design
- EN 10025 Hot rolled products of structural steels
- EN 10210 Hot finished structural hollow sections of non-alloy and fine grain steels
- EN 10219 Cold formed welded structural hollow sections of non-alloy and fine grain steels

### 6.4 South African Standards

- SANS 10160-2 Self-weight and imposed loads
- SANS 10160-4 Seismic actions and general requirements for buildings
- SANS 10160-7 Thermal actions

### 6.5 Guidelines

A number of design guidelines will be used. The following publications may be referenced:

- Port Engineering Handbook (Portnet, 1994)
- Port Engineering Handbook (Transnet National Ports Authority, 2015)
- Port Designer's Handbook (Thoresen, 2010)
- Pile Design and Construction Practice, 4th Edition (Tomlinson, 1994)
- Arcelor Mittal Piling Handbook 8$^{th}$ Edition (Mittal, 2008)

# 7. REFERENCES

Buchule Engineers (Pty) Ltd, 2017. *Old Tug Jetty Wharf Assessment Report,* Port Elizabeth: Buchule Engineers (Pty) Ltd.

IPCC, 2014. *Climate Change 2014: Synthesis Report. Contribution of Working Groups I, II and III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change,* Geneva: IPCC.

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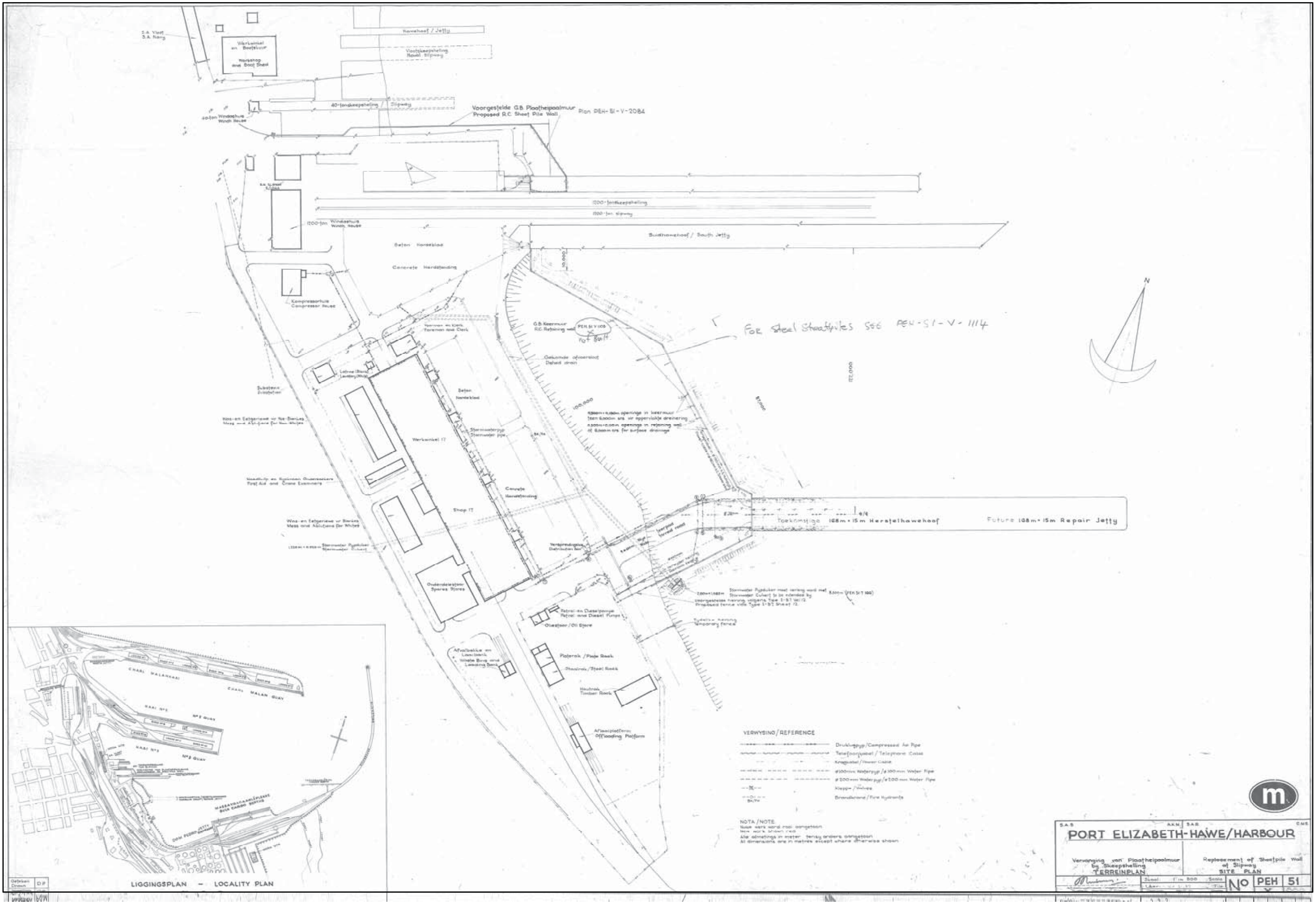
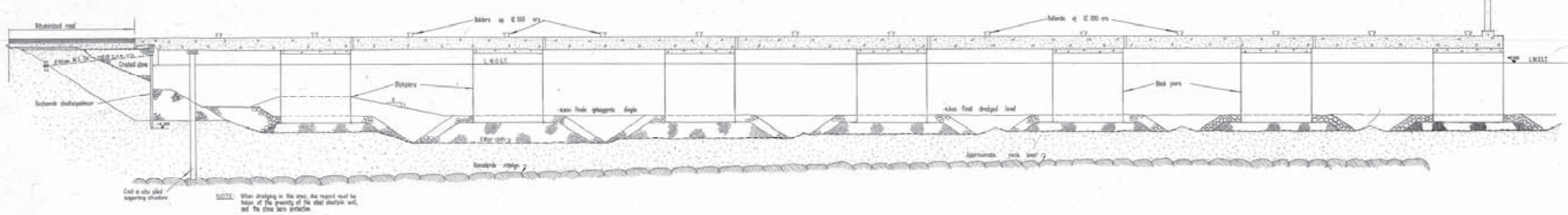
**ANNEXURE A** – AS-BUILT DRAWING

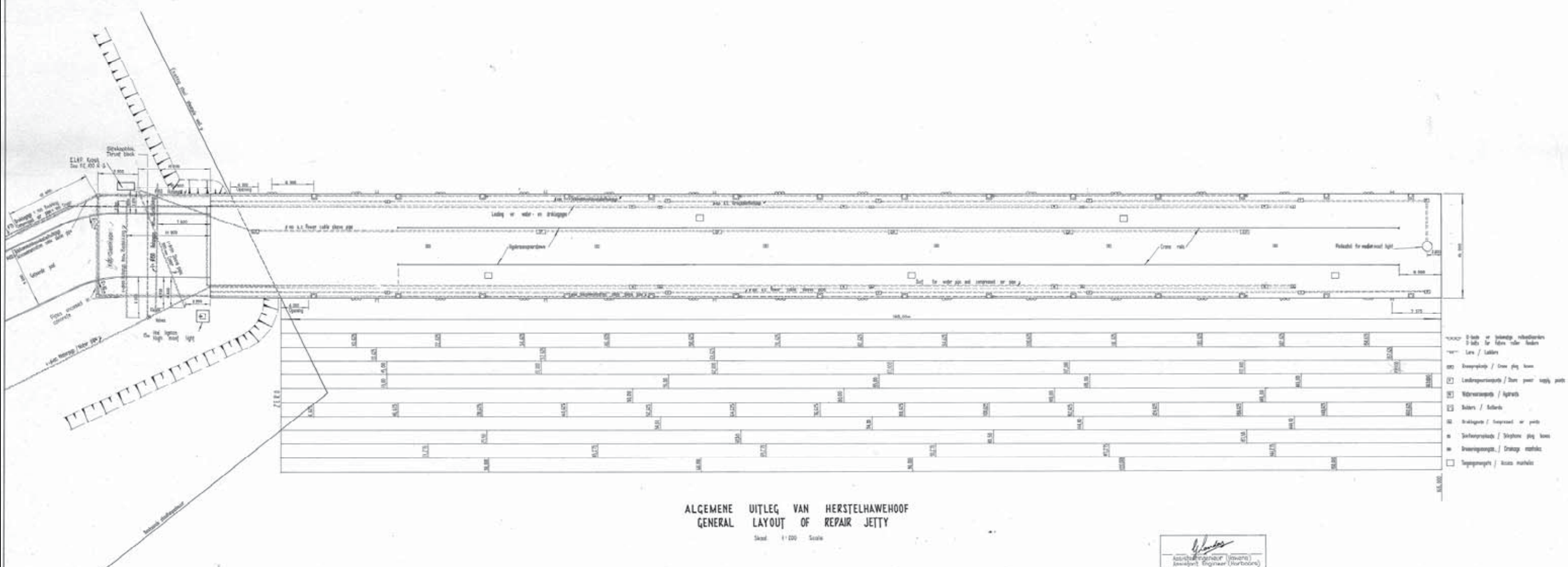


S.A. Vloot
S.A. Navy
Werkwinkel en Bootskuur
Workshop and Boat Shed
Kanshoof / Jetty
Vlootskeepshelling
Naval Slipway
40-t-langskeepshelling / Slipway
40-t-Windashuis
Winch House
Voorgestelde G.B. Plaatheipaalmuur
Proposed R.C. Sheet Pile Wall
Plan PEH-51-V-2084
1200-t-Windashuis
Winch House
1200-t-langskeepshelling
1200-t-Slipway
Suidhawehoof / South Jetty
Beton Hardeblad
Concrete Hardstanding
Kompressorhuis
Compressor House
Voorman en Klerk
Foreman and Clerk
G.B. Keermuur
R.C. Retaining wall
PEH.51 V 100
Not Built
For steel sheetpiles see PEH-51-V-1114
Gesluimde afvoerslot
Dished drain
Substasie
Substation
Werkwinkel 17
Shop 17
Stormwaterpyp
Stormwater pipe
Beton Hardeblad
Concrete Hardstanding
Verspreidingskas
Distribution Box
Toekomstige 108 m × 15 m Herstelhawehoof
Future 108 m × 15 m Repair Jetty
Onderdelestoor
Spares Stores
Petrol-en Dieselpompe
Petrol and Diesel Pumps
Oliestoor / Oil Store
Plaatrak / Plate Rack
Staalrak / Steel Rack
Houtrak
Timber Rack
Aflaaiplatform
Offloading Platform
Tydelike heining
Temporary fence
Eerstehulp en Kraanman Ondersoekers
First Aid and Crane Examiners
VERWYSING / REFERENCE
Drukluggyp / Compressed Air Pipe
Telefoonkabel / Telephone Cable
Kragkabel / Power Cable
Kleppe / Valves
Brandkrane / Fire Hydrants
NOTA / NOTE
LIGGINGSPLAN - LOCALITY PLAN
CHARL MALAN KAAI
CHARL MALAN QUAY
KAAI No 2
No 2 QUAY
KAAI No 3
No 3 QUAY
DOM PEDRO JETTY
S.A.S.
PORT ELIZABETH-HAWE/HARBOUR
Vervanging van Plaatheipaalmuur by Skeepshelling
TERREINPLAN
Replacement of Sheetpile Wall of Slipway
SITE PLAN
No PEH 51




LANGSDEURSNEE DEUR HERSTELHAWEHOOF
LONGITUDINAL SECTION THROUGH REPAIR JETTY

Skaal 1:200 Scale




ALGEMENE UITLEG VAN HERSTELHAWEHOOF
GENERAL LAYOUT OF REPAIR JETTY

Skaal 1:200 Scale

NOTAS / NOTES

1. Vir details van ligmasfondasie sien PEH 51 G 606.
For details of light mast foundation see PEH 51 G 606.
2. Vir details van stutblokke sien PEH 51 J 02.
For details of thrust blocks see PEH 51 J 02.

Assistent-ingenieur (Hawens)
Assistant Engineer (Harbours)
Datum 1972/09/06 Date

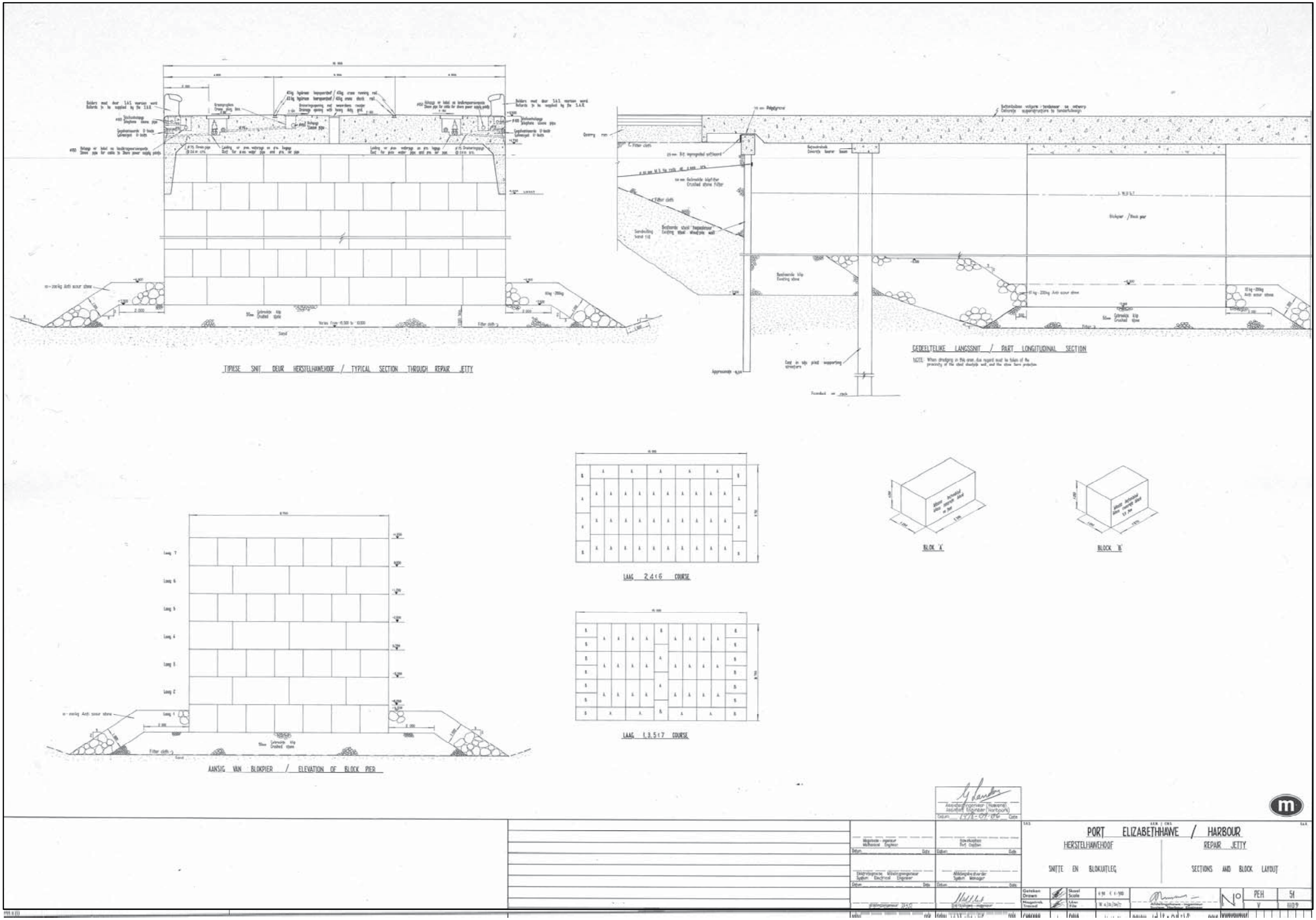
PORT ELIZABETHHAWE / HARBOUR
HERSTELHAWEHOOF / REPAIR JETTY

ALGEMENE UITLEG VAN DIENSTE
GENERAL LAYOUT OF SERVICES

Skaal / Scale 1:200

Stelselhawe-ingenieur
System Harbour Engineer

N° PEH 51 V 1110


TIPIESE SNIT DEUR HERSTELHAWEHOOF / TYPICAL SECTION THROUGH REPAIR JETTY
GEDEELTELIKE LANGSSNIT / PART LONGITUDINAL SECTION
AANSIG VAN BLOKPIER / ELEVATION OF BLOCK PIER
LAAG 2,4 & 6 COURSE
LAAG 1,3,5 & 7 COURSE
BLOK 'A'
BLOCK 'B'
PORT ELIZABETHHAWE / HARBOUR
HERSTELHAWEHOOF
REPAIR JETTY
SNITTE EN BLOKUITLEG
SECTIONS AND BLOCK LAYOUT
PEH
5I

**ANNEXURE B –** GEOTECHNICAL INVESTIGATION

**GEOTECHNICAL DRILLING INVESTIGATION AT THE PORT OF PORT ELIZABETH – LEAD-IN JETTIES**

**PREPARED BY:**

Jeffares & Green
ENGINEERING & ENVIRONMENTAL CONSULTING

**PREPARED FOR:**

**FRANKI AFRICA**
Unit 30, Plantation Centre
60 Plantation Road
Ottery
Cape Town
7790

***APRIL 2015***

Jeffares & Green
ENGINEERING & ENVIRONMENTAL CONSULTING

# VERIFICATION PAGE

Form 403.1

Rev 10/06

**GEOTECHNICAL DRILLING INVESTIGATION AT THE PORT OF PORT ELIZABETH – LEAD-IN JETTIES**

| | | |
|---|---|---|
| **JOB NO:** 3726 | **DATE:** APRIL 2015 | **REPORT STATUS:** Final Letter Report |


**CARRIED OUT BY:**

Jeffares & Green (Pty) Ltd
PO Box 27308
Greenacres
6057

Phone: (041) 363 1900
Fax: (041) 363 1922

**COMMISSIONED BY:**

Franki Africa
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Cape Town
7790

Phone: (021) 797 0525

**AUTHOR:**
Mr L Parfitt

**CLIENT CONTACT PERSONS:**
Mr A Stoll


**SYNOPSIS:**

GEOTECHNICAL DRILLING INVESTIGATION AT THE PORT OF PORT ELIZABETH – LEAD-IN JETTIES


**KEY WORDS:**

Geotechnical, geology




**QUALITY VERIFICATION**

This report has been prepared under the controls established by a quality management system that meets the requirements of ISO9001: 2008 which has been independently certified by DEKRA Certification under certificate number 90906882

| Verification | Capacity | Name | Signature | Date |
|---|---|---|---|---|
| **By Author** | Geologist | Lyzander Parfitt | | April 2015 |
| **Checked by** | Senior Associate | Tom Speirs | | April 2015 |
| **Authorised by** | Executive Associate | Richard Fyvie | | April 2015 |

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**FRANKI AFRICA**
Unit 30, Plantation Centre
60 Plantation Road
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Cape Town
7790

**ATTENTION: MR A STOLL**

Dear Sir

**RE: GEOTECHNICAL DRILLING INVESTIGATION AT THE PORT OF PORT ELIZABETH – LEAD-IN JETTIES**

*Jeffares & Green (Pty) Ltd* were invited by *Franki Africa* to prepare a proposal and cost estimate to conduct core logging and evaluate founding conditions for the construction of two lead-in jetties at the Port of Port Elizabeth in the Eastern Cape. A quotation dated 19 March 2015 and referenced 3113/99/General/028/LP/lp was submitted. *Frankie Africa* issued Purchase Order #CPT29954, dated 23 March 2015, as confirmation of their acceptance of this quotation.

**Introduction**

This letter report presents the interpretation of results for a geotechnical drilling investigation undertaken, by *Franki Africa*, for the construction of two proposed lead-in jetties at the Port of Port Elizabeth. A Locality Plan is provided in Figure 1, Appendix A.

**Branches**

Cape Town
Durban
Johannesburg
Maputo
Maun
Pietermaritzburg
Port Elizabeth
Postmasburg
Pretoria



**Jeffares & Green (Pty) Ltd • Reg. No. 1977/000524/07**
**Directors**: PA Olivier (Managing), Ms MV Makhetha, SN Makhetha, Ms VG Mkaza, Ms JC Norris, PL Ngqumshe, HH Tiganis
**Member Firm**: Consulting Engineers South Africa (CESA)
Jeffares & Green is a level 2 B-BBEE contributor and is ISO 9001:2008 certified

The investigation site is located within the Port of Port Elizabeth, which is situated on the western city boundary, adjacent to the suburb of South End and the Indian Ocean. The site can be accessed via Lower Valley Road, which runs below the M4 highway and curves to the right, where a security plaza must be negotiated. The site is located at the existing jetties, approximately 170m east of the security plaza, adjacent to the slip way.

The regional topography slopes towards the east, in the direction of the Port. Locally, the topography is fairly level, as the investigation area has been developed and is used as a cargo port with supporting infrastructure.

Fieldwork was completed during March 2015, with periodic visits to the site, and consisted of the logging of six (6) rotary drilled borehole cores. The boreholes were drilled in the footprint of the proposed new lead-in jetties, which was sited and managed by the client, along the condemned jetties which are to be replaced. *Jeffares & Green* was only appointed to log the core and provide a report based on the findings.

**Geology and Geohydrology**

According to the 1:250 000 geological map (3324 PORT ELIZABETH) and 1:50 000 geological map (3325 DA & DD, 3425 BA) published by the Council of Geoscience, the investigation area is underlain by a combination of land-fill material and Quaternary alluvial sand, gravel, cobbles and boulders. This material is underlain, at depth, by the Peninsula Formation of the Table Mountain Group. The local geology underlying the area is presented in Figure 2, Appendix A.

The land-fill material, which consists of building rubble, crushed stone and sand was used to reclaim large areas surrounding the Port Elizabeth Harbour, according to Le Roux (2000). The Port Elizabeth Harbour is situated in the mouth of the Baakens River, which serves as the source of deposition of alluvial material, along with the fringe of the Indian Ocean.

According to Le Roux (2000), the Ordovician-aged Peninsula Formation consists of light grey, medium- to course-grained quartzite with minor lenticular shale layers. The quartzite is typically well bedded. Deposition of the Peninsula Formation is believed to have occurred on a shallow marine shelf.

No large faulting is known to occur in the proximity of investigation area.  An unconformity is found between the older Peninsula Formation rocks and the younger alluvial deposits.

According to the 1:500 000 hydrogeological map (3324 PORT ELIZABETH) published by the *Department of Water Affairs and Forestry*, the investigation area has historically received a mean annual precipitation of 800 to 1000mm, with boreholes in the area potentially yielding 0.5 - 2.0 litres/second.

According to the 1:6 000 000 Seismic Hazard Map of Southern Africa, the site falls within a level five area on the Modified Mercalli Scale (MMS). Peak horizontal ground acceleration of 50-100cm/s$^2$ has been recorded, with a 10% probability of this being exceeded at least once in a 50 year period.

**Boreholes**

Six (6) boreholes, labelled BH01 through BH06, were drilled at predetermined positions utilising rotary core drilling methods by *Franki Africa* and *Terrafound CC*. The core drilling and associated activities, other than logging, were managed by *Franki Africa.* The co-ordinate positions of all boreholes, taken with a hand-held GPS, are illustrated in Figure 1, Appendix A.

Boreholes were drilled to depths between -23.00 m to -35.30 m relative to mean sea level. All boreholes were logged by *Jeffares & Green* Geologists, and the soil conditions described using standard methods and terminology outlined by Jennings et al. (1973), the Core Logging Committee of South Africa (1976) and Guidelines for Soil and Rock Logging in South Africa (2002). Borehole logs and photographic plates are included in Appendix B.

The core drilling generally yielded very poor material recovery, which is attributed to the difficulty in retrieving samples from horizons dominated by a combination of sand, gravel and cobbles. No Standard Penetration Tests (SPTs) were conducted, which may have yielded the recovery of material and informed on bearing capacities, especially in sections where the recovery was very low or zero. It is thus recommended that any further drilling in the Port area include the conducting of SPTs.

Alluvium/fill dominated all boreholes and is mainly comprised of sub-angular to rounded GRAVEL, COBBLES and minor boulders of quartzitic sandstone and gravelly SAND. Alluvial, silty CLAY was encountered in borehole; BH06 between -14.60m and -15.60m. None of the boreholes terminated in rock, which can be attributed to the Port of Port Elizabeth being underlain by an alluvial/fill deposit of variable thickness.

**Founding Recommendations**

A review of the boreholes indicate the absence of hard rock, as described above. The harbour area is significantly inconsistent in its horizontal and vertical profile, showing wide variability in strata levels. This is owing to the irregular erosional development of palaeo-gullies as a typical shoreline erosional feature, as well as the legacy of coastline reclamation and construction along Port Elizabeth's beachfront. Founding in cobbles and boulders may, however, be problematic as variable settlement may occur. It is thus recommended that a specific pile driving set be maintained, to which the piling installation must adhere to.

Piles may be installed in the boulder/cobble horizons, provided that the piling is driven to a set equivalent to a SPT N-value of 50 i.e. this is basically the SPT N value for 'near refusal'.

**Conclusions**

Taking all factors into account, it is considered that conditions prevailing on site are potentially suitable for the specific development of the structures, provided the recommendations given in this report are adhered to.

Recommendations provided in this report refer specifically to conditions encountered at the borehole positions. Should material of a different nature be found elsewhere on site, conditions may be different and must be re-evaluated.

Should you have any further enquiries in this regard, please contact the author.

Yours Faithfully,

**LYZANDER PARFITT**
Geologist
For: **JEFFARES & GREEN (Pty) Ltd**

**RICHARD FYVIE** *Pr.Sci.Nat.*
Executive Associate
For: **JEFFARES & GREEN (Pty) Ltd**

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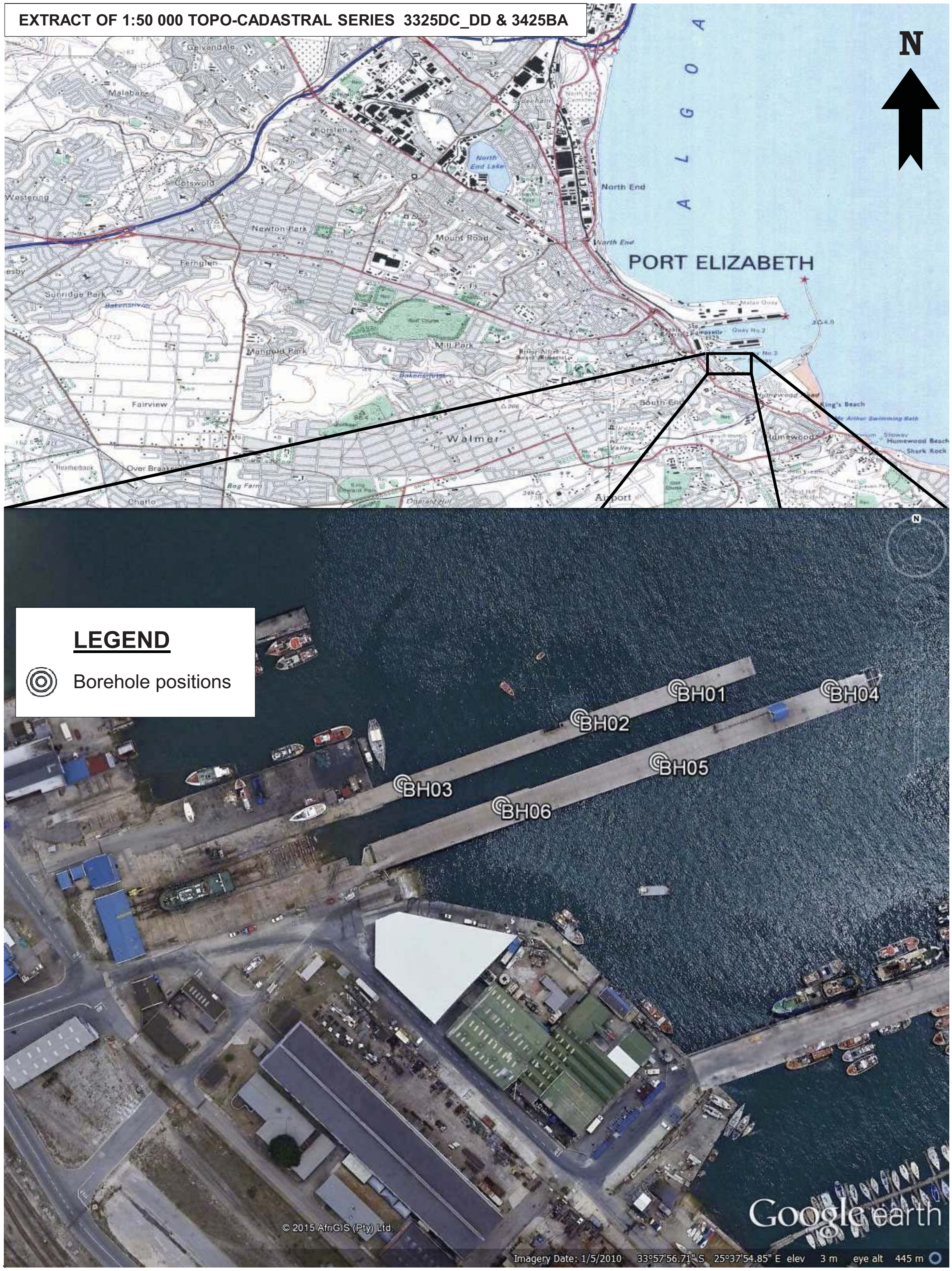
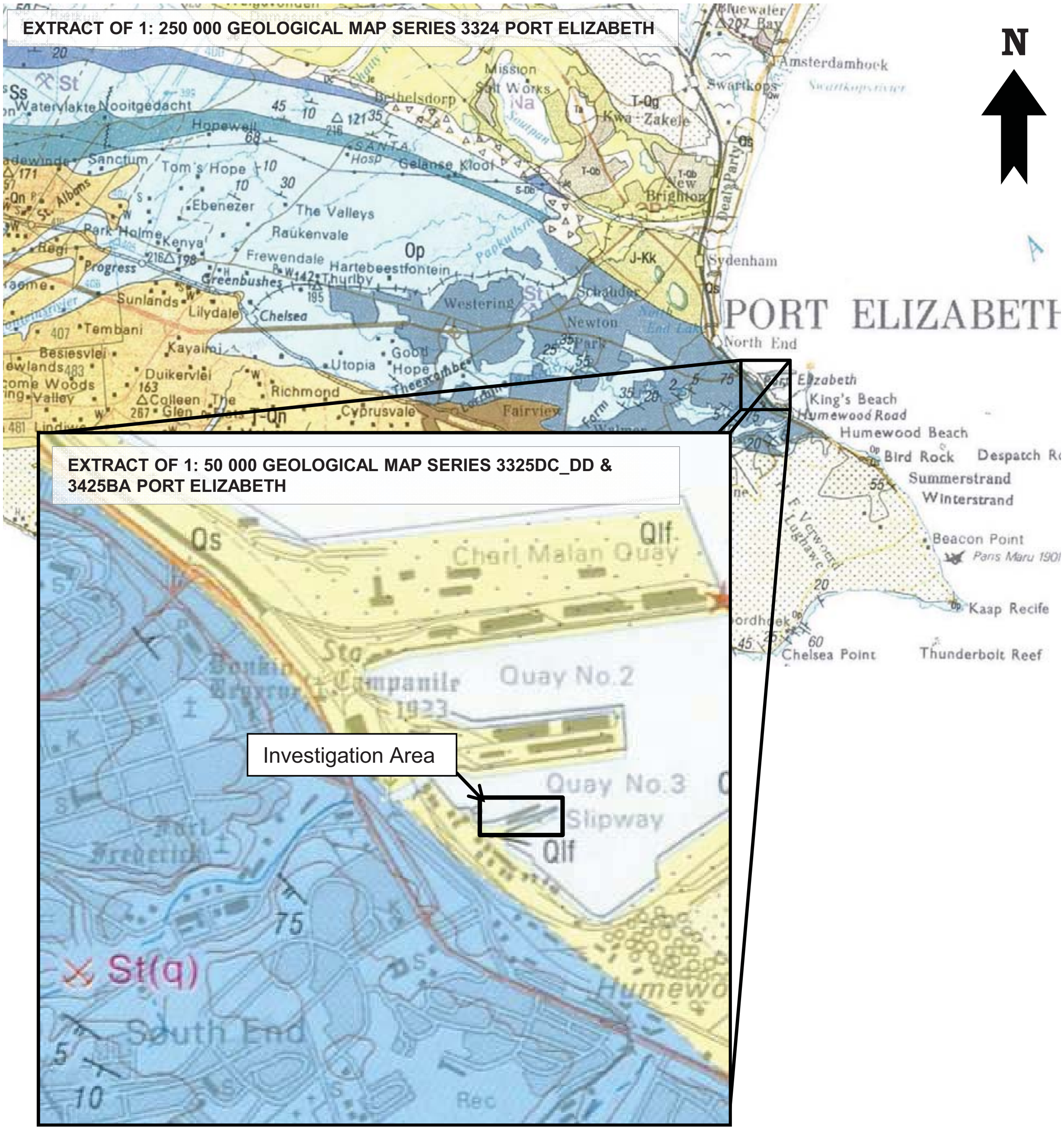
www.GoogleEarth.com

# APPENDIX A
# FIGURES




| Jeffares & Green<br>ENGINEERING & ENVIRONMENTAL CONSULTING | PORT OF PORT ELIZABETH – LEAD-IN JETTIES<br>GEOTECHNICAL DRILLING INVESTIGATION | SCALE<br>As indicated on plan |
|---|---|---|
| | **LOCALITY PLAN** | Figure 1 |




## LEGEND

| GROUP | FORMATION | | |
|---|---|---|---|
| | | Landfill Material | Qlf |
| Algoa | Salnova | Marine-estuarine Sand and Gravel; marine terrace deposit | Qs |
| Table Mountain | Peninsula | Quartzitic Sandstone | Op |

Jeffares & Green
ENGINEERING & ENVIRONMENTAL CONSULTING

PORT OF PORT ELIZABETH – LEAD-IN JETTIES

GEOTECHNICAL DRILLING INVESTIGATION

**GEOLOGICAL PLAN**

SCALE

not to scale

Figure 2

# APPENDIX B

# BOREHOLE LOGS AND PHOTOGRAPHIC PLATES

HOLE No: BH 01
Sheet 1 of 2

JOB NUMBER: 3726

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

Jeffares & Green
ENGINEERING & ENVIRONMENTAL CONSULTING

FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 01
Sheet 1 of 2

JOB NUMBER: 3726

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH Scale 1:100 | Description |
|---|---|---|---|---|---|---|
| | 0.00 | N/A | N/A | +5.00 | 0.00 | Air. |
| | | | | 0.00 | 5.00 | Water. |
| | | | | -5.00 | 10.00 | No Sample. |
| | 0.10 | | | -13.40 | 18.40 | Whitish grey, slightly to moderately weathered, hard rock, rounded quartzitic sandstone GRAVEL and COBBLES with silty fine grained sand: Fill/Alluvial. |
| | 0.13 | | | | | |
| | 0.30 | | | | | |
| | 0.15 | | | | | |
| | 0.22 | | | | | |
| | 0.20 | | | -15.57 | 20.57 | Whitish grey mottled dark grey, slightly to moderately weathered, hard rock, rounded quartzitic sandstone GRAVEL in a silty, fine to medium grained sand groundmass: Fill/Alluvial. |
| | 0.60 | | | | | |

Scale 1:100

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

HOLE No: BH 01
Sheet 2 of 2

JOB NUMBER: 3726

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

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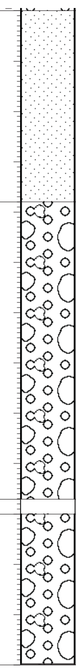
FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 01
Sheet 2 of 2

JOB NUMBER: 3726

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH Scale 1:100 | | Description |
|---|---|---|---|---|---|---|---|
| | 0.66 | | | -17.00 | 22 | 22.00 | Tan-brown with grey, silty fine grained, gravelly SAND with minor cobbles of quartzitic sandstone: Fill/Alluvial. |
| | 0.80 | | | | 23 | | |
| | 1.23 | | | | 24, 25 | | |
| | 1.08 | | | -20.80 | 26 | 25.80 | Whitish grey, moderately weathered, hard rock, sub-rounded quartzitic sandstone GRAVEL and COBBLES with silty fine to medium grained sand in places: Fill/Alluvial. |
| | 0.00 | | | | 27 | | |
| | 0.00 | | | | 28 | | |
| | 0.34 | | | | 29 | | |
| | 0.00 | | | | 30 | | |
| | 0.38 | | | -26.71 | 31 | 31.71 | Whitish grey, slightly to moderately weathered, hard rock, fractured, quartzitic sandstone BOULDER: Fill/Alluvial. |
| | 0.00 | | | -27.00 | 32 | 32.00 | Whitish grey, moderately weathered, hard rock, sub-angular to sub-rounded quartzitic sandstone GRAVEL and COBBLES: Fill/Alluvial. |
| | 0.38 | | | | 33 | | |
| | 0.23 | | | | 34 | | |
| | | | | -30.00 | 35 | 35.00 | |



NOTES

1) End of Hole at 35.00m.

CONTRACTOR: FRANKI AFRICA
MACHINE :
DRILLED BY:
PROFILED BY : L. PARFITT

TYPE SET BY : M. RICHARDS
SETUP FILE : BH-JG.SET

INCLINATION : 90deg
DIAM : NX
DATE : 11-03-2015
DATE : 11-03-2015

DATE : 10/04/2015 13:53
TEXT : ..TFILES\DOTS\3726BH01.TXT

ELEVATION +5.00
X-COORD :
Y-COORD :

HOLE No: BH 01

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

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FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 02
Sheet 1 of 2

JOB NUMBER: 3726

| DEPTH (Scale 1:100) | REDUCED LEVELS | DESCRIPTION |
|---|---|---|
| 0.00 | +5.00 | Air. |
| 5.00 | 0.00 | Water. |
| 11.00 | -6.00 | No Sample. |
| 16.80 | -11.80 | Whitish grey stained reddish brown, slightly to moderately weathered, hard rock, sub-angular to sub-rounded quartzitic sandstone GRAVEL and COBBLES with clayey material 17.50-18.00m: Fill/Alluvial. |
| 18.50 | -13.50 | Dark grey stained reddish brown, quartzitic sandstone GRAVEL with silty, slightly clayey, fine to medium grained sand: Fill/Alluvial. |
| 19.00 | -14.00 | Whitish grey, slightly to moderately weathered, hard rock, sub-angular to sub-rounded quartzitic sandstone GRAVEL and COBBLES with clayey material at 23.20-23.50m: Fill/Alluvial. |

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ |
|---|---|---|---|
| | 0.20 | | |
| | 0.20 | | |
| | 0.24 | | |
| | 0.17 | | |
| | 0.59 | N/A | N/A |
| | 0.13 | | |
| | 0.57 | | |
| | 0.54 | | |

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

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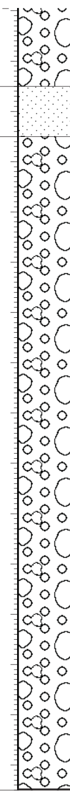
FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 02
Sheet 2 of 2

JOB NUMBER: 3726

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH Scale 1:100 |
|---|---|---|---|---|---|
| | 0.34 | | | | 22 |
| | 0.36 | | | | 23 |
| | | | | -18.50 | 23.50 |
| | 0.64 | | | | 24 |
| | | | | -19.50 | 24.50 |
| | 0.32 | | | | 25 |
| | 0.35 | | | | 26 |
| | 0.34 | | | | 27 |
| | 0.36 | | | | 28 |
| | 0.18 | | | | 29 |
| | 0.45 | | | | 30 |
| | 0.16 | | | | 31 |
| | 0.18 | | | | 32 |
| | 0.00 | | | | 33 |
| | 0.22 | | | | 34 |
| | 0.22 | | | | 35 |
| | 0.21 | | | | 36 |
| | 0.19 | | | | 37 |
| | | | | -32.50 | 37.50 |



23.50 – 24.50: Greyish white speckled red, slightly silty, fine to medium grained SAND with quartzitic sandstone gravel: Fill/Alluvial.

24.50 – 37.50: Whitish grey stained reddish brown, moderately weathered, hard rock, fractured, sub-angular to sub-rounded quartzitic sandstone GRAVEL and COBBLES with minor boulders and fine grained fracture fill in places: Fill/Alluvial.
Fracture: Slightly rough, narrow separation, filled to clean.

NOTES

1) End of Hole at 37.50m.

CONTRACTOR: FRANKI AFRICA
MACHINE :
DRILLED BY:
PROFILED BY : L. PARFITT

TYPE SET BY : M. RICHARDS
SETUP FILE : BH-JG.SET

INCLINATION : 90deg
DIAM : NX
DATE : 11-03-2015
DATE : 11-03-2015

DATE : 10/04/2015 13:53
TEXT : ..TFILES\DOTS\3726BH02.TXT

ELEVATION +5.00
X-COORD :
Y-COORD :

HOLE No: BH 02

HOLE No: BH 03
Sheet 1 of 2

JOB NUMBER: 3726

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

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ENGINEERING & ENVIRONMENTAL CONSULTING

FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 03
Sheet 1 of 2

JOB NUMBER: 3726

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH (m) | DESCRIPTION |
|---|---|---|---|---|---|---|
| | 0.25 | | | +5.00 | 0.00 | Air |
| | | | | 0.00 | 5.00 | Water |
| | | | | -2.50 | 7.50 | No sample. |
| | 0.23, 0.22, 0.20, 0.22 | | | -8.25 | 13.25 | Whitish grey and reddish brown, moderately weathered, hard rock, rounded, quartzitic sandstone GRAVEL and COBBLES: Fill/Alluvial. |
| | 0.41 | N/A | N/A | | | |
| | 0.42, 0.19, 0.27, 0.24, 0.13 | | | -13.26 | 18.26 | Whitish grey, moderately weathered, hard rock, rounded, quartzitic sandstone GRAVEL, silty, fine to medium grained sand groundmass: Alluvial. |
| | 0.00 | | | -16.00 | 21.00 | No sample. |

DEPTH Scale 1:100 (1–21)

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

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FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 03
Sheet 2 of 2

JOB NUMBER: 3726

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH Scale 1:100 |
|---|---|---|---|---|---|
| | 0.00 | | | | 22 |
| | 0.26 | | | -18.00 | 23 |
| | 0.59 | | | | 24 |
| | 0.77 | | | | 25 |
| | 1.00 | | | | 26 |
| | 0.31 | | | -22.00 | 27 |
| | 0.36 | | | | 28 |
| | 0.48 | | | -24.00 | 29 |
| | 0.49 | | | -24.94 | 30 |
| | 0.21 | | | | 31 |
| | 0.26 | | | | 32 |
| | 0.21 | | | | 33 |
| | 0.41 | | | | 34 |
| | 0.25 | | | | 35 |
| | | | | -31.00 | 36 |

| Depth (m) | Description |
|---|---|
| 23.00 | Greyish white stained reddish brown in places, gravelly, silty, fine to medium grained SAND with quartzitic sandstone gravel and cobbles: Alluvial. |
| 27.00 | Whitish grey, moderately weathered, hard rock, rounded GRAVEL and COBBLES of quartzitic sandstone: Alluvial. |
| 29.00 | Greyish white stained reddish brown in places, gravelly, silty, fine to medium grained SAND with quartzitic sandstone gravel: Alluvial. |
| 29.94 | Whitish grey, moderately weathered, hard rock, rounded GRAVEL and COBBLES of quartzitic sandstone: Alluvial. |
| 36.00 | |

NOTES

1) End of Hole at 36.00m.

CONTRACTOR: TERRA-FOUND CC
MACHINE :
DRILLED BY: TERRA-FOUND CC
PROFILED BY : L. PARFITT

TYPE SET BY : M. RICHARDS
SETUP FILE : BH-JG.SET

INCLINATION : 90deg
DIAM : NX
DATE : 24-03-2015
DATE : 24-03-2015

DATE : 10/04/2015 13:53
TEXT : ..TFILES\DOTS\3726BH03.TXT

ELEVATION +5.00
X-COORD :
Y-COORD :

HOLE No: BH 03

**HOLE No: BH 04**
*Sheet 1 of 2*

*JOB NUMBER:* 3726

*SOIL TYPE*
*Boulder >200mm*
*Cobble 60 - 200mm*
*Gravel*
*- Coarse 20 - 60mm*
*- Medium 6 - 20mm*
*- Fine 2 - 6mm*
*Sand*
*- Coarse 0.6 - 2mm*
*- Medium 0.2 - 0.6mm*
*- Fine 0.06 - 0.2mm*
*Silt 0.002 - 0.06mm*
*Clay <0.002mm*

*ROCK HARDNESS*
*Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick*
*Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point*
*Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick*
*Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing*

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PORT ELIZABETH JETTIES

**HOLE No: BH 04**
*Sheet 1 of 2*

*JOB NUMBER:* 3726

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH Scale 1:100 | Description |
|---|---|---|---|---|---|---|
| | 0.20 | | | +5.00 | 0.00 | Air. |
| | | | | 0.00 | 5.00 | Water. |
| | | | | -8.50 | 13.50 | No sample. |
| | 0.17 | N/A | N/A | -13.00 | 18.00 | Whitish grey, slightly to moderately weathered, hard rock, sub-rounded GRAVEL and COBBLES of quartzitic sandstone: Fill/Alluvial. |
| | 0.33 | | | | | |
| | 0.12 | | | | | |

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

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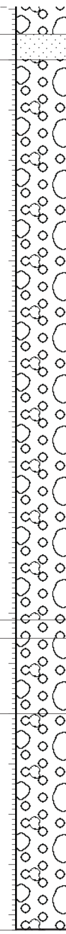
FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 04
Sheet 2 of 2

JOB NUMBER: 3726

MATERIAL REC.(m): 0.13, 0.10, 0.15, 0.34, 0.29, 0.15, 0.17, 0.19, 0.08, 0.16, 0.30, 0.55, 0.23, 0.49, 0.28, 0.48

DEPTH Scale 1:100: 22, 23, 24, 25, 26, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 39, 40



| REDUCED LEVELS | Depth (m) | Description |
|---|---|---|
| -17.50 | 22.50 | |
| -18.00 | 23.00 | Greyish white, silty, fine to medium grained SAND with quartzitic sandstone gravel: Fill/Alluvial. |
| -29.14 | 34.14 | Whitish grey, slightly to moderately weathered, hard rock, sub-angular to sub-rounded GRAVEL and COBBLES of quartzitic sandstone: Fill/Alluvial. |
| -29.50 | 34.50 | Greyish white, sub-rounded quartzitic sandstone GRAVEL in a silty, fine to medium grained sand groundmass: Fill/Alluvial. |
| -31.00 | 36.00 | Whitish grey stained brown, moderately weathered, hard rock, rounded quartzitic sandstone GRAVEL and COBBLES: Fill/Alluvial. |
| -35.30 | 40.30 | Whitish grey, moderately weathered, hard rock, fractured, sub-angular to sub-rounded quartzitic sandstone GRAVEL and COBBLES with minor boulders and gravelly sand in places: Fill/Alluvial. Fracture: Slightly rough, narrow separation, clean to filled. |

NOTES

1) End of Hole at 40.30m.

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH Scale 1:100 |
|---|---|---|---|---|---|

CONTRACTOR: FRANKI AFRICA
MACHINE :
DRILLED BY:
PROFILED BY : L. PARFITT

TYPE SET BY : M. RICHARDS
SETUP FILE : BH-JG.SET

INCLINATION : 90deg
DIAM : NX
DATE : 11-03-2015
DATE : 11-03-2015

DATE : 10/04/2015 13:53
TEXT : ..TFILES\DOTS\3726BH04.TXT

ELEVATION +5.00
X-COORD :
Y-COORD :

HOLE No: BH 04

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

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FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 05
Sheet 1 of 2

JOB NUMBER: 3726

| DEPTH (m) | REDUCED LEVELS | DESCRIPTION |
|---|---|---|
| 0.00 | +5.00 | Air |
| 5.00 | 0.00 | Water |
| 8.10 | -3.10 | No sample. |
| 15.00 | -10.00 | Whitish grey stained reddish brown, moderately weathered, hard rock, sub-rounded, quartzitic sandstone GRAVEL and COBBLES: Fill/Alluvial. |
| 16.82 | -11.82 | Light tan-brown, slightly silty, fine to medium grained SAND with minor rounded quartzitic sandstone gravel: Alluvial. |
| 17.15 | -12.15 | Grey, stained red in places, rounded quartzitic sandstone GRAVEL in a silty, clay groundmass (possibly drilling fluid): Alluvial. |
| 20.00 | -15.00 | Whitish grey, moderately weathered, hard rock, sub-rounded, quartzitic sandstone GRAVEL and COBBLES: Alluvial. |

MATERIAL REC.(m): 0.00, 0.17, 0.31, 0.32, 0.31, 0.29, 0.20

RQD %: N/A

FRAC FREQ: N/A

DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH Scale 1:100

HOLE No: BH 05
Sheet 2 of 2

JOB NUMBER: 3726

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

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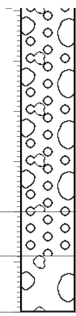
FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 05
Sheet 2 of 2

JOB NUMBER: 3726

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH Scale 1:100 |
|---|---|---|---|---|---|
| | 0.32 | | | | 22 |
| | 0.19 | | | | 23–24 |
| | 0.21 | | | | 25 |
| | 0.28 | | | -21.00 | 26 |
| | 0.22 | | | -21.88 | 27 |
| | | | | -23.00 | 28 |



26.00 Grey, sub-rounded GRAVEL of quartzitic sandstone in a silty, fine to medium grained sand groundmass: Alluvial.

26.88 Whitish grey stained reddish brown in places, moderately weathered, hard rock, COBBLES of quartzitic sandstone with minor gravel: Alluvial.

28.00

NOTES

1) End of Hole at 28.00m.

CONTRACTOR: FRANKI AFRICA
MACHINE :
DRILLED BY:
PROFILED BY : L. PARFITT

TYPE SET BY : M. RICHARDS
SETUP FILE : BH-JG.SET

INCLINATION : 90deg
DIAM : NX
DATE : 24-03-2015
DATE : 24-03-2015

DATE : 10/04/2015 13:53
TEXT : ..TFILES\DOTS\3726BH05.TXT

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: BH 05

HOLE No: BH 06
Sheet 1 of 2

JOB NUMBER: 3726

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

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FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 06
Sheet 1 of 2

JOB NUMBER: 3726

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH Scale 1:100 | Depth (m) | Description |
|---|---|---|---|---|---|---|---|
| | 0.23 | | | +5.00 | | 0.00 | Air |
| | | | | 0.00 | | 5.00 | Water |
| | | | | -2.50 | | 7.50 | No sample. |
| | 0.18 | N/A | N/A | -9.37 | | 14.37 | Whitish grey, moderately weathered, hard rock, sub-rounded, quartzitic sandstone GRAVEL and COBBLES: Fill/Alluvial. |
| | 0.12 | | | | | | |
| | 0.00 | | | -11.60 | | 16.60 | No sample. |
| | 0.00 | | | | | | |
| | 0.00 | | | | | | |
| | 0.86 | | | -14.60 | | 19.60 | Mottled tan-brown and reddish brown, silty CLAY: Alluvial. |
| | 0.20 | | | -15.60 | | 20.60 | Greyish light tan-brown, silty, fine to medium grained SAND: Alluvial. |

Scale 1:100
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21

SOIL TYPE
Boulder >200mm
Cobble 60 - 200mm
Gravel
- Coarse 20 - 60mm
- Medium 6 - 20mm
- Fine 2 - 6mm
Sand
- Coarse 0.6 - 2mm
- Medium 0.2 - 0.6mm
- Fine 0.06 - 0.2mm
Silt 0.002 - 0.06mm
Clay <0.002mm

ROCK HARDNESS
Very soft rock - Can be peeled with a knife; material crumbles under firm blow with the sharp end of a geological pick
Soft rock - Can just be scraped with a knife; indentations of 2mm to 4mm with firm blows of the pick point
Medium hard rock - Cannot be scraped or peeled with a knife; hand-held specimen breaks with firm blows of the pick
Hard rock/Very hard rock/Extremely hard rock - These materials are usually only broken with some difficulty and ring when struck. Classification can be assessed by Schmidt hammer/point load test and verified by uniaxial compressive strenght testing

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FRANKI AFRICA
PORT ELIZABETH JETTIES

HOLE No: BH 06
Sheet 2 of 2

JOB NUMBER: 3726

| DRILL METH | MATERIAL REC.(m) | RQD % | FRAC FREQ | REDUCED LEVELS | DEPTH (m) | DESCRIPTION |
|---|---|---|---|---|---|---|
| | 1.13 | | | -17.30 | 22.30 | |
| | 0.00 | | | -17.60 | 22.60 | Greyish white, sandy, quartzitic sandstone GRAVEL: Alluvial. |
| | 0.52 | | | -18.60 | 23.60 | No sample. |
| | 0.30 | | | | | Greyish white, moderately weathered, hard rock, sub-rounded, quartzitic sandstone GRAVEL and COBBLES with silty, fine to medium grained sand and minor boulders in places: Alluvial. |
| | 0.24 | | | | | |
| | 0.19 | | | | | |
| | 0.21 | | | | | |
| | 0.40 | | | | | |
| | 0.24 | | | | | |
| | 0.43 | | | -26.60 | 31.60 | |

DEPTH Scale 1:100 (22, 23, 24, 25, 26, 27, 28, 29, 30, 31)

NOTES

1) End of Hole at 31.60m.

CONTRACTOR: TERRA-FOUND CC
MACHINE :
DRILLED BY: TERRA-FOUND CC
PROFILED BY : L. PARFITT

TYPE SET BY : M. RICHARDS
SETUP FILE : BH-JG.SET

INCLINATION : 90deg
DIAM : NX
DATE : 24-03-2015
DATE : 24-03-2015

DATE : 10/04/2015 13:54
TEXT : ..TFILES\DOTS\3726BH06.TXT

ELEVATION :
X-COORD :
Y-COORD :

HOLE No: BH 06


**PLATE 1:** Borehole core for BH01 from depth 18.40 m – 35.00 m.


**PLATE 2:** Borehole core for BH02 from depth 16.80 m – 37.50 m.


**PLATE 3**: Borehole core for BH03 from depth 13.25 m – 36.00 m.


**PLATE 4:** Borehole core for BH04 from depth 18.00 m – 40.30 m.


**PLATE 5:** Borehole core for BH05 from depth 15.00 m – 28.00 m.


**PLATE 6:** Borehole core for BH06 from depth 14.37 m – 31.60 m.

**ANNEXURE B |** MULTI-CRITERIA ANALYSIS

Consulting Port and Coastal Engineers

# PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE REHABILITATION

**OPTIONEERING AND MULTI-CRITERIA ANALYSIS**

FEL 2 STUDY

REV.02

26 March 2019

TRANSNET NATIONAL PORTS AUTHORITY
Port of Port Elizabeth, South Africa

PRDW
Consulting Port and Coastal Engineers

# PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE REHABILITATION

**OPTIONEERING AND MULTI-CRITERIA ANALYSIS**

PRE-FEASIBILITY STUDY (FEL 2)

S2001-109-TN-ST-001-R2

26 March 2019

| REV. | TYPE | DATE | EXECUTED | CHECK | APPROVED | CLIENT | DESCRIPTION / COMMENTS |
|---|---|---|---|---|---|---|---|
| 00 | A | 18/12/2018 | JPR/YH | PES | AEL | | FOR COMMENTS |
| 01 | C | 31/01/2019 | JPR/YH | PES | AEL | | ADDRESSING CLIENT'S COMMENTS |
| 02 | D | 26/03/2019 | JPR/YH | PES | AEL | | ADDRESSING CLIENT'S COMMENTS |

TYPE OF ISSUE: (A) Draft (B) To bid or proposal (C) For Approval (D) Approved (E) Void

TRANSNET NATIONAL PORTS AUTHORITY
Port of Port Elizabeth, South Africa

TRANSNET
national ports authority

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Vitoria, Brazil

Consulting Port and Coastal Engineers

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## ANNEXURES

ANNEXURE A | OPTIONEERING DRAWINGS
ANNEXURE B | PRE-SCREENING ASSESSMENT
ANNEXURE C | MULTI-CRITERIA WEIGHTING
ANNEXURE D | MULTI-CRITERIA ANALYSIS

# 1. INTRODUCTION

## 1.1 Background

PRDW have been appointed by Transnet National Ports Authority (TNPA) to conduct a pre-feasibility (FEL 2) study for the rehabilitation of the Old Tug Jetty sheet pile wall. The Old Tug Jetty sheet pile wall is a steel sheet pile wall located within the Port of Port Elizabeth, refer to Figure 1-1.


**Figure 1-1: Port Elizabeth Old Tug Jetty sheet pile wall site location**

The quay wall is currently being used for the berthing of fishing vessels and trawlers. The northern extent of the back of quay area is used for the transhipment of cargo and supplies, whilst the southern extent is used for boat maintenance (for yachts).

The sheet piles have corroded significantly with large voids visible in the tidal zone. These voids have caused leaching of backfill material resulting in the subsidence of the back of quay area.

## 1.2 Purpose of document

The purpose of this document is to detail the optioneering and multi-criteria process undertaken to determine the most appropriate rehabilitation solution.

## 2. SITE INFORMATION AND KEY FUNCTIONAL REQUIREMENTS

This section serves as a summary of information extracted from the Basis of Design that was deemed critical for the multi-criteria analysis (MCA). It is recommended that this document be read in conjunction with the Basis of Design for the Old Tug Jetty Sheetpile rehabilitation.

### 2.1 General

Rehabilitation options will consider the method and duration of construction in order to minimise operational downtime, taking into account the limited back of quay area due to existing infrastructure. A key design consideration will also be the integration of the new structure with the existing structure.

### 2.2 Design life

The design service life of the rehabilitated structure is 50 years as per design working life category 4 of the TNPA Port Engineering handbook (Transnet National Ports Authority, 2015). The design will focus on maximum operational flexibility and safety with an emphasis on the fishing industry.

### 2.3 Design vessels

The Client has provided the 2018 vessel register which contains limited specifications for the vessel sizes that will be utilizing this facility. The design berthing load in generally governed by the largest vessel which is the *Adamant*. The vessel specifications for the *Adamant* will therefore be inferred from a vessel of similar length and type operating out of Saldanha Bay, namely, the *Krotoa*. The design vessel specifications are shown in Table 2-1.

**Table 2-1: Design vessel specifications**

| Parameter | Assumed | Available vessel information as provided by TNPA | | |
|---|---|---|---|---|
| | Krotoa | Adamant (Largest vessel) | Zanette (Smallest vessel) | Black Jack (Shortest vessel) |
| Gross registered tonnage (t) | 1111 | 974 | 25 | - |
| Displacement ($m^3$) | 1399 | - | - | - |
| Length overall (m) | 47.5 | 61.0 | - | 6.1 |
| Length between perp. (m) | 42.0 | - | - | - |
| Beam (m) | 11.9 | - | - | - |
| Laden draft (m) | 5.7 | - | - | - |

### 2.4 Quay operations

The Old Tug Jetty Sheetpile back-up area can be divided into two sections based on operations. The northern side is mainly used for the berthing of fishing boats and trawlers, with the back of quay area used for the transhipment of cargo and supplies. The southern side is used for the staging of boats for maintenance and repair. A fixed 4t crane is used for vessel handling, along with an occasional mobile crane.

### 2.5 Tide levels

The tide levels shown in Table 2-2 have been sourced from the South African Navy Hydrographic Office (SANHO, 2018). The levels are referenced to Chart Datum (CD), defined as 0.836 m below Land Levelling Datum (LLD).

**Table 2-2: Predicted tide levels for Port Elizabeth**

| Tide level | Abbreviation | Water level [m CD] |
|---|---|---|
| Highest Astronomical Tide | HAT | + 2.12 |
| Mean High Water Springs | MHWS | + 1.86 |
| Mean High Water Neaps | MHWN | + 1.29 |
| Mean Level | ML | + 1.04 |
| Mean Low Water Neaps | MLWN | + 0.79 |
| Mean Low Water Springs | MLWS | + 0.21 |
| Lowest Astronomical Tide | LAT | 0.00 |

## 2.6 Waves

The wave climate at the Old Tug Jetty was found to be dominated by locally generated wind-waves associated with dominant north easterly-winds. The location of the Old Tug Jetty (situated on the lee of the main breakwater) results in the facility being sheltered from wind-waves associated with winds from other directions as well as swell waves penetrating into Algoa Bay.

For this study, currents and waves in the vicinity of the Old Tug Jetty have been assumed to be insignificant due to its sheltered location in the harbour. However, it is recommended that this be confirmed as part of the subsequent project study (FEL 3).

## 2.7 Bathymetry

A single-beam survey of the seabed is annually carried out by Transnet Dredging Services.

This survey shows the depths directly in front and along the sheet pile wall range from -3.2m CD to -4.3m CD. This slopes down into the berth pocket of Old Tug Jetty which has a depth ranging from -6.7m CD to -7.2m CD. The berthing depth in front of the sheet pile wall is advertised as -4m CD, gradually deepening to -6.5m CD at the Old Tug Jetty.

## 2.8 Geotechnical conditions

In 2015, Jeffares & Green (Pty) Ltd conducted a geotechnical investigation in the Port of Port Elizabeth. The investigation was undertaken for the construction of the proposed 40 ton slipway as well as for the construction of the two Lead-in jetties. The geotechnical investigation comprised of a drilling campaign consisting of 12 rotary drilled boreholes cores, 6 along the proposed slipway and 6 cores along the two Lead-in jetties. The investigation used rotary core drilling to depths between -21.96m CD to -25.56m CD.

Due to the close proximity of these boreholes to the site and the required level of design, this geotechnical investigation was deemed fit for this study.

According to Jeffares & Green, alluvium/fill dominated all boreholes and is mainly comprised of sub-angular to rounded gravel, cobbles and minor boulders of quartzitic sandstone and gravelly sand. The boreholes indicate the absence of hard rock and the harbour area is significantly inconsistent in its horizontal and vertical profile, showing wide variability in strata levels.

Based on the material descriptions from the borehole logs and as-built drawings, their typical design material properties have been defined in Table 2-3 below.

**Table 2-3: Soil properties**

| Material description | Saturated density $\gamma_{sat}$ [kN/m³] | Bulk density $\gamma_{bulk}$ [kN/m³] | Effective internal friction Angle φ' [°] | Cohesion c' [kN/m²] | Reference |
|---|---|---|---|---|---|
| Marine sediment/Loose sand/Silty sand | 18.5 | 17.5 | 30 | - | Arcelor Piling Handbook 8th Edition |
| Sand fill/Medium dense sand | 19.0 | 18.5 | 32 | - | |
| Gravel backfill | 20.0 | 19.0 | 38 | - | |
| Quarry run | 19.5 | 18.5 | 45 | - | |
| Scour rock | 20.5 | 19.5 | 45 | - | |
| Alluvial gravel and cobbles | 20.0 | 19.0 | 35 | - | |
| Pavement layer work (assumed to be highly compacted gravel) | 21.0 | 20 | 45 | - | |
| Existing rock fill (assumed to be weathered quarry run) | 19.5 | 18.5 | 40 | - | |

Based on the founding structures for the adjacent Old Tug Jetty and Lead-in Jetties and the results from the interpretative geotechnical report undertaken by Jeffares & Green, the preferred structure should minimise piled foundations.

It is recommended that for the following project phase (FEL 3 study), a detailed geotechnical investigation along the Old Tug Jetty sheet pile wall be undertaken to confirm the soil properties and material stratigraphy.

# 3. OPTIONEERING ASSESSMENT

## 3.1 Methodology

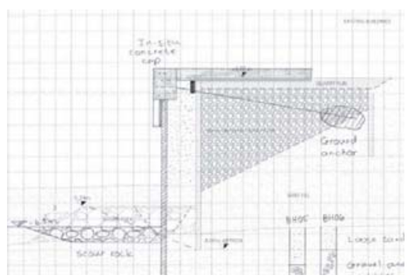
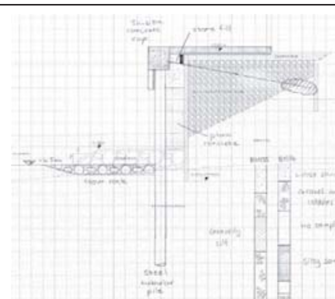
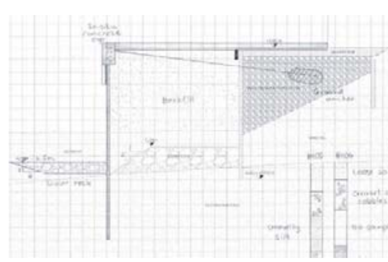
A set of rehabilitation concepts for the Old Tug Jetty sheet pile wall were developed based on typical marine structure types, construction techniques, functional requirements, and existing site conditions. A pre-screening assessment of the concepts was then undertaken using a high level, qualitative, multi-criteria analysis to eliminate options that were not considered viable, or which had fatal flaws. Thereafter, the remaining options were assessed in a multi-criteria analysis to determine the preferred solution.

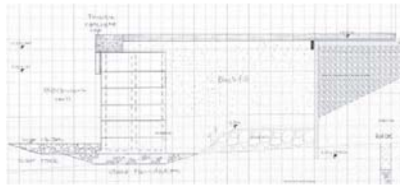
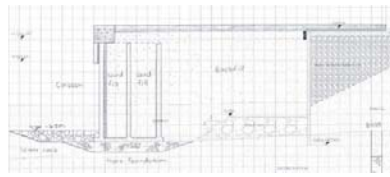
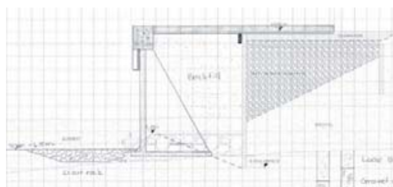
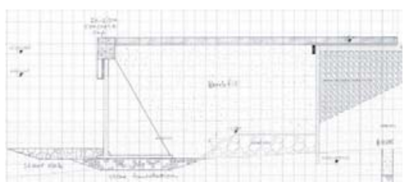
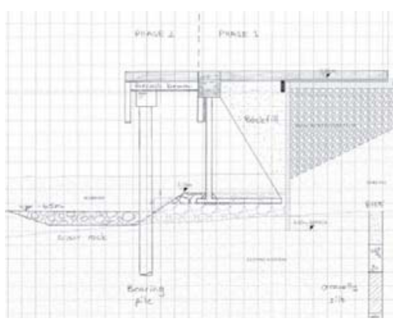
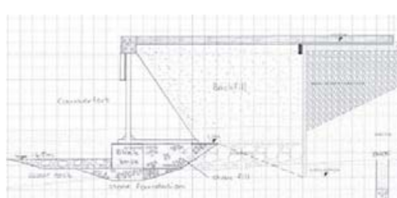
## 3.2 Pre-screening assessment

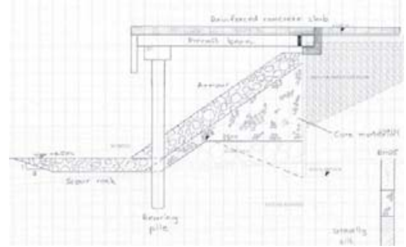
The full set of Old Tug Jetty sheet pile wall rehabilitation options that were considered for the pre-screening assessment are detailed in Table 3-1 below.

All the rehabilitation options presented in Table 3-1 below, assume that the existing Old Tug Jetty sheet pile wall will be abandoned and buried and the back of quay area remediated.

**Table 3-1: Optioneering**

| No. | Option | Illustration | Description |
|---|---|---|---|
| 1 | **Steel sheet pile wall** |  | Construction of a new steel sheet pile wall in front of the existing steel sheet pile wall. Excavation of existing scour rock would be required before the piles could be driven. Wall would thereafter be backfilled and an in-situ cap and slab cast. |
| 2 | **Steel tubular combi-wall** |  | Construction of a sheet pile wall using steel tubular piles. Tubular piles would be advanced through the existing scour protection by chiselling/excavating through the tube. The piles would have a minimal offset from the existing wall which would be grouted up. |
| 3 | **Steel sheet pile wall (offset)** |  | The proposed sheet pile would be offset beyond the toe of the existing scour rock layer. This would allow the existing sheet pile to remain unaffected by the proposed construction. Wall would thereafter be backfilled and an in-situ cap and slab cast. |

| No. | Option | Illustration | Description |
|---|---|---|---|
| 4 | **Blockwork gravity wall** |  | The blockwork wall would be located seaward of the existing scour protection in order to avoid destabilizing the existing sheet pile wall. The option would entail the construction of a stone foundation, placing the concrete blocks, backfilling, casting an in-situ cap and slab. |
| 5 | **Caisson gravity wall** |  | The caisson option is very similar to the blockwork structure. The caissons would be constructed in the dry, launched on one of the slipways adjacent to the Old Tug Jetty, floated into place and submerged. |
| 6 | **Counterfort gravity wall** |  | Construction of the counterfort wall would require dredging and removal of existing rock material in order to place a stone bed foundation. Partial relief of the backfill behind the existing sheet pile wall would probably be required during construction. Thereafter, the wall would be placed, backfilled, scour rock placed and concrete works undertaken. |
| 7 | **Counterfort gravity wall (offset)** |  | Similar to option 6, the only difference is that the counterfort wall would be placed seaward of the existing scour protection in order to avoid destabilizing the existing sheet pile wall. |
| 8 | **Counterfort and deck on pile hybrid** |  | This option is broken into two phases:<br><br>**Phase 1** – Dredge and excavate to the top of the existing scour rock. Thereafter, construct the counterfort wall similar to option 6. Interim berth depth -5.2m CD.<br><br>**Phase 2** – When there is sufficient demand for a deeper berth, the structure could be expanded by driving piles beyond the existing scour rock and constructing a deck on pile structure with the designed berth depth of -6.5m CD. |
| 9 | **Blockwork counterfort hybrid** |  | This option would entail dredging and constructing a stone foundation for a concrete block. This would serve as a step and provides a foundation for the counterfort which would be constructed on top of the block. This option was considered since it would reduce the structure's footprint in comparison to option 7. |

| No. | Option | Illustration | Description |
|---|---|---|---|
| **10** | **Deck on pile wharf** |  | The deck on pile option would entail driving the piles just beyond the toe of the existing scour protection. Thereafter, the existing wall would be buttressed by the rock fill, and precast beams and slabs are used to construct the deck. |

### 3.2.1 Assessment criteria

The options were assessed qualitatively against the following criteria:

- Health and safety considerations

  The safety of personnel during construction considering the extent of dive work and working over water required. The structural redundancy in the event of an accident i.e. is the damage localised and how damage will be repaired. The risk of partial or catastrophic collapse of existing infrastructure during construction was also considered.

- Environmental considerations

  The impact of the increased footprint of the facility on the environment along with the permit or authorization requirements. Permanent impact on the port operations i.e. access to slipways and Old Tug Jetty and whether the structure is recyclable in future demolition. The carbon footprint is also considered by accounting for the quantum of material needed for each option.

- Constructability

  The schedule and risk of delays that can occur due to ground conditions. Considerations around the practical aspects of construction i.e. the contractor's working site and the extent of temporary work required. Impact on port operations, and whether partial works can be done with partial handover and if there is access to the slipways and Old Tug Jetty.

- Localisation

  Locally sourcing plant, material and skills.

- Maintainability

  The cost (materials and labour,) and the skilled personnel (e.g. divers) required to maintain the proposed solution for the structure's design service life.

- Capital costs

  Capital cost associated with the proposed solution.

- Upgradeability

  The flexibility and adaptability of the structure i.e. provision for future increased depth, capacity for increased lateral and vertical loading and its adaptability for future change of use.

Pre-screening options were then assessed holistically in a qualitative manner relative to the other options being considered, according to the scoring guideline outlined in Table 3-2.

The rating was scored from poor to excellent or when considering cost, from expensive to cheapest. If an option was deemed as fatally flawed, it was automatically eliminated as it was no longer considered viable.

**Table 3-2: Pre-screening assessment – scoring guideline**

| Rating | | |
|---|---|---|
| | Excellent / | Cheapest |
| | Good / | Modest cost |
| | Average / | Moderate cost |
| | Fair / | Fairly expensive |
| | Poor / | Expensive |
| | Fatal flaw | |

## 3.2.2 Results

The summary results of the pre-screening assessment for the rehabilitation of the Old Tug Jetty sheet pile is presented in Table 3-3 below. For the detailed assessment comments please refer to Annexure B.

**Table 3-3: Pre-screening assessment summary of results (preferred options are numbered red)**

| REHABILITATION OPTIONS | | CRITERIA | | | | | | |
|---|---|---|---|---|---|---|---|---|
| No. | Option | Health and safety considerations | Environmental considerations | Constructability | Localisation | Maintainability | Capital cost | Upgradeability |
| 1 | Steel sheet pile wall | Fatal flaw | Excellent | Good | Fair | Poor | Cheapest | Poor |
| 2 | Steel tubular combi-wall | Good | Excellent | Good | Poor | Fair | Average | Fair |
| 3 | Steel sheet pile wall (offset) | Excellent | Good | Average | Fair | Poor | Modest cost | Average |
| 4 | Blockwork gravity wall | Fair | Poor | Fair | Excellent | Good | Fairly expensive | Good |
| 5 | Caisson gravity wall | Fair | Poor | Poor | Average | Excellent | Expensive | Good |
| 6 | Counterfort gravity wall | Fatal flaw | Average | Good | Excellent | Excellent | Average | Average |
| 7 | Counterfort gravity wall (offset) | Average | Poor | Fair | Excellent | Good | Fairly expensive | Good |
| 8 | Counterfort deck on pile hybrid | Good | Good | Excellent | Good | Average | Good | Excellent |
| 9 | Blockwork counterfort hybrid | Poor | Average | Poor | Excellent | Excellent | Fairly expensive | Average |
| 10 | Deck on pile wharf | Good | Average | Good | Good | Average | Modest cost | Good |

### 3.2.3 Summary of pre-screening assessment results

Based on the pre-screening assessment, the following concept options were selected to proceed to the multi-criteria assessment to determine the preferred option:

- Steel tubular combi-wall (2)
- Offset sheet pile (3)
- Counterfort deck on pile hybrid (8)
- Deck on pile (10)

These 4 options were selected since they scored the best holistically. Refer to Annexure B for further discussion on the options assessment.

# 4. MULTI-CRITERIA ANALYSIS

The selected options identified by the pre-screening assessment has been assessed using the multi-criteria analysis (MCA) presented herein. The criteria used is the same as in the pre-screening assessment however, the associated criteria weightings have been used to determine the scoring for the MCA.

## 4.1 Criteria weighting

The MCA criteria weighting were determined, as per the Client's request, by means of a pairwise ranking survey. Based on this survey the average weighting for the criteria were assessed and where necessary modified in consultation with the Client to produce the base case MCA weighting listed in Table 4-1 below.

**Table 4-1: Multi-criteria assessment – base case weightings**

| Criteria | Weighting |
|---|---|
| Health and safety considerations | 15% |
| Environmental considerations | 20% |
| Constructability | 15% |
| Localisation | 5% |
| Maintainability | 15% |
| Capital cost | 20% |
| Upgradeability | 10% |
| **Total** | **100%** |

Furthermore, a sensitivity analysis was undertaken to assess the sensitivity of the MCA to the criteria weightings. The criteria weightings for the various scenarios considered in the sensitivity analysis are presented in Table 4-2 below.

**Table 4-2: Multi-criteria assessment – sensitivity analysis weightings**

| Main criteria | Weighting bias | | | | | |
|---|---|---|---|---|---|---|
| | Equal | Health and safety considerations | Environmental considerations | Constructability | Capital cost | Upgradeability |
| Health and safety considerations | 14% | 30% | 12% | 12% | 12% | 12% |
| Environmental considerations | 14% | 12% | 30% | 12% | 12% | 12% |
| Constructability | 14% | 12% | 12% | 30% | 12% | 12% |
| Localisation | 14% | 12% | 12% | 12% | 12% | 12% |
| Maintainability | 14% | 12% | 12% | 12% | 12% | 12% |
| Capital cost | 14% | 12% | 12% | 12% | 30% | 12% |
| Upgradeability | 14% | 12% | 12% | 12% | 12% | 30% |
| **TOTAL** | **100%** | **100%** | **100%** | **100%** | **100%** | **100%** |

One of the purposes of the sensitivity analysis was to verify the base case weighting by unduly skewing the MCA in the sensitivity analysis in favour of the other criteria. This would help identify the sensitivities of the preferred solution in comparison to the MCA criteria.

## 4.2 Scoring

For all criteria the options were assigned quantitative scores relative to their qualitative assessment. Scoring was undertaken relative to the other options being considered, according to the scoring guideline outlined in Table 4-3 below.

**Table 4-3: Multi-criteria assessment – scoring guideline**

| Comment | Scores |
|---|---|
| Excellent | 10 |
| Good | 7.5 |
| Average | 5 |
| Fair | 2.5 |
| Poor | 1 |
| Fatal flaw | 0 |

## 4.3 Results

### 4.3.1 Base case weighting

The assigned scores for each criterion and the MCA outcome for the base weighting are presented in Table 4-4 below.

**Table 4-4: MCA base case scenario**

| | PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REHABILITATION OPTIONS ASSESSMENT | | | | | |
|---|---|---|---|---|---|---|
| | Multi-criteria analysis for selection of preferred option - Base case weighting | | | | | |
| | | | | | | |
| | TOTAL | | Option 1: Deck on pile | Option 2: Offset sheet pile wall | Option 3: Counterfort deck on pile hybrid | Option 4: Steel tubular combi-wall |
| **Ref.** | **Criteria** | **Weighting** | | | | |
| 1 | **Health and safety considerations** | 15% | 11% | 14% | 7% | 13% |
| 2 | **Environmental considerations** | 20% | 8% | 9% | 15% | 18% |
| 3 | **Constructability** | 15% | 10% | 4% | 13% | 11% |
| 4 | **Localisation** | 5% | 4% | 1% | 5% | 1% |
| 5 | **Maintainability** | 15% | 11% | 5% | 15% | 5% |
| 6 | **Capital cost** | 20% | 17% | 20% | 14% | 11% |
| 7 | **Upgradeability** | 10% | 8% | 5% | 10% | 3% |
| | | | | | | |
| | **Total** | **100%** | **68%** | **58%** | **78%** | **61%** |
| | | | | | | |
| **1** | **Health and safety considerations** | **100%** | **7.1** | **9.4** | **4.4** | **8.8** |

| | PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REHABILITATION OPTIONS ASSESSMENT | | | | | |
|---|---|---|---|---|---|---|
| | **Multi-criteria analysis for selection of preferred option - Base case weighting** | | | | | |
| | | | | | | |
| | **TOTAL** | | **Option 1: Deck on pile** | **Option 2: Offset sheet pile wall** | **Option 3: Counterfort deck on pile hybrid** | **Option 4: Steel tubular combi-wall** |
| **Ref.** | **Criteria** | **Weighting** | | | | |
| 1.1 | Safety of personnel during construction, considering the extent of dive work and time working over water. | 25% | 7.5 | 7.5 | 2.5 | 10 |
| | | | *During construction of the steel tubular combi-wall, no work over water is required, it does however require dive work for inspections. The counterfort deck on pile hybrid requires extensive dive work to inspect the stone bed and work will be required over water when phase 2 commences. General safety is also a concern when working with large precast units. The health and safety considerations for the deck on pile and sheet pile wall is deemed, good, with some dive work and over water work required for both.* | | | |
| 1.2 | Redundancy of the structure, whether damage is localised, and the ease of repair i.e. is damage localised or does it place the complete facility at risk. | 25% | 1 | 10 | 5 | 10 |
| | | | *Damage to the sheet pile wall and steel tubular combi wall will be localised in the case of a berthing accident. Repairs will however be costly, but the facility will not be at risk and operations would be able to continue. Accidental damage to the deck on pile solution will result in a partial temporary decommissioning of the facility while the damaged piles are being repaired. The counterfort deck on pile hybrid solution is therefore deemed to be more robust than the deck on pile seeing as it is partially a counterfort wall.* | | | |
| 1.3 | Risk of partial or catastrophic collapse of existing infrastructure during construction. | 50% | 10 | 10 | 5 | 7.5 |
| | | | *The deck on pile and sheet pile wall are deemed to have the least risk of collapsing the existing infrastructure. They are located further away from the existing sheet pile wall and construction does not require interaction with the existing structure. The steel tubular combi-wall has moderate risk, but there are methods available in order to de-risk this option like partial relieving of backfill. The counterfort deck on pile hybrid requires removal of a section of the passive soil wedge which is seen as a higher risk.* | | | |
| | | | | | | |
| **2** | **Environmental considerations** | **100%** | **3.8** | **4.4** | **7.5** | **8.8** |
| 2.1 | Negative impacted of increased footprint of facility due to rehabilitation and the permit or authorisation requirements. | 25% | 2.5 | 5 | 5 | 10 |
| | | | *12m cope line offset* | *9m cope line offset* | *Phase 1: 6m cope line offset Phase 2: 12m cope line offset* | *1.5m cope line offset* |
| | | | *All options will require an EIA.* | | | |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REHABILITATION OPTIONS ASSESSMENT** | | | | | |
| | **Multi-criteria analysis for selection of preferred option - Base case weighting** | | | | | |
| | **TOTAL** | | **Option 1: Deck on pile** | **Option 2: Offset sheet pile wall** | **Option 3: Counterfort deck on pile hybrid** | **Option 4: Steel tubular combi-wall** |
| **Ref.** | **Criteria** | **Weighting** | | | | |
| 2.2 | Permanent impact on port operations i.e. access to slipways and Old Tug Jetty, usable berth area. | 50% | 2.5 | 5 | 7.5 | 10 |
| | | | *The steel tubular combi-wall does not have an effect on the adjacent slipway. The counterfort deck on pile hybrid can be adapted to have less impact on port operations e.g. tapering the counterfort units closer to the slipways and not constructing the deck on pile near the slipways. The sheet pile and deck on pile will result in the same loss of berthing space at Old Tug Jetty, but the deck on pile will also lose berthing space as the structure approaches the slipways (where most likely only the revetment will be constructed) as opposed to the sheet pile wall that will be tapered.* | | | |
| 2.3 | Construction impact on environment i.e. use of green materials and construction methods. Also considers carbon footprint by accounting the quantum of material needed for each option. | 25% | 7.5 | 2.5 | 10 | 5 |
| | | | *The sheet pile and tubular combi-wall requires the most imported material that has a resulting carbon footprint. The sheet pile wall however requires much more backfill material. The deck on pile and counterfort deck on pile hybrid both require piles that might be imported based on local availability, but the deck on pile requires more imported quarry material to construct the revetment.* | | | |
| | | | | | | |
| **3** | **Constructability** | **100%** | **6.65** | **2.5** | **8.35** | **7.5** |
| 3.1 | Considering the construction schedule and the risk of delays due to ground conditions. | 33% | 10 | 2.5 | 5 | 7.5 |
| | | | *Modest construction schedule with risk of delays due to ground conditions. Anticipated construction duration 9 to 12 months.* | *Moderate construction schedule with risk of delays due to ground conditions. Anticipated construction duration 12 to 18 months.* | *Average construction schedule with partial risk of delays due to ground conditions when constructing deck on pile structure. Phase 1 anticipated construction duration 12 to 15 months. Phase 2 anticipated* | *Average construction schedule with risk of delays due to ground conditions. Anticipated construction duration 12 to 15 months.* |

| Ref. | Criteria | Weighting | Option 1: Deck on pile | Option 2: Offset sheet pile wall | Option 3: Counterfort deck on pile hybrid | Option 4: Steel tubular combi-wall |
|---|---|---|---|---|---|---|
| | **PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REHABILITATION OPTIONS ASSESSMENT** | | | | | |
| | **Multi-criteria analysis for selection of preferred option - Base case weighting** | | | | | |
| | **TOTAL** | | | | | |
| | | | | | *construction duration 9 to 10 months.* | |
| 3.2 | Considerations around the practical aspects of construction, contractor's working site and the extent of temporary works required. | 33% | 5 | 2.5 | 10 | 7.5 |
| | | | *The counterfort deck on pile hybrid will require the least amount of temporary work due to the counterfort units being cast in a casting yard. Working site is not congested with large plant. The tubular combi-wall will require large plant to drive the piles, but the required backfill is small and the limited backup area will not affect construction. The deck on pile requires large amounts of rock to be dumped in order to construct the revetment. Access in order to dump the material could be challenging. The sheet pile wall is similar with large plant and more backfill required.* | | | |
| 3.3 | Construction impact on port operations i.e. access to existing slipways and Old Tug Jetty and the impact on operations during construction e.g. closing of entire area versus partial works being done and partial handover. | 34% | 5 | 2.5 | 10 | 7.5 |
| | | | *The counterfort deck on pile hybrid will have the least impact on port operations during construction. Counterfort units are cast in a yard and dropped in place. Driving of piles will disrupt port operations with the deck on pile deemed worse than the tubular combi-wall due to the revetment that will need to be constructed prior to piling. The offset sheet pile wall will impact a larger area of the port due to its large step-out.* | | | |
| | | | | | | |
| **4** | **Localisation** | **100%** | **7.5** | **2.5** | **10** | **1** |
| 4.1 | Whether material, plant and skills can be locally sourced for construction. | 100% | 7.5 | 2.5 | 10 | 1 |
| | | | *All the skills required can be locally sourced. The material for the counterfort deck on pile hybrid can be sourced locally. The deck on pile will require more imported material and the sheet pile and combi-wall options having the most imported material. The steel tubular combi-wall was scored worse due to the need for specialised plant that can chisel through scour rock.* | | | |
| | | | | | | |
| **5** | **Maintainability** | **100%** | **7.5** | **3.4** | **10.0** | **3.4** |
| 5.1 | Maintenance cost | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| | | | *1.75% CAPEX cost* | *2% CAPEX cost at present value p.a* | *1.5% CAPEX cost at present value p.a* | *2% CAPEX cost at* |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REHABILITATION OPTIONS ASSESSMENT** | | | | | |
| | **Multi-criteria analysis for selection of preferred option - Base case weighting** | | | | | |
| | | | | | | |
| | **TOTAL** | | **Option 1: Deck on pile** | **Option 2: Offset sheet pile wall** | **Option 3: Counterfort deck on pile hybrid** | **Option 4: Steel tubular combi-wall** |
| **Ref.** | **Criteria** | **Weighting** | | | | |
| | | | *at present value p.a* | | | *present value p.a* |
| 5.2 | Personal required for maintenance i.e. skills and material | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| | | | *Minor skill required and material for piles* | *Anodes required - specialist skill* | *Minor skill required and less material for piles* | *Anodes required - specialist skill* |
| 5.3 | Design service life | 34% | 7.5 | 5.0 | 10.0 | 5.0 |
| | | | | | | |
| **6** | **Capital cost** | **100%** | **8.5** | **10.0** | **6.9** | **5.6** |
| 6.1 | Capital cost | 100% | 8.5 | 10.0 | 6.9 | 5.6 |
| | | R million | *R164* | *R140* | *R202* | *R250* |
| | | | | | | |
| **7** | **Upgradeability (flexibility and adaptability)** | **100%** | **7.5** | **5.0** | **10.0** | **2.5** |
| 7.1 | Provision for future increased berth depth and the structure's capacity for increased loading (vertical and lateral).<br>The adaptability for future change of use. | 100% | 7.5 | 5.0 | 10.0 | 2.5 |
| | | | *The deck on pile and counterfort deck on pile hybrid has provision for increased berth depth. Loading arrangements can be made and additional piles driven to accommodate an increased vertical and lateral loading. The counterfort deck on pile hybrid is deemed capable of a larger loading due to its gravity wall section. The sheet pile wall and tubular combi-wall have no provision for increased berth depth. The tubular combi-wall has the least capacity for increased loading due to its limited back-up area and close proximity to buildings.* | | | |

The base-case scenario indicates that the counterfort deck on pile hybrid option outscored the other options by performing best at constructability, localisation, maintainability and upgradeability. The deck on pile and steel tubular combi-wall scored closely at second and third respectively. Finally, the offset sheet pile wall scored overall the worst but scored favourably for capital cost.

### 4.3.2 Sensitivity analysis on the weightings

The sensitivity analysis on the criteria weightings is provided in Table 4-5.

**Table 4-5: MCA sensitivity analysis**

| PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REHABILITATION OPTIONS ASSESSMENT | | | | |
|---|---|---|---|---|
| Multi-criteria analysis for selection of preferred option - Summary of sensitivity analysis | | | | |
| | | | | |
| **Weighting bias** | **Option 1:** Deck on pile | **Option 2:** Offset sheet pile wall | **Option 3:** Counterfort deck on pile hybrid | **Option 4:** Steel tubular combi-wall |
| **Base case** | 68% | 58% | 78% | 61% |
| **Equal** | 69% | 53% | 82% | 54% |
| **Health and safety considerations** | 70% | 60% | 75% | 60% |
| **Environmental considerations** | 64% | 51% | 80% | 60% |
| **Constructability** | 69% | 48% | 82% | 57% |
| **Capital cost** | 72% | 62% | 79% | 54% |
| **Upgradeability (flexibility and adaptability)** | 70% | 52% | 85% | 48% |
| | | | | |
| **Average score:** | **69%** | **55%** | **80%** | **56%** |
| **Overall rank:** | **2** | **4** | **1** | **3** |

The sensitivity analysis indicates that the offset sheet pile wall and steel tubular combi-wall scores consistently poorly across all weighting biases and are therefore not preferred.

The clear preferred solution that scored the best across all sensitivities is the counterfort deck on pile hybrid. It is the best overall solution and is versatile seeing as it can be constructed in two phases according to port needs.

## 5. Preferred option

Based on the results from the MCA and the sensitivity analysis, the counterfort deck on pile hybrid is recommended as the preferred option.

# 6. REFERENCES

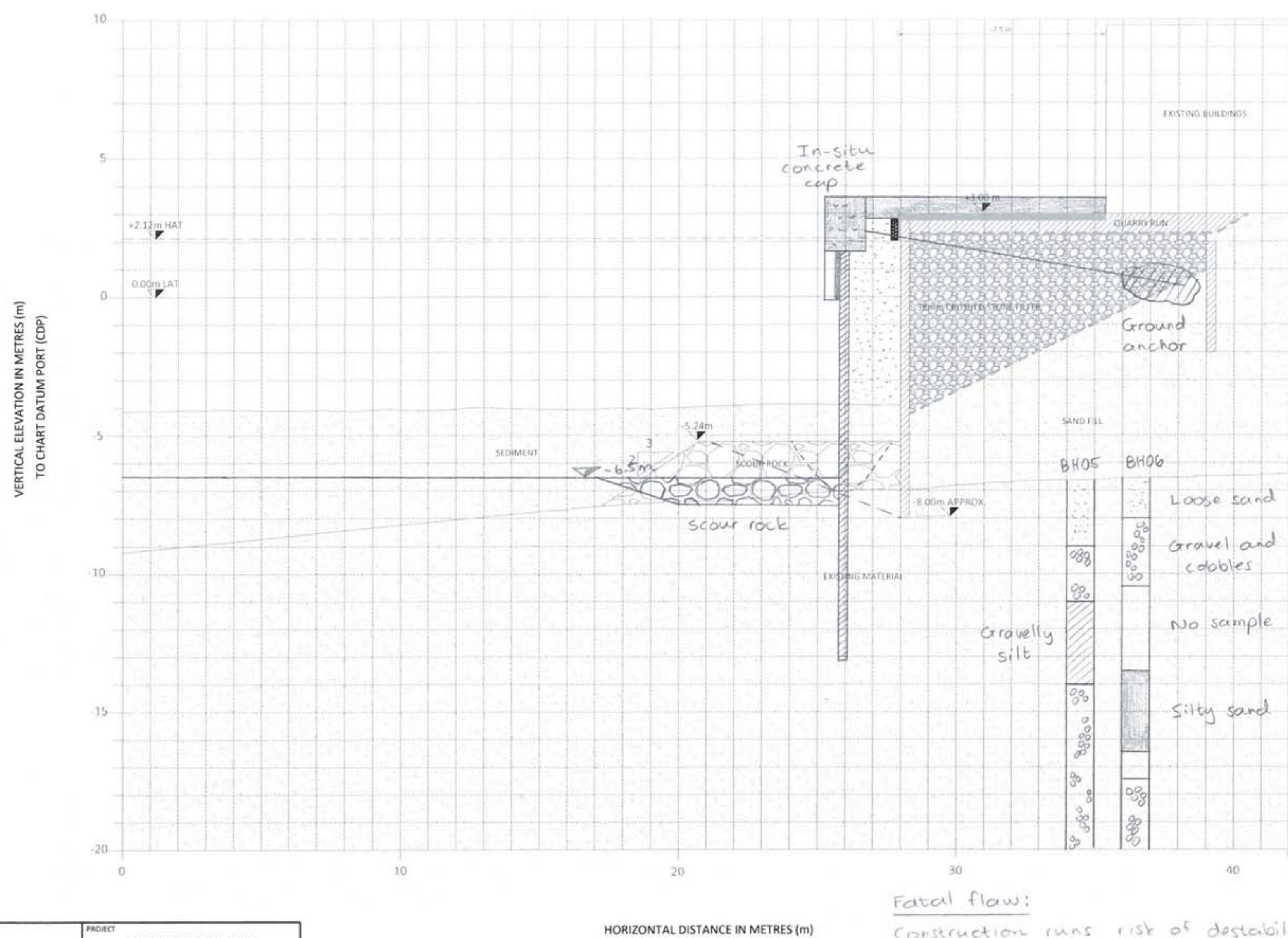

PRDW, 2018. *Old Tug Jetty sheet pile rehabilitation basis of design,* Cape Town: s.n.

SANHO, 2018. *South African Tide Tables,* Cape Town: Hydrographer South African Navy.

Transnet National Ports Authority, 2015. *Port Engineering handbook,* Johannesburg: PRDW.

# **ANNEXURE A |** OPTIONEERING DRAWINGS

A1 DO NOT SCALE - IF IN DOUBT ASK




Remarks:

Difficulty driving through scour rock
- will require scour rock removal

Less step-out
Not much loss of berthing space on Old Tug Jetty
Less backfill

Can be constructed using concrete or steel sheetpiles

Steel:
- corrosion
- imported
- better to drive

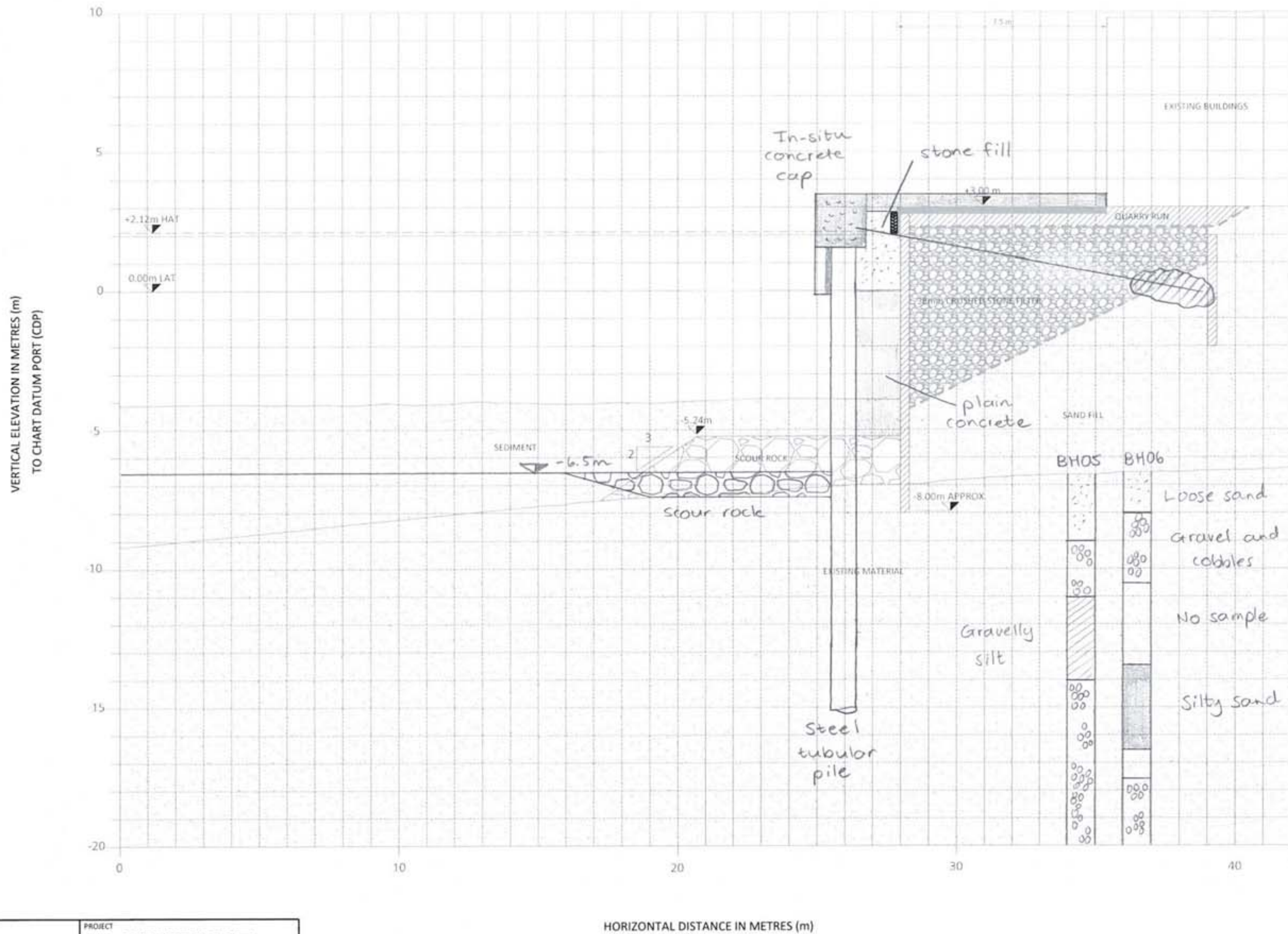
Concrete
- durable
- vulnerable to loss of material through joints
- less imported material
- cannot be driven as hard.

Fatal flaw:

Construction runs risk of destabilizing existing sheetpile by removing the rock providing passive resistance.

| | |
|---|---|
| CLIENT: TNPA | PROJECT: PORT ELIZABETH OLD TUG JETTY REHABILITATION |
| | DRAWING TITLE: SHEETPILE |
| PRDW Consulting Port and Coastal Engineers | SCALE: S2001_109 - - - - |

A1 | DO NOT SCALE - IF IN DOUBT ASK



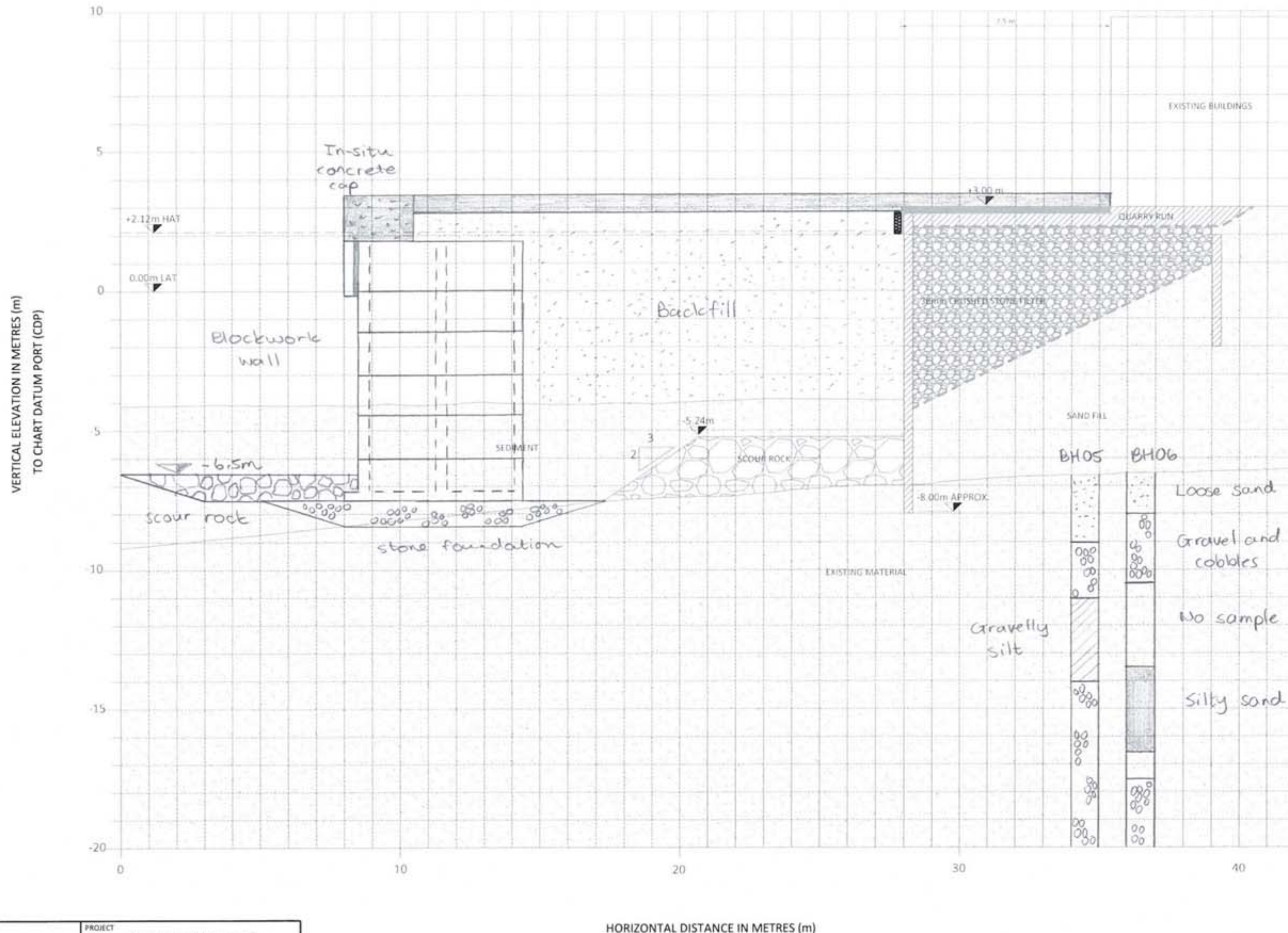

Remarks:

Drive steel tubular piles with big enough diameter to go through scour rock.

Two options:
- Drive deep enough so pile is fixed
- Tie back pile with anchor

Fill back of pile with plain concrete to LAT.

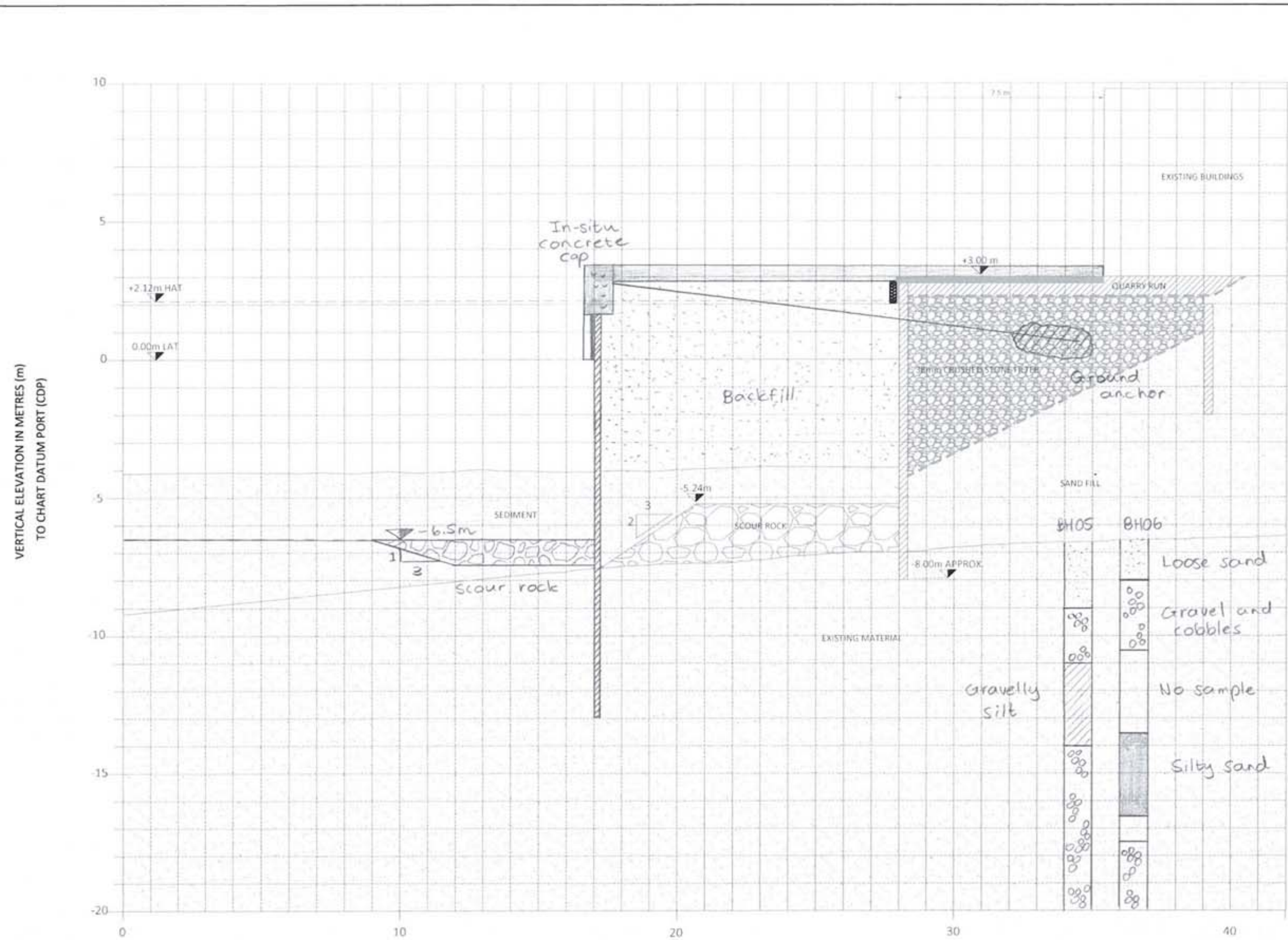
| | | |
|---|---|---|
| CLIENT: TNPA | PROJECT: PORT ELIZABETH OLD TUG JETTY REHABILITATION | |
| | DRAWING TITLE | |
| PRDW Consulting Port and Coastal Engineers | SCALE | S2001_109 - - - - |




Remarks:

- Durable design
- Expensive
- Modest maintenance plan
- No driving of piles – eliminates risk of encountering unforeseen geotechnical findings
- Very similar to caisson structure.
- Precast block units constructed on land.

| | |
|---|---|
| CLIENT: TNPA | PROJECT: PORT ELIZABETH OLD TUG JETTY REHABILITATION |
| | DRAWING TITLE: BLOCKWORK WALL |
| PRDW Consulting Port and Coastal Engineers | SCALE; S2001_109 - - - - |




Remarks:

Large amount of backfill

Driving piles to embedment depth is concern due to the presence of cobbles and gravel.

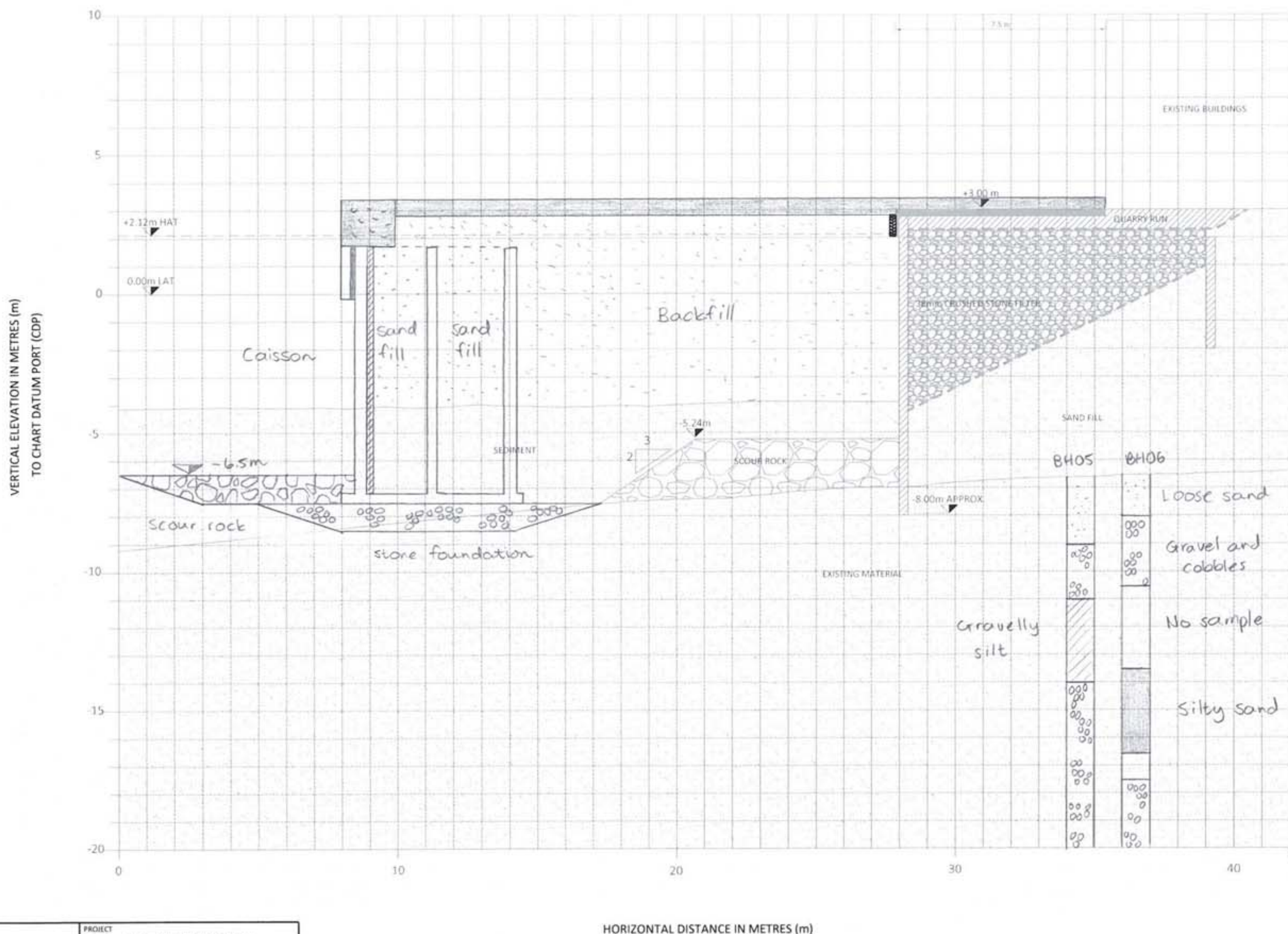
Steel sheetpile – large amount of imported material corrosion problem

Concrete sheetpile – less imported material vulnerable to loss of retained material through joints.

cannot be driven as hard – could use locally manufactured steel tubes which will give the opportunity to chisel through cobble pebble layers to achieve required pile penetration.

| | |
|---|---|
| CLIENT: TNPA | PROJECT: PORT ELIZABETH OLD TUG JETTY REHABILITATION |
| | DRAWING TITLE: SHEETPILE (OFFSET) |
| PRDW Consulting Port and Coastal Engineers | S2001_109 |

A1 DO NOT SCALE - IF IN DOUBT ASK




Remarks:

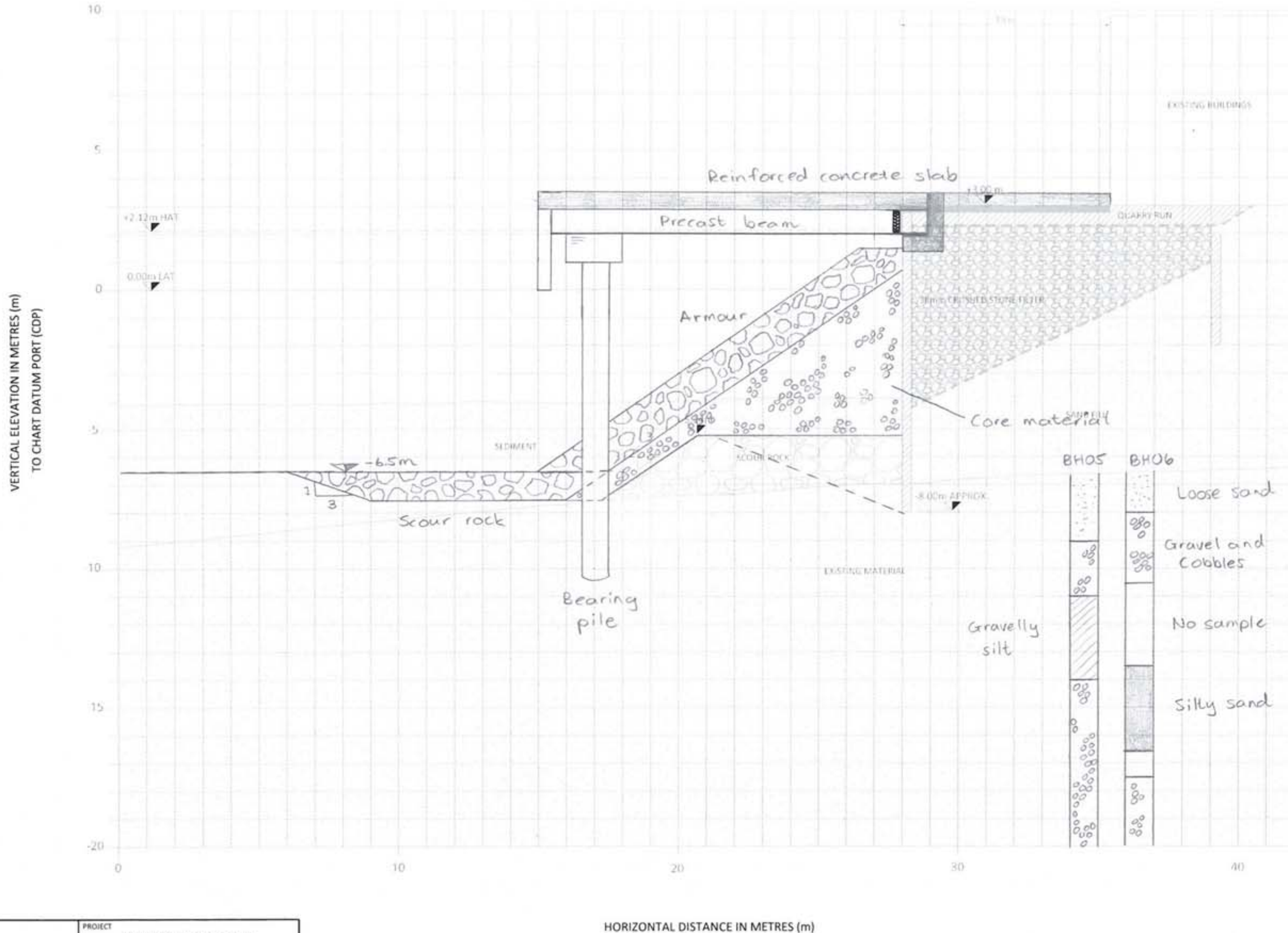
Constructed in the dry and launched from the slipways adjacent to Old Tug Jetty

Very similar to Blockwork wall

Floated into position and sunk

| CLIENT | PROJECT |
|---|---|
| TNPA | PORT ELIZABETH OLD TUG JETTY REHABILITATION |
| | DRAWING TITLE: CAISSON |
| PRDW Consulting Port and Coastal Engineers | S2001_109 |

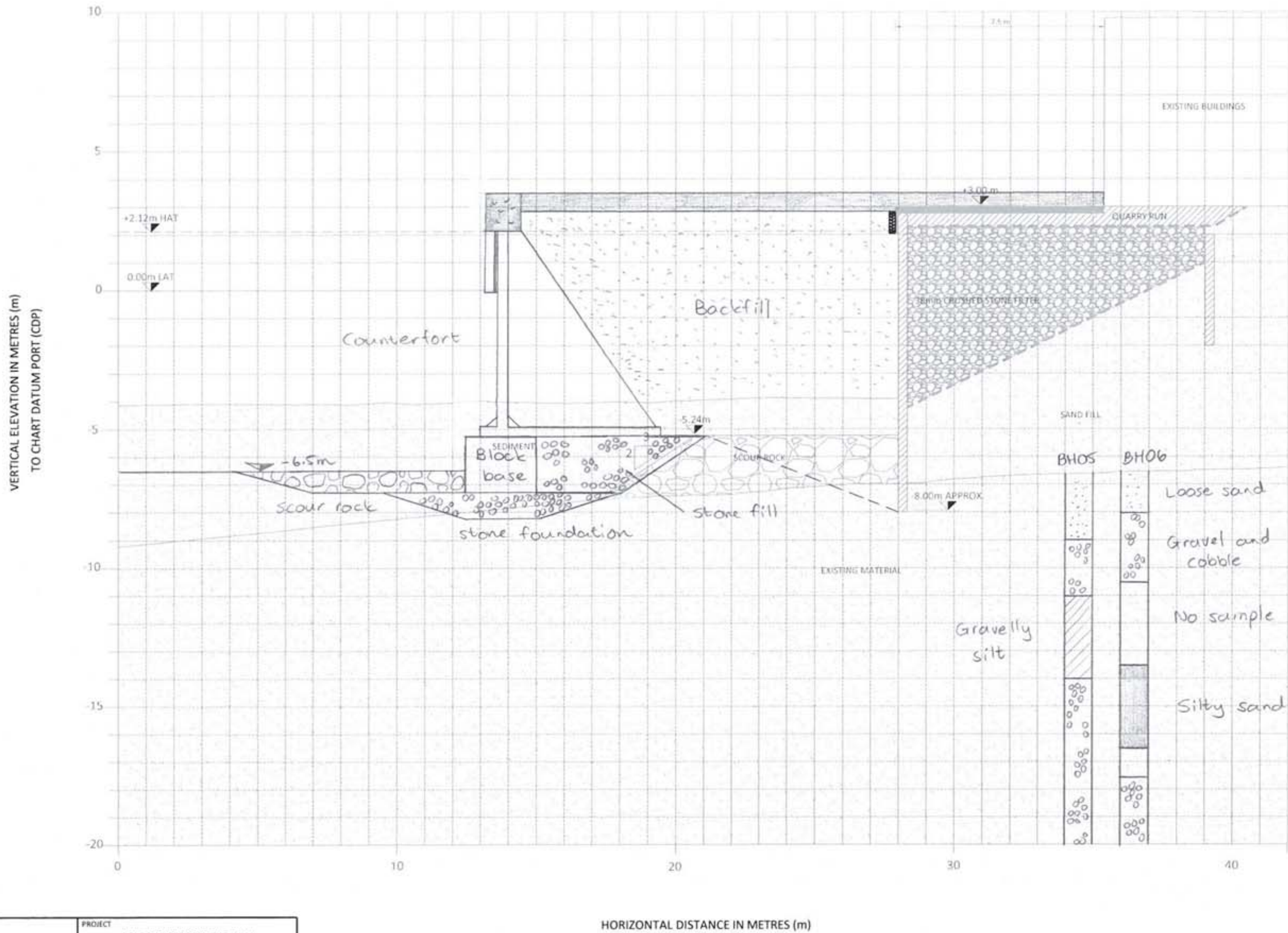
A1 DO NOT SCALE - IF IN DOUBT ASK




Remarks:
Dredge to level
Drive piles
Place Scour protection, core material and armour
Construct deck-on-pile

| | |
|---|---|
| CLIENT: TNPA | PROJECT: PORT ELIZABETH OLD TUG JETTY REHABILITATION |
| | DRAWING TITLE: DECK-ON-PILES |
| PRDW Consulting Port and Coastal Engineers | SCALE / S2001_109 - - - - |

A1 DO NOT SCALE - IF IN DOUBT ASK




Remarks:

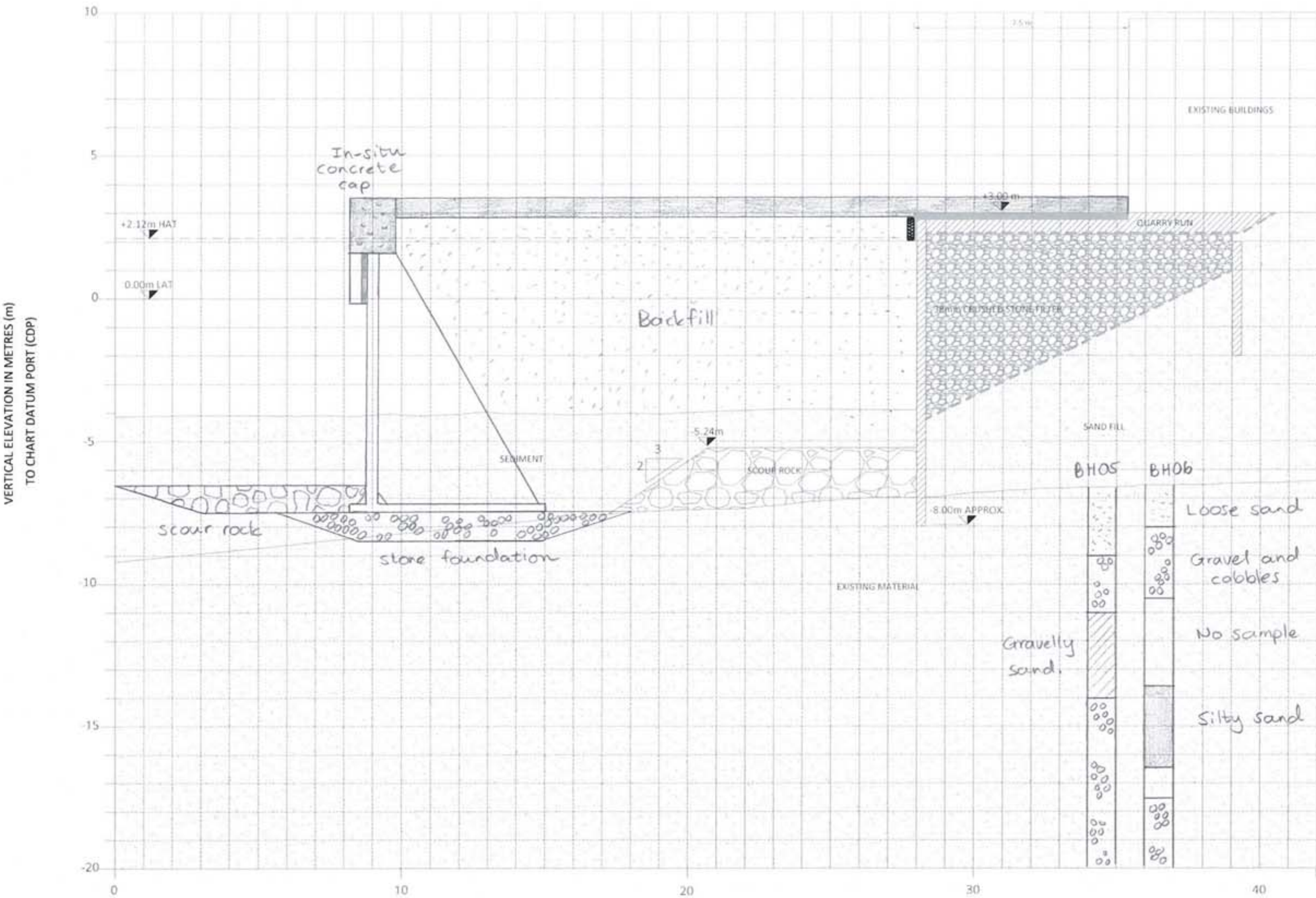
Similar to counterfort option

Block is used to raise counterfort in order to avoid risk of reduction in sheetpile passive resistance.

Saves 15m backup area from counterfort option.

| CLIENT | PROJECT |
|---|---|
| TNPA | PORT ELIZABETH OLD TUG JETTY REHABILITATION |
| | DRAWING TITLE: COUNTERFORT AND BLOCKWORK HYBRID |
| PRDW Consulting Port and Coastal Engineers | SCALE: S2001_109 |

A1 DO NOT SCALE - IF IN DOUBT ASK




Remarks:

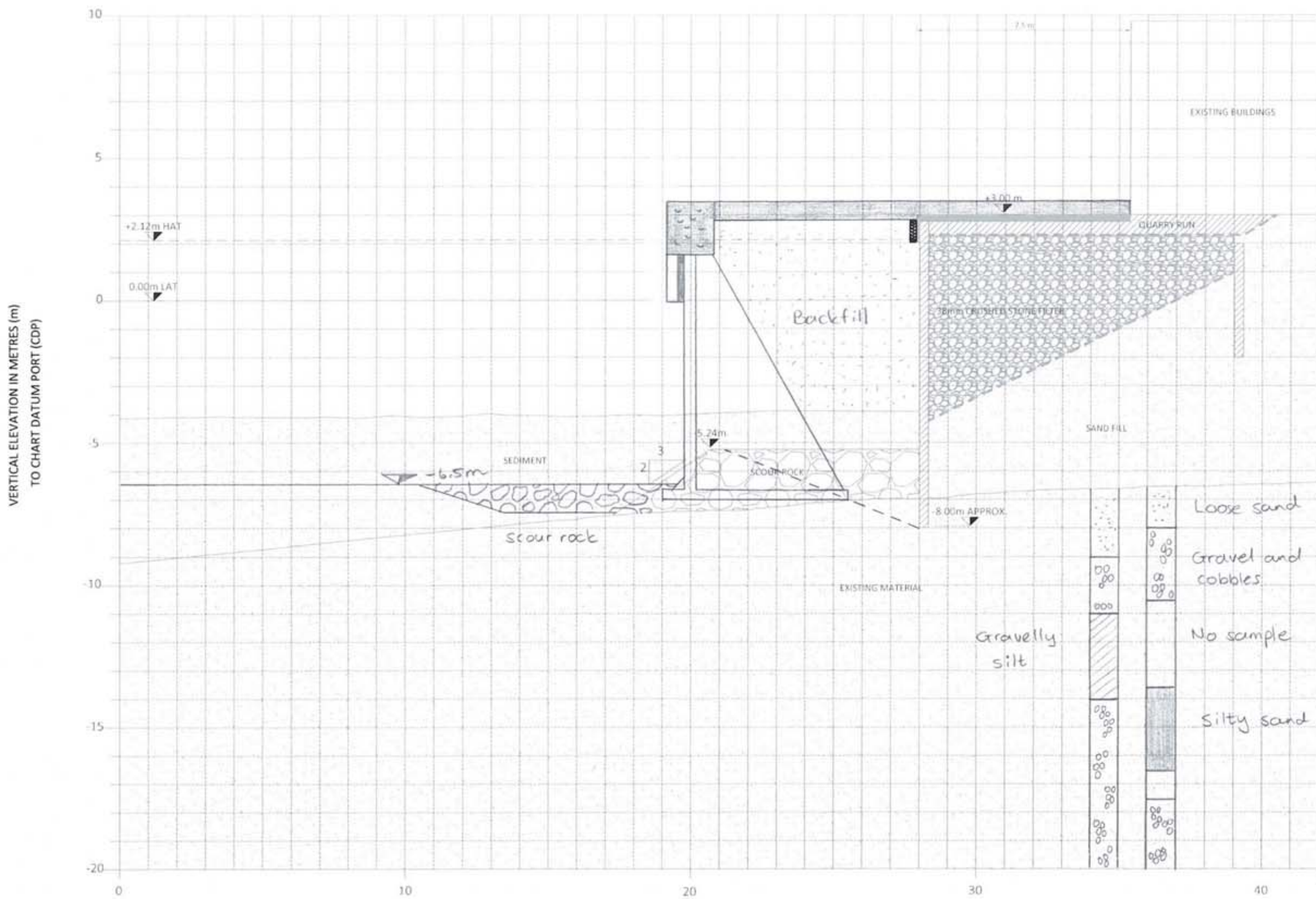
Large environmental impact

Increase of back-up space

Loss of berthing space on old Tug Jetty

| | |
|---|---|
| CLIENT: TNPA | PROJECT: PORT ELIZABETH OLD TUG JETTY REHABILITATION |
| | DRAWING TITLE: COUNTERFORT (OFFSET) |
| PRDW Consulting Port and Coastal Engineers | SCALE: S2001_109 - - - - |

A1 DO NOT SCALE - IF IN DOUBT ASK




Remarks:

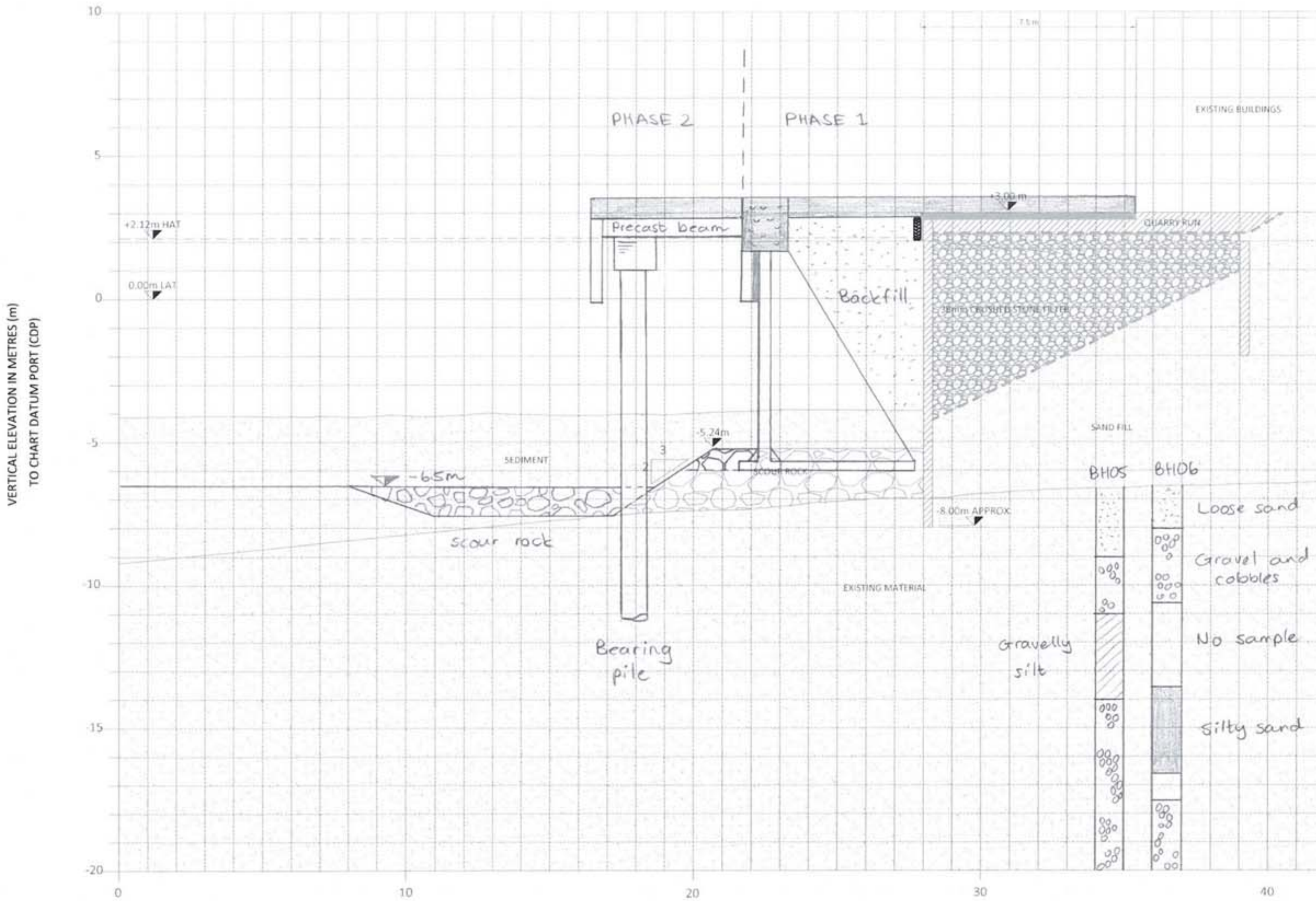
Removal of scour rock is required.

Fatal flaw:

Construction runs risk of destabilizing existing sheetpile by removing the rock providing passive resistance.

| | |
|---|---|
| CLIENT: TNPA | PROJECT: PORT ELIZABETH OLD TUG JETTY REHABILITATION |
| | DRAWING TITLE: COUNTERFORT |
| PRDW Consulting Port and Coastal Engineers | S2001_109 |

A1 DO NOT SCALE - IF IN DOUBT ASK




PHASE 1:
Excavate layer of scour rock
Construct counterfort wall

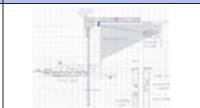
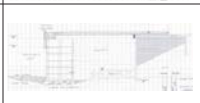
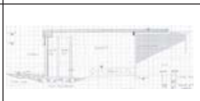
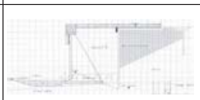
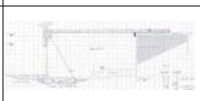
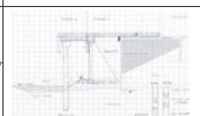
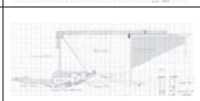
PHASE 2:
Dredge to new scour layer depth
Drive piles
Construct deck-on-pile structure
Place scour rock

Phase 1 will have a berth depth of -4.5m

When expansion is required, phase 2 will have a depth of -6.5m CD.

| | |
|---|---|
| CLIENT: TNPA | PROJECT: PORT ELIZABETH OLD TUG JETTY REHABILITATION |
| | DRAWING TITLE: COUNTERFORT WITH DECK-ON-PILE EXPANSION |
| PRDW Consulting Port and Coastal Engineers | SCALE: N/A — S2001_109 - - - - - |

**ANNEXURE B |** PRE-SCREENING ASSESSMENT

| No. | Option | Illustration | Description | Health and safety considerations | | Environmental considerations | | Constructability | | Localisation | | Maintainability | | Capital cost | | Upgradeability | | Overall score | Conclusion |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | **Steel sheet pile wall** |  | Construction of a new steel sheet pile wall in front of the existing wall. Excavation of existing scour rock is required before piles can be driven. Wall is thereafter backfilled and an in-situ cap and slab is cast. | 0 | Risk of collapse of existing sheetpile structure. | 5 | Estimated footprint of 3m; Material can be recycled. | 4 | Modest construction schedule; Risk of delays due to ground conditions; Standard construction; Limited impact on port operations. | 2 | Steel sheet piles and tie rods need to be imported; Local skills and plant. | 1 | Maintenance of anodes to provide corrosion protection of submerged portion of the wall. | 5 | Cheapest | 1 | Limited adaptibility for increase in capacity; Future change of use is limited, unless suitable wall section is provided upfront. | 0 | Fatal flaw in construction - risk of collapse of exisiting sheet pile wall. **Therefore, this option has been eliminated** |
| 2 | **Steel tubular combi-wall** |  | Construction of a sheet pile wall using steel tubular piles. Tubular piles would be advanced through the existing scour protection by chiseling/excavating through the tube. The piles will have an minimal offset from the existing wall which will be grouted up. | 4 | Dive work is limited; Sheet pile is interlocked, therefore a accident will be localised. Minor risk during construction | 5 | Estimated footprint of 3m; Material can be partially recycled. | 4 | Moderate construction schedule; Risk of delays due to ground conditions; Minimal impact on port operations. | 1 | Steel tubular piles, sheets and tie rods need to be imported; Local skills and plant. | 2 | Maintenance of anodes to provide corrosion protection of submerged portion of the wall. | 3 | Modest Cost | 2 | Limited adaptibility for increased capacity; Future change of use is limited. | 21 | **Carried foreward to multi-criteria analysis.** |
| 3 | **Steel sheet pile wall (offset)** |  | Similar to option 1. The proposed sheet pile has been offset beyond the toe of the existing scour rock layer. This allows the existing sheetpile to remain unaffected by the proposed construction. Wall is thereafter backfilled and a in-situ cap and slab is cast. | 5 | Dive work is limited; Sheet pile is interlocked, therefore a accident will be localised. | 4 | Estimated footprint of 11m; Material can be recycled; Sides tapered to accommodate slipway. | 3 | Modest construction schedule; Risk of delays due to ground conditions; Standard construction. | 2 | Steel sheet piles and tie rods need to be imported; Local skills and plant; Local skills and plant. | 1 | Maintenance of anodes to provide corrosion protection of submerged portion of the wall. | 4 | Modest Cost | 3 | Increased back of quay area; Limited adaptibility for increase in capacity; Future change of use is limited, unless suitable wall section is provided upfront. | 22 | **Carried foreward to multi-criteria analysis.** |
| 4 | **Blockwork gravity wall** |  | The blockwork wall would be located seaward of the existing scour protection in order to avoid destabilizing the existing sheetpile wall. The options entails the construction of a stone foundation, placing the concrete blocks, backfilling, casting a in-situ cap and slab. | 2 | Large amount of dive work and work over water required; Working with heavy precast elements; Damage is localised in case of an accident. | 1 | Estimated footprint of 20m which would obstruct slipways adjacent to Old Tug Jetty sheet pile wall; Material cannot be recycled. | 2 | Lengthy construction schedule; Challenging construction; Large impact on port operations. | 5 | All locally sourced material, skills and plant. | 4 | Modest maintenance plan; Standard concrete maintainance. | 2 | Fairly Expensive | 4 | Capacity for increased loading; Adaptable for future change of use. | 20 | Blockwork wall will have a large impact on permanent port operations. Construction is expensive and lengthy. **Therefore, this option has been eliminated** |
| 5 | **Caisson gravity wall** |  | The caisson option is very similar to the blockwork structure. The caissons can be constructed in the dry, launched at the slipways adjacent to Old Tug Jetty, floated into place and submerged. | 2 | Large amount of dive work and work over water required; Caisson needs to be towed into the harbour; Damage is localised in case of an accident. | 1 | Estimated footprint of 20m which would obstruct slipways adjacent to Old Tug Jetty sheet pile wall; Material cannot be recycled. | 1 | Lengthy construction schedule; Challenging construction; Large impact on port operations. | 3 | All locally sourced material and skills however, a suitably sized floating dry dock needs to be brought in from Durban. | 5 | Modest maintenance plan; Standard concrete maintainance. | 1 | Expensive | 4 | Increased back of quay area; Limited adaptable for future change of use; Provision for future increased depth. | 17 | Caisson will have a large impact on permanent port operations. Construction is expensive and lengthy. Casting of structure in the dry will require specialist knowledge. Launching and floating of caissons could prove challenging. **Therefore, this option has been eliminated** |
| 6 | **Counterfort gravity wall** |  | Construction of the counterfort wall requires dredging and removal of scour material in order to place a stone bed foundation. Thereafter, the wall is placed, backfilled, scour rock is placed and concrete works undertaken. | 0 | Risk of partial collapse of existing sheetpile structure. | 3 | Estimated footprint of 8m; Material can not be recycled; Tapered but still partial obstruction of adjacent slipways. | 4 | Modest construction schedule; Risk of delays due to ground conditions; Standard construction; Minimal impact on port operations | 5 | All locally sourced skills, material and plant. | 5 | Modest maintenance plan; Standard concrete maintainance. | 3 | Moderate Cost | 3 | Increased back of quay area; Limited adaptable for future change of use; Provision for future increased depth. | 0 | Fatal flaw in construction - risk of collapse of exisiting sheet pile wall. **Therefore, this option has been eliminated** |
| 7 | **Counterfort gravity wall (offset)** |  | Similar to option 6, the only difference is the counterfort wall would be placed seaward of the existing scour protection in order to avoid destabilizing the existing sheet pile wall. | 3 | Large amount of dive work and work over water required; Working with heavy precast elements; Damage is localised in case of an accident. | 1 | Estimated footprint of 19m which would obstruct slipways adjacent to Old Tug Jetty sheet pile wall; Material cannot be recycled. | 2 | Lengthy construction schedule; Large impact on port operations. | 5 | All locally sourced skills, material and plant. | 4 | Modest maintenance plan; Standard concrete maintainance. | 2 | Fairly Expensive | 4 | Increased back of quay area; Limited adaptable for future change of use; Provision for future increased depth. | 21 | Structure will have a significant impact on permanent port operation in both construction and permanent basis. Construction is expensive and lengthy. **Therefore, this option has been eliminated** |
| 8 | **Counterfort deck-on-pile hybrid** |  | This option is broken into two phases:<br>**Phase 1** – Dredge and excavate to the top of the existing scour rock. Thereafter, construct counterfort wall similar to option 6. Interim berth depth -5.2m CD.<br>**Phase 2** – When there is sufficient demand for a deeper berth, the structure can be expanded by driving piles beyond the existing scour rock and constructing a deck-on-pile structure with the designed berth depth of -6.5m CD. | 4 | Large amount of dive work required; Limited work over water required; Damage is localised in case of an accident. | 4 | Estimated footprint of 6+6m; Material be partially recycled. Counterfort tapered to accommodate slipway; No deck-on-pile close to slipway. | 5 | Average construction schedule; Limited impact on port operations. | 4 | Steel tubular piles may need to be imported depending on local availability; Local skills and plant. | 3 | Inspection and maintenance of piles is required; Piles could alternatively be made of concrete. | 4 | Expensive. | 5 | Adaptable for future change of use; Provision for future increased depth. | 29 | **Carried foreward to multi-criteria analysis.** |
| 9 | **Blockwork counterfort hybrid** |  | This option entails dredging and constructing a stone foundation for a concrete block. This serves as a step and provides a foundation for the counterfort which will be constructed on top of the block. This option was considered since it reduces the structures footprint in comparison to option 7. | 1 | Large amount of dive work required; Working with heavy precast elements; Minor risk of partial collapse during construction; Damage is localised in case of an accident. | 3 | Estimated footprint of 15m; Material can not be recycled; Tapered but partial obstruction of adjacent slipways. | 1 | Average construction schedule; Risk in design and construction because of uniqueness of solution. | 5 | All locally sourced skills, material and plant. | 5 | Modest maintenance plan; Standard concrete maintainance. | 2 | Fairly Expensive | 3 | Increased back of quay area; Limited adaptable for future change of use; Limited provision for future increased depth. | 20 | Due to the uniqueness of this solution, the health and safety considerations and constructability is poor. The structure will also have a large impact on permanent port operations. **Therefore, this option has been eliminated** |
| 10 | **Deck-on-pile wharf** |  | The deck-on-pile option entails driving the piles just beyond the toe of the existing scour protection. Thereafter, the existing wall is buttressed by rock and precast beams and slabs are used to construct the deck. | 4 | Limited amount of diving required; Damage is extensive in case of an accident. | 3 | Estimated footprint of 12m; Material be partially recycled; No deck-on-pile at slipways. | 4 | Modest construction schedule; Risk of delays due to ground conditions; Standard construction; Minimal impact on port operations | 4 | Steel tubular piles may need to be imported depending on local availability; Local skills and plant. | 3 | Inspection and maintenance of piles is required; Piles could alternatively be made of concrete. | 4 | Modest Cost | 4 | Increased back of quay area; Limited adaptable for future change of use; Provision for future increased depth. | 26 | **Carried foreward to multi-criteria analysis.** |

| CLIENT | PROJECT | RESPONSIBILITIES | INITIALS |
|---|---|---|---|
| TRANSNET national ports authority | PORT OF PORT ELIZABETH OLD TUG JETTY | COMPILED | JPR |
| | SHEETPILE WALL REFURBISHMENT (FEL 2) | CHECKED | YH |
| | **DOCUMENT TITLE** | APPROVED | PES |
| | PRE-SCREENING ASSESSMENT | | |
| PRDW www.prdw.com | **DOCUMENT NUMBER** | | |
| | S2001-109-TN-ST-001-R0 | | |

| Rating | | |
|---|---|---|
| 5 | Excelent/ | Cheapest |
| 4 | Good/ | Modest Cost |
| 3 | Average/ | Moderate Cost |
| 2 | Fair/ | Fairly Expensive |
| 1 | Poor/ | Expensive |
| 0 | Fatal flaw | |

**ANNEXURE C** | MULTI-CRITERIA WEIGHTING

| | |
|---|---|
| **PROJECT** | PORT ELIZABETH OLD TUG JETTY SHEET PILE WALL REHABILITATION FEL 2 STUDY |
| **DOCUMENT TITLE** | MULTI-CRITERIA ANALYSIS WEIGHTING VIA PAIRWISE SURVEY |
| **DOCUMENT NUMBER** | S2001_109-TN-ST-001-R0 |

**ZM Pairwise MCA Weighting Survey**

| **MCA Criteria** | Health and Safety Considerations | Enviromental Considerations | Constructability | Localisation | Maintainability | Capital Cost | Flexibility & Adaptability | Total | Weighting |
|---|---|---|---|---|---|---|---|---|---|
| Health and Safety Considerations | | 0 | 0 | 2 | 1 | 0 | 1 | 4 | 10 |
| Enviromental Considerations | 2 | | 0 | 1 | 1 | 0 | 1 | 5 | 12 |
| Constructability | 2 | 2 | | 2 | 2 | 1 | 1 | 10 | 24 |
| Localisation | 0 | 1 | 0 | | 1 | 1 | 1 | 4 | 10 |
| Maintainability | 1 | 1 | 0 | 1 | | 0 | 1 | 4 | 10 |
| Capital Cost | 2 | 2 | 1 | 1 | 2 | | 2 | 10 | 24 |
| Flexibility & Adaptability | 1 | 1 | 1 | 1 | 1 | 0 | | 5 | 12 |
| | | | | | | | | 42 | 100 |

**PvR Pairwise MCA Weighting Survey**

| **MCA Criteria** | Health and Safety Considerations | Enviromental Considerations | Constructability | Localisation | Maintainability | Capital Cost | Flexibility & Adaptability | Total | Weighting |
|---|---|---|---|---|---|---|---|---|---|
| Health and Safety Considerations | | 1 | 2 | 1 | 2 | 0 | 1 | 7 | 17 |
| Enviromental Considerations | 1 | | 0 | 2 | 0 | 0 | 0 | 3 | 7 |
| Constructability | 0 | 2 | | 2 | 1 | 0 | 1 | 6 | 14 |
| Localisation | 1 | 0 | 0 | | 0 | 0 | 0 | 1 | 2 |
| Maintainability | 0 | 2 | 1 | 2 | | 0 | 2 | 7 | 17 |
| Capital Cost | 2 | 2 | 2 | 2 | 2 | | 2 | 12 | 29 |
| Flexibility & Adaptability | 1 | 2 | 1 | 2 | 0 | 0 | | 6 | 14 |
| | | | | | | | | 42 | 100 |

**MM Pairwise MCA Weighting Survey**

| **MCA Criteria** | Health and Safety Considerations | Enviromental Considerations | Constructability | Localisation | Maintainability | Capital Cost | Flexibility & Adaptability | Total | Weighting |
|---|---|---|---|---|---|---|---|---|---|
| Health and Safety Considerations | | 2 | 1 | 2 | 1 | 1 | 2 | 9 | 21 |
| Enviromental Considerations | 0 | | 1 | 2 | 1 | 1 | 2 | 7 | 17 |
| Constructability | 1 | 1 | | 2 | 2 | 1 | 1 | 8 | 19 |
| Localisation | 0 | 0 | 0 | | 0 | 0 | 1 | 1 | 2 |
| Maintainability | 1 | 1 | 0 | 2 | | 1 | 1 | 6 | 14 |
| Capital Cost | 1 | 1 | 1 | 2 | 1 | | 1 | 7 | 17 |
| Flexibility & Adaptability | 0 | 0 | 1 | 1 | 1 | 1 | | 4 | 10 |
| | | | | | | | | 42 | 100 |

**FJ Pairwise MCA Weighting Survey**

| **MCA Criteria** | Health and Safety Considerations | Enviromental Considerations | Constructability | Localisation | Maintainability | Capital Cost | Flexibility & Adaptability | Total | Weighting |
|---|---|---|---|---|---|---|---|---|---|
| Health and Safety Considerations | | 2 | 0 | 2 | 0 | 0 | 0 | 4 | 10 |
| Enviromental Considerations | 0 | | 2 | 2 | 0 | 2 | 2 | 8 | 19 |
| Constructability | 2 | 0 | | 2 | 0 | 0 | 0 | 4 | 10 |
| Localisation | 0 | 0 | 0 | | 0 | 0 | 0 | 0 | 0 |
| Maintainability | 2 | 2 | 2 | 2 | | 2 | 0 | 10 | 24 |
| Capital Cost | 2 | 0 | 2 | 2 | 0 | | 0 | 6 | 14 |
| Flexibility & Adaptability | 2 | 0 | 2 | 2 | 2 | 2 | | 10 | 24 |
| | | | | | | | | 42 | 100 |

**TM Pairwise MCA Weighting Survey**

| **MCA Criteria** | Health and Safety Considerations | Enviromental Considerations | Constructability | Localisation | Maintainability | Capital Cost | Flexibility & Adaptability | Total | Weighting |
|---|---|---|---|---|---|---|---|---|---|
| Health and Safety Considerations | | 2 | 0 | 0 | 2 | 2 | 2 | 8 | 19 |
| Enviromental Considerations | 0 | | 0 | 2 | 0 | 2 | 2 | 6 | 14 |
| Constructability | 2 | 2 | | 2 | 2 | 2 | 2 | 12 | 29 |
| Localisation | 2 | 0 | 0 | | 2 | 2 | 2 | 8 | 19 |
| Maintainability | 0 | 2 | 0 | 0 | | 2 | 2 | 6 | 14 |
| Capital Cost | 0 | 0 | 0 | 0 | 0 | | 0 | 0 | 0 |
| Flexibility & Adaptability | 0 | 0 | 0 | 0 | 0 | 2 | | 2 | 5 |
| | | | | | | | | 42 | 100 |

**AM Pairwise MCA Weighting Survey**

| **MCA Criteria** | Health and Safety Considerations | Enviromental Considerations | Constructability | Localisation | Maintainability | Capital Cost | Flexibility & Adaptability | Total | Weighting |
|---|---|---|---|---|---|---|---|---|---|
| Health and Safety Considerations | | 1 | 2 | 1 | 1 | 1 | 1 | 7 | 17 |
| Enviromental Considerations | 1 | | 2 | 1 | 1 | 1 | 1 | 7 | 17 |
| Constructability | 0 | 0 | | 1 | 2 | 1 | 0 | 4 | 10 |
| Localisation | 1 | 1 | 1 | | 1 | 0 | 0 | 4 | 10 |
| Maintainability | 1 | 1 | 0 | 1 | | 0 | 1 | 4 | 10 |
| Capital Cost | 1 | 1 | 1 | 2 | 2 | | 2 | 9 | 21 |
| Flexibility & Adaptability | 1 | 1 | 2 | 2 | 1 | 0 | | 7 | 17 |
| | | | | | | | | 42 | 100 |

**YH Pairwise MCA Weighting Survey**

| **MCA Criteria** | Health and Safety Considerations | Enviromental Considerations | Constructability | Localisation | Maintainability | Capital Cost | Flexibility & Adaptability | Total | Weighting |
|---|---|---|---|---|---|---|---|---|---|
| Health and Safety Considerations | | 0 | 1 | 1 | 2 | 0 | 1 | 5 | 12 |
| Enviromental Considerations | 2 | | 2 | 2 | 2 | 2 | 2 | 12 | 29 |
| Constructability | 1 | 0 | | 2 | 1 | 0 | 0 | 4 | 10 |
| Localisation | 1 | 0 | 0 | | 1 | 0 | 0 | 2 | 5 |
| Maintainability | 0 | 0 | 1 | 1 | | 0 | 1 | 3 | 7 |
| Capital Cost | 2 | 0 | 2 | 2 | 2 | | 1 | 9 | 21 |
| Flexibility & Adaptability | 1 | 0 | 2 | 2 | 1 | 1 | | 7 | 17 |
| | | | | | | | | 42 | 100 |

**JPR Pairwise MCA Weighting Survey**

| **MCA Criteria** | Health and Safety Considerations | Enviromental Considerations | Constructability | Localisation | Maintainability | Capital Cost | Flexibility & Adaptability | Total | Weighting |
|---|---|---|---|---|---|---|---|---|---|
| Health and Safety Considerations | | 1 | 0 | 2 | 1 | 1 | 2 | 7 | 17 |
| Enviromental Considerations | 1 | | 1 | 2 | 2 | 1 | 1 | 8 | 19 |
| Constructability | 2 | 1 | | 1 | 2 | 1 | 2 | 9 | 21 |
| Localisation | 0 | 0 | 1 | | 0 | 1 | 1 | 3 | 7 |
| Maintainability | 1 | 0 | 0 | 2 | | 1 | 2 | 6 | 14 |
| Capital Cost | 1 | 1 | 1 | 1 | 1 | | 2 | 7 | 17 |
| Flexibility & Adaptability | 0 | 1 | 0 | 1 | 0 | 0 | | 2 | 5 |
| | | | | | | | | 42 | 100 |

| PES Pairwise MCA Weighting Survey | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **MCA Criteria** | Health and Safety Considerations | Enviromental Considerations | Constructability | Localisation | Maintainability | Capital Cost | Flexibility & Adaptability | Total | Weighting |
| Health and Safety Considerations | | 1 | 2 | 2 | 2 | 2 | 2 | 11 | 26 |
| Enviromental Considerations | 1 | | 2 | 2 | 2 | 2 | 2 | 11 | 26 |
| Constructability | 0 | 0 | | 1 | 1 | 0 | 2 | 4 | 10 |
| Localisation | 0 | 0 | 1 | | 0 | 0 | 2 | 3 | 7 |
| Maintainability | 0 | 0 | 1 | 2 | | 1 | 2 | 6 | 14 |
| Capital Cost | 0 | 0 | 2 | 2 | 1 | | 2 | 7 | 17 |
| Flexibility & Adaptability | 0 | 0 | 0 | 0 | 0 | 0 | | 0 | 0 |
| | | | | | | | | 42 | 100 |

| LS2 Pairwise MCA Weighting Survey | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **MCA Criteria** | Health and Safety Considerations | Enviromental Considerations | Constructability | Localisation | Maintainability | Capital Cost | Flexibility & Adaptability | Total | Weighting |
| Health and Safety Considerations | | 1 | 1 | 2 | 1 | 0 | 2 | 7 | 17 |
| Enviromental Considerations | 1 | | 2 | 2 | 0 | 0 | 1 | 6 | 14 |
| Constructability | 1 | 0 | | 2 | 1 | 0 | 0 | 4 | 10 |
| Localisation | 0 | 0 | 0 | | 1 | 0 | 0 | 1 | 2 |
| Maintainability | 1 | 2 | 1 | 1 | | 1 | 2 | 8 | 19 |
| Capital Cost | 2 | 2 | 2 | 2 | 1 | | 1 | 10 | 24 |
| Flexibility & Adaptability | 0 | 1 | 2 | 2 | 0 | 1 | | 6 | 14 |
| | | | | | | | | 42 | 100 |

| Summarised MCA Weighting | | |
|---|---|---|
| **MCA Criteria** | **Average Weighting** | **Final Weighting** |
| Health and Safety Considerations | *16* | ***15*** |
| Enviromental Considerations | *17* | ***20*** |
| Constructability | *15* | ***15*** |
| Localisation | *6* | ***5*** |
| Maintainability | *14* | ***15*** |
| Capital Cost | *18* | ***20*** |
| Flexibility & Adaptability | *12* | ***10*** |
| | *100* | ***100*** |

**ANNEXURE D |** MULTI-CRITERIA ANALYSIS

## PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REFURBISHMENT OPTIONS ASSESSMENT

### Multi-criteria analysis for selection of preferred option - Base case weighting

| Ref. | Criteria | Weighting | Option 1: Deck-on-pile | Option 2: Offset sheet pile wall | Option 3: Counterfort deck-on-pile hybrid | Option 4: Steel tubular combi-wall |
|---|---|---|---|---|---|---|
| | **TOTAL** | | | | | |
| 1 | **Health and safety considerations** | 15% | 11% | 14% | 7% | 13% |
| 2 | **Environmental considerations** | 20% | 8% | 9% | 15% | 18% |
| 3 | **Constructability** | 15% | 10% | 4% | 13% | 11% |
| 4 | **Localisation** | 5% | 4% | 1% | 5% | 1% |
| 5 | **Maintainability** | 15% | 11% | 5% | 15% | 5% |
| 6 | **Capital cost** | 20% | 17% | 20% | 14% | 11% |
| 7 | **Upgradeability (flexibility and adaptability)** | 10% | 8% | 5% | 10% | 3% |
| | **Total** | **100%** | **68%** | **58%** | **78%** | **61%** |
| **1** | **Health and safety considerations** | **100%** | **7.1** | **9.4** | **4.4** | **8.8** |
| 1.1 | Safety of personnel during construction, considering the extent of dive work and time working over water. | 25% | 7.5 | 7.5 | 2.5 | 10 |
| | | | *During construction of the steel tubular combi-wall, no work over water is required, it does however require dive work for inspections. The counterfort deck-on-pile hybrid requires extensive dive work to inspect the stone bed and work will be required over water when phase 2 commences. General safety is also a concern when working with large precast units. The health and safety considerations for the deck-on-pile and sheet pile wall is deemed, good, with some dive work and over water work required for both.* | | | |
| 1.2 | Redundancy of the structure, whether damage is localised and the ease of repair i.e. is damage localised or does it place the complete facility at risk. | 25% | 1 | 10 | 5 | 10 |
| | | | *Damage to the sheet pile wall and steel tubular wall will be localised in the case of a berthing accident. Repairs will however be costly, but the facility will not be at risk and operations would be able to continue. Accidental damage to the deck on pile solution will result in a partial temporary decommissioning of the facility while the damaged piles are being repaired. The counterfort deck-on-pile hybrid solution is therefore deemed to be more robust than the deck-on-pile seeing as it is partially a counterfort wall.* | | | |
| 1.3 | Risk of partial or catastrophic collapse of existing infrastructure during construction. | 50% | 10 | 10 | 5 | 7.5 |
| | | | *The deck-on-pile and sheet pile wall are deemed to have the least risk of collapsing the existing infrastructure. They are located further away from the existing sheet pile wall and construction does not require interaction with the existing structure. The steel tubular combi-wall has moderate risk, but there are methods available in order to de-risk this option like partial relieving of backfill. The counterfort deck-on-pile hybrid requires removal of a section of the passive soil wedge which is seen as a higher risk.* | | | |
| **2** | **Environmental considerations** | **100%** | **3.8** | **4.4** | **7.5** | **8.8** |
| 2.1 | Negative impacted of increased footprint of facility due to rehabilitation and the permit or authorisation requirements. | 25% | 2.5 | 5 | 5.0 | 10 |
| | | | 12m cope line offset | 9m cope line offset | Phase 1: 6m cope line offset<br>Phase 2: 12m cope line offset | 1.5m cope line offset |
| | | | All options will require and EIA. | | | |
| 2.2 | Permanent impact on port operations i.e. access to slipways and Old Tug Jetty, usable berth area. | 50% | 2.5 | 5 | 7.5 | 10 |
| | | | The steel tubular combi-wall does not have an effect on the adjacent slipway. The counterfort deck-on-pile hybrid can be adapted to have less impact on port operations e.g. tapering the counterfort units closer to the slipways and not constructing the deck-on-pile near the slipways. The sheet pile and deck-on-pile will result in the same loss of berthing space at Old Tug Jetty, but the deck-on-pile will also lose berthing space as the structure approaches the slipways (where most likely only the revetment will be constructed) as opposed to the sheet pile wall that will be tapered. | | | |
| 2.3 | Construction impact on environment i.e. use of green materials and construction methods. Also considers carbon footprint by accounting the quantum of material needed for each option. | 25% | 7.5 | 2.5 | 10 | 5 |
| | | | The sheet pile and tubular combi-wall requires the most imported material that has a resulting carbon footprint. The sheet pile wall however requires much more backfill material. The deck-on-pile and counterfort deck-on-pile hybrid both require piles that might be imported based on local availability, but the deck-on-pile requires more imported quarry material to construct the revetment. | | | |
| **3** | **Constructability** | **100%** | **6.65** | **2.5** | **8.35** | **7.5** |
| 3.1 | Considering the construction schedule and the risk of delays due to ground conditions. | 33% | 10 | 2.5 | 5 | 7.5 |
| | | | Modest construction schedule with risk of delays due to ground conditions. Anticipated construction duration 9 to 12 months. | Moderate construction schedule with risk of delays due to ground conditions. Anticipated construction duration 12 to 18 months. | Average construction schedule with partial risk of delays due to ground conditions when constructing deck-on-pile structure. Phase 1 anticipated construction duration 12 to 15 months. Phase 2 anticipated construction duration 9 to 10 months. | Average construction schedule with risk of delays due to ground conditions. Anticipated construction duration 12 to 15 months. |
| 3.2 | Considerations around the practical aspects of construction, contractor's working site and the extent of temporary works required. | 33% | 5 | 2.5 | 10 | 7.5 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | | The counterfort deck-on-pile hybrid will require the least amount of temporary work due to the counterfort units being cast in a casting yard. Working site is not congested with large plant. The tubular combi-wall will require large plant to drive the piles, but the required backfill is small and the limited backup area will not affect construction. The deck-on-pile requires large amounts of rock to be dumped in order to construct the revetment. Access in order to dump the material could be challenging. The sheet pile wall is similar with large plant and more backfill required. | | | |
| 3.3 | Construction impact on port operations i.e. access to existing slipways and Old Tug Jetty and the impact on operations during construction e.g. closing of entire area versus partial works being done and partial handover. | 34% | 5 | 2.5 | 10 | 7.5 |
| | | | The counterfort deck-on-pile hybrid will have the least impact on port operations during construction. Counterfort units are cast in a yard and dropped in place. Driving of piles will disrupt port operations with the deck-on-pile deemed worse than the tubular combi-wall due to the revetment that will need to be constructed prior to piling. The offset sheet pile wall will impact a larger area of the port due to its large step-out. | | | |
| | | | | | | |
| **4** | **Localisation** | **100%** | **7.5** | **2.5** | **10** | **1** |
| 4.1 | Whether material, plant and skills can be locally sourced for construction. | 100% | 7.5 | 2.5 | 10 | 1 |
| | | | *All the skills required can be locally sourced. The material for the counterfort deck-on-pile hybrid can be sourced locally. The deck-on-pile will require more imported material and the sheet pile and combi-wall options having the most imported material. The steel tubular combi-wall was scored worse due to the need for specialised plant that can chisel through scour rock.* | | | |
| | | | | | | |
| **5** | **Maintainability** | **100%** | **7.5** | **3.4** | **10.0** | **3.4** |
| 5.1 | Maintenance cost | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| | | | *1.75% CAPEX cost at present value p.a* | *2% CAPEX cost at present value p.a* | *1.5% CAPEX cost at present value p.a* | *2% CAPEX cost at present value p.a* |
| 5.2 | Personal required for maintenance i.e. skills and material | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| | | | *Minor skill required and material for piles* | *Anodes required - specialist skill* | *Minor skill required and less material for piles* | *Anodes required - specialist skill* |
| 5.3 | Design service life | 34% | 7.5 | 5.0 | 10.0 | 5.0 |
| | | | | | | |
| **6** | **Capital cost** | **100%** | **8.5** | **10.0** | **6.9** | **5.6** |
| 6.1 | Capital cost | 100% | 8.5 | 10.0 | 6.9 | 5.6 |
| | | R million | *R164* | *R140* | *R202* | *R250* |
| | | | | | | |
| **7** | **Upgradeability (flexibility and adaptability)** | **100%** | **7.5** | **5.0** | **10.0** | **2.5** |
| 7.1 | Provision for future increased berth depth and the structure's capacity for increased loading (vertical and lateral).<br>The adaptability for future change of use. | 100% | 7.5 | 5.0 | 10.0 | 2.5 |
| | | | *The deck-on-pile and counterfort deck-on-pile hybrid has provision for increased berth depth. Loading arrangements can be made and additional piles driven to accommodate an increased vertical and lateral loading. The counterfort deck-on-pile hybrid is deemed capable of a larger loading due to its gravity wall section. The sheet pile wall and tubular combi-wall have no provision for increased berth depth. The tubular combi-wall has the least capacity for increased loading due to its limited back-up area and close proximity to buildings.* | | | |

| | |
|---|---|
| Excellent | 10 |
| Good | 7.5 |
| Average | 5 |
| Fair | 2.5 |
| Poor | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REFURBISHMENT OPTIONS ASSESSMENT** | | | | | |
| | **Multi-criteria analysis for selection of preferred option - Equal weighting** | | | | | |
| | **TOTAL** | | **Option 1: Deck-on-pile** | **Option 2: Offset sheet pile wall** | **Option 3: Counterfort deck-on-pile hybrid** | **Option 4: Steel tubular combi-wall** |
| **Ref.** | **Criteria** | **Weighting** | | | | |
| 1 | **Health and safety considerations** | 14% | 10% | 13% | 6% | 13% |
| 2 | **Environmental considerations** | 14% | 5% | 6% | 11% | 13% |
| 3 | **Constructability** | 14% | 10% | 4% | 12% | 11% |
| 4 | **Localisation** | 14% | 11% | 4% | 14% | 1% |
| 5 | **Maintainability** | 14% | 11% | 5% | 14% | 5% |
| 6 | **Capital cost** | 14% | 12% | 14% | 10% | 8% |
| 7 | **Upgradeability (flexibility and adaptability)** | 14% | 11% | 7% | 14% | 4% |
| | **Total** | **100%** | **69%** | **53%** | **82%** | **54%** |
| **1** | **Health and safety considerations** | **100%** | **7.1** | **9.4** | **4.4** | **8.8** |
| 1.1 | Safety of personnel during construction, considering the extent of dive work and time working over water. | 25% | 7.5 | 7.5 | 2.5 | 10.0 |
| 1.2 | Redundancy of the structure, whether damage is localised and the ease of repair i.e. is damage localised or does it place the complete facility at risk. | 25% | 1.0 | 10.0 | 5.0 | 10.0 |
| 1.3 | Risk of partial or catastophic collapse of existing infrastructure during construction. | 50% | 10.0 | 10.0 | 5.0 | 7.5 |
| **2** | **Environmental considerations** | **100%** | **3.8** | **4.4** | **7.5** | **8.8** |
| 2.1 | Increased footprint of facility due to rehabilitation and the permit or authorisation requirements. | 25% | 2.5 | 5.0 | 5.0 | 10.0 |
| 2.2 | Permanent impact on port operations i.e. access to slipways and Old Tug Jetty. | 50% | 2.5 | 5.0 | 7.5 | 10.0 |
| 2.3 | Construction impact on environment i.e. use of green materials and construction methods. Also considers carbon footprint by accounting the quantum of material needed for each option. | 25% | 7.5 | 2.5 | 10.0 | 5.0 |
| **3** | **Constructability** | **100%** | **6.7** | **2.5** | **8.4** | **7.5** |
| 3.1 | Considering the construction schedule and the risk of delays due to ground conditions. | 33% | 10.0 | 2.5 | 5.0 | 7.5 |
| 3.2 | Considerations around the practical aspects of construction, contractor's working site and the extent of temporary works required. | 33% | 5.0 | 2.5 | 10.0 | 7.5 |
| 3.3 | Construction impact on port operations i.e. access to existing slipways and Old Tug Jetty and the impact on operations during construction e.g. closing of entire area versus partial works being done and partial handover. | 34% | 5.0 | 2.5 | 10.0 | 7.5 |
| **4** | **Localisation** | **100%** | **7.5** | **2.5** | **10.0** | **1.0** |
| 4.1 | Whether material, plant and skills can be locally sourced for construction. | 100% | 7.5 | 2.5 | 10.0 | 1.0 |
| **5** | **Maintainability** | **100%** | **7.5** | **3.4** | **10.0** | **3.4** |
| 5.1 | Maintenance cost | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.2 | Personal required for maintenance i.e. skills and material | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.3 | Design service life | 34% | 7.5 | 5.0 | 10.0 | 5.0 |
| **6** | **Capital cost** | **100%** | **8.5** | **10.0** | **6.9** | **5.6** |
| 6.1 | Capital cost | 100% | 8.5 | 10.0 | 6.9 | 5.6 |
| **7** | **Upgradeability (flexibility and adaptability)** | **100%** | **7.5** | **5.0** | **10.0** | **2.5** |
| 7.1 | Provision for future increased berth depth and the structure's capacity for increased loading (vertical and lateral).<br>The adaptability for future change of use. | 100% | 7.5 | 5.0 | 10.0 | 2.5 |

| | |
|---|---|
| Excellent | 10 |
| Good | 7.5 |
| Average | 5 |
| Fair | 2.5 |
| Poor | 1 |

| | PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REFURBISHMENT OPTIONS ASSESSMENT | | | | | |
|---|---|---|---|---|---|---|
| | Multi-criteria analysis for selection of preferred option - Weighting skewed towards health and safety considerations | | | | | |
| | TOTAL | | Option 1: Deck-on-pile | Option 2: Offset sheet pile wall | Option 3: Counterfort deck-on-pile hybrid | Option 4: Steel tubular combi-wall |
| Ref. | Criteria | Weighting | | | | |
| 1 | **Health and safety considerations** | 30% | 21% | 28% | 13% | 26% |
| 2 | **Environmental considerations** | 12% | 4% | 5% | 9% | 10% |
| 3 | **Constructability** | 12% | 8% | 3% | 10% | 9% |
| 4 | **Localisation** | 12% | 9% | 3% | 12% | 1% |
| 5 | **Maintainability** | 12% | 9% | 4% | 12% | 4% |
| 6 | **Capital cost** | 12% | 10% | 12% | 8% | 7% |
| 7 | **Upgradeability (flexibility and adaptability)** | 12% | 9% | 6% | 12% | 3% |
| | **Total** | **100%** | **70%** | **60%** | **75%** | **60%** |
| **1** | **Health and safety considerations** | **100%** | **7.1** | **9.4** | **4.4** | **8.8** |
| 1.1 | Safety of personnel during construction, considering the extent of dive work and time working over water. | 25% | 7.5 | 7.5 | 2.5 | 10.0 |
| 1.2 | Redundancy of the structure, whether damage is localised and the ease of repair i.e. is damage localised or does it place the complete facility at risk. | 25% | 1.0 | 10.0 | 5.0 | 10.0 |
| 1.3 | Risk of partial or catastophic collapse of existing infrastructure during construction. | 50% | 10.0 | 10.0 | 5.0 | 7.5 |
| **2** | **Environmental considerations** | **100%** | **3.8** | **4.4** | **7.5** | **8.8** |
| 2.1 | Increased footprint of facility due to rehabilitation and the permit or authorisation requirements. | 25% | 2.5 | 5.0 | 5.0 | 10.0 |
| 2.2 | Permanent impact on port operations i.e. access to slipways and Old Tug Jetty. | 50% | 2.5 | 5.0 | 7.5 | 10.0 |
| 2.3 | Construction impact on environment i.e. use of green materials and construction methods. Also considers carbon footprint by accounting the quantum of material needed for each option. | 25% | 7.5 | 2.5 | 10.0 | 5.0 |
| **3** | **Constructability** | **100%** | **6.7** | **2.5** | **8.4** | **7.5** |
| 3.1 | Considering the construction schedule and the risk of delays due to ground conditions. | 33% | 10.0 | 2.5 | 5.0 | 7.5 |
| 3.2 | Considerations around the practical aspects of construction, contractor's working site and the extent of temporary works required. | 33% | 5.0 | 2.5 | 10.0 | 7.5 |
| 3.3 | Construction impact on port operations i.e. access to existing slipways and Old Tug Jetty and the impact on operations during construction e.g. closing of entire area versus partial works being done and partial handover. | 34% | 5.0 | 2.5 | 10.0 | 7.5 |
| **4** | **Localisation** | **100%** | **7.5** | **2.5** | **10.0** | **1.0** |
| 4.1 | Whether material, plant and skills can be locally sourced for construction. | 100% | 7.5 | 2.5 | 10.0 | 1.0 |
| **5** | **Maintainability** | **100%** | **7.5** | **3.4** | **10.0** | **3.4** |
| 5.1 | Maintenance cost | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.2 | Personal required for maintenance i.e. skills and material | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.3 | Design service life | 34% | 7.5 | 5.0 | 10.0 | 5.0 |
| **6** | **Capital cost** | **100%** | **8.5** | **10.0** | **6.9** | **5.6** |
| 6.1 | Capital cost | 100% | 8.5 | 10.0 | 6.9 | 5.6 |
| **7** | **Upgradeability (flexibility and adaptability)** | **100%** | **7.5** | **5.0** | **10.0** | **2.5** |
| 7.1 | Provision for future increased berth depth and the structure's capacity for increased loading (vertical and lateral).<br>The adaptability for future change of use. | 100% | 7.5 | 5.0 | 10.0 | 2.5 |

| | |
|---|---|
| Excellent | 10 |
| Good | 7.5 |
| Average | 5 |
| Fair | 2.5 |
| Poor | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REFURBISHMENT OPTIONS ASSESSMENT** | | | | | |
| | **Multi-criteria analysis for selection of preferred option - Weighting skewed towards environmental considerations** | | | | | |
| | **TOTAL** | | **Option 1: Deck-on-pile** | **Option 2: Offset sheet pile wall** | **Option 3: Counterfort deck-on-pile hybrid** | **Option 4: Steel tubular combi-wall** |
| **Ref.** | **Criteria** | **Weighting** | | | | |
| 1 | **Health and safety considerations** | 12% | 8% | 11% | 5% | 10% |
| 2 | **Environmental considerations** | 30% | 11% | 13% | 23% | 26% |
| 3 | **Constructability** | 12% | 8% | 3% | 10% | 9% |
| 4 | **Localisation** | 12% | 9% | 3% | 12% | 1% |
| 5 | **Maintainability** | 12% | 9% | 4% | 12% | 4% |
| 6 | **Capital cost** | 12% | 10% | 12% | 8% | 7% |
| 7 | **Upgradeability (flexibility and adaptability)** | 12% | 9% | 6% | 12% | 3% |
| | **Total** | **100%** | **64%** | **51%** | **80%** | **60%** |
| **1** | **Health and safety considerations** | **100%** | **7.1** | **9.4** | **4.4** | **8.8** |
| 1.1 | Safety of personnel during construction, considering the extent of dive work and time working over water. | 25% | 7.5 | 7.5 | 2.5 | 10.0 |
| 1.2 | Redundancy of the structure, whether damage is localised and the ease of repair i.e. is damage localised or does it place the complete facility at risk. | 25% | 1.0 | 10.0 | 5.0 | 10.0 |
| 1.3 | Risk of partial or catastophic collapse of existing infrastructure during construction. | 50% | 10.0 | 10.0 | 5.0 | 7.5 |
| **2** | **Environmental considerations** | **100%** | **3.8** | **4.4** | **7.5** | **8.8** |
| 2.1 | Increased footprint of facility due to rehabilitation and the permit or authorisation requirements. | 25% | 2.5 | 5.0 | 5.0 | 10.0 |
| 2.2 | Permanent impact on port operations i.e. access to slipways and Old Tug Jetty. | 50% | 2.5 | 5.0 | 7.5 | 10.0 |
| 2.3 | Construction impact on environment i.e. use of green materials and construction methods. Also considers carbon footprint by accounting the quantum of material needed for each option. | 25% | 7.5 | 2.5 | 10.0 | 5.0 |
| **3** | **Constructability** | **100%** | **6.7** | **2.5** | **8.4** | **7.5** |
| 3.1 | Considering the construction schedule and the risk of delays due to ground conditions. | 33% | 10.0 | 2.5 | 5.0 | 7.5 |
| 3.2 | Considerations around the practical aspects of construction, contractor's working site and the extent of temporary works required. | 33% | 5.0 | 2.5 | 10.0 | 7.5 |
| 3.3 | Construction impact on port operations i.e. access to existing slipways and Old Tug Jetty and the impact on operations during construction e.g. closing of entire area versus partial works being done and partial handover. | 34% | 5.0 | 2.5 | 10.0 | 7.5 |
| **4** | **Localisation** | **100%** | **7.5** | **2.5** | **10.0** | **1.0** |
| 4.1 | Whether material, plant and skills can be locally sourced for construction. | 100% | 7.5 | 2.5 | 10.0 | 1.0 |
| **5** | **Maintainability** | **100%** | **7.5** | **3.4** | **10.0** | **3.4** |
| 5.1 | Maintenance cost | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.2 | Personal required for maintenance i.e. skills and material | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.3 | Design service life | 34% | 7.5 | 5.0 | 10.0 | 5.0 |
| **6** | **Capital cost** | **100%** | **8.5** | **10.0** | **6.9** | **5.6** |
| 6.1 | Capital cost | 100% | 8.5 | 10.0 | 6.9 | 5.6 |
| **7** | **Upgradeability (flexibility and adaptability)** | **100%** | **7.5** | **5.0** | **10.0** | **2.5** |
| 7.1 | Provision for future increased berth depth and the structure's capacity for increased loading (vertical and lateral).<br>The adaptability for future change of use. | 100% | 7.5 | 5.0 | 10.0 | 2.5 |

| | |
|---|---|
| Excellent | 10 |
| Good | 7.5 |
| Average | 5 |
| Fair | 2.5 |
| Poor | 1 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | **PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REFURBISHMENT OPTIONS ASSESSMENT** | | | | | |
| | **Multi-criteria analysis for selection of preferred option - Weightings skewed towards constructability** | | | | | |
| | **TOTAL** | | **Option 1: Deck-on-pile** | **Option 2: Offset sheet pile wall** | **Option 3: Counterfort deck-on-pile hybrid** | **Option 4: Steel tubular combi-wall** |
| **Ref.** | **Criteria** | **Weighting** | | | | |
| 1 | **Health and safety considerations** | 12% | 8% | 11% | 5% | 10% |
| 2 | **Environmental considerations** | 12% | 4% | 5% | 9% | 10% |
| 3 | **Constructability** | 30% | 20% | 8% | 25% | 23% |
| 4 | **Localisation** | 12% | 9% | 3% | 12% | 1% |
| 5 | **Maintainability** | 12% | 9% | 4% | 12% | 4% |
| 6 | **Capital cost** | 12% | 10% | 12% | 8% | 7% |
| 7 | **Upgradeability (flexibility and adaptability)** | 12% | 9% | 6% | 12% | 3% |
| | **Total** | **100%** | **69%** | **48%** | **82%** | **57%** |
| **1** | **Health and safety considerations** | **100%** | **7.1** | **9.4** | **4.4** | **8.8** |
| 1.1 | Safety of personnel during construction, considering the extent of dive work and time working over water. | 25% | 7.5 | 7.5 | 2.5 | 10.0 |
| 1.2 | Redundancy of the structure, whether damage is localised and the ease of repair i.e. is damage localised or does it place the complete facility at risk. | 25% | 1.0 | 10.0 | 5.0 | 10.0 |
| 1.3 | Risk of partial or catastophic collapse of existing infrastructure during construction. | 50% | 10.0 | 10.0 | 5.0 | 7.5 |
| **2** | **Environmental considerations** | **100%** | **3.8** | **4.4** | **7.5** | **8.8** |
| 2.1 | Increased footprint of facility due to rehabilitation and the permit or authorisation requirements. | 25% | 2.5 | 5.0 | 5.0 | 10.0 |
| 2.2 | Permanent impact on port operations i.e. access to slipways and Old Tug Jetty. | 50% | 2.5 | 5.0 | 7.5 | 10.0 |
| 2.3 | Construction impact on environment i.e. use of green materials and construction methods. Also considers carbon footprint by accounting the quantum of material needed for each option. | 25% | 7.5 | 2.5 | 10.0 | 5.0 |
| **3** | **Constructability** | **100%** | **6.7** | **2.5** | **8.4** | **7.5** |
| 3.1 | Considering the construction schedule and the risk of delays due to ground conditions. | 33% | 10.0 | 2.5 | 5.0 | 7.5 |
| 3.2 | Considerations around the practical aspects of construction, contractor's working site and the extent of temporary works required. | 33% | 5.0 | 2.5 | 10.0 | 7.5 |
| 3.3 | Construction impact on port operations i.e. access to existing slipways and Old Tug Jetty and the impact on operations during construction e.g. closing of entire area versus partial works being done and partial handover. | 34% | 5.0 | 2.5 | 10.0 | 7.5 |
| **4** | **Localisation** | **100%** | **7.5** | **2.5** | **10.0** | **1.0** |
| 4.1 | Whether material, plant and skills can be locally sourced for construction. | 100% | 7.5 | 2.5 | 10.0 | 1.0 |
| **5** | **Maintainability** | **100%** | **7.5** | **3.4** | **10.0** | **3.4** |
| 5.1 | Maintenance cost | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.2 | Personal required for maintenance i.e. skills and material | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.3 | Design service life | 34% | 7.5 | 5.0 | 10.0 | 5.0 |
| **6** | **Capital cost** | **100%** | **8.5** | **10.0** | **6.9** | **5.6** |
| 6.1 | Capital cost | 100% | 8.5 | 10.0 | 6.9 | 5.6 |
| **7** | **Upgradeability (flexibility and adaptability)** | **100%** | **7.5** | **5.0** | **10.0** | **2.5** |
| 7.1 | Provision for future increased berth depth and the structure's capacity for increased loading (vertical and lateral).<br>The adaptability for future change of use. | 100% | 7.5 | 5.0 | 10.0 | 2.5 |

| | |
|---|---|
| Excellent | 10 |
| Good | 7.5 |
| Average | 5 |
| Fair | 2.5 |
| Poor | 1 |

| Ref. | PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REFURBISHMENT OPTIONS ASSESSMENT | | | | | |
|---|---|---|---|---|---|---|
| | Multi-criteria analysis for selection of preferred option - Weightings skewed towards capital cost | | | | | |
| | TOTAL | | Option 1: Deck-on-pile | Option 2: Offset sheet pile wall | Option 3: Counterfort deck-on-pile hybrid | Option 4: Steel tubular combi-wall |
| Ref. | Criteria | Weighting | | | | |
| 1 | **Health and safety considerations** | 12% | 8% | 11% | 5% | 10% |
| 2 | **Environmental considerations** | 12% | 4% | 5% | 9% | 10% |
| 3 | **Constructability** | 12% | 8% | 3% | 10% | 9% |
| 4 | **Localisation** | 12% | 9% | 3% | 12% | 1% |
| 5 | **Maintainability** | 12% | 9% | 4% | 12% | 4% |
| 6 | **Capital cost** | 30% | 26% | 30% | 21% | 17% |
| 7 | **Upgradeability (flexibility and adaptability)** | 12% | 9% | 6% | 12% | 3% |
| | **Total** | **100%** | **72%** | **62%** | **79%** | **54%** |
| **1** | **Health and safety considerations** | **100%** | **7.1** | **9.4** | **4.4** | **8.8** |
| 1.1 | Safety of personnel during construction, considering the extent of dive work and time working over water. | 25% | 7.5 | 7.5 | 2.5 | 10.0 |
| 1.2 | Redundancy of the structure, whether damage is localised and the ease of repair i.e. is damage localised or does it place the complete facility at risk. | 25% | 1.0 | 10.0 | 5.0 | 10.0 |
| 1.3 | Risk of partial or catastophic collapse of existing infrastructure during construction. | 50% | 10.0 | 10.0 | 5.0 | 7.5 |
| **2** | **Environmental considerations** | **100%** | **3.8** | **4.4** | **7.5** | **8.8** |
| 2.1 | Increased footprint of facility due to rehabilitation and the permit or authorisation requirements. | 25% | 2.5 | 5.0 | 5.0 | 10.0 |
| 2.2 | Permanent impact on port operations i.e. access to slipways and Old Tug Jetty. | 50% | 2.5 | 5.0 | 7.5 | 10.0 |
| 2.3 | Construction impact on environment i.e. use of green materials and construction methods. Also considers carbon footprint by accounting the quantum of material needed for each option. | 25% | 7.5 | 2.5 | 10.0 | 5.0 |
| **3** | **Constructability** | **100%** | **6.7** | **2.5** | **8.4** | **7.5** |
| 3.1 | Considering the construction schedule and the risk of delays due to ground conditions. | 33% | 10.0 | 2.5 | 5.0 | 7.5 |
| 3.2 | Considerations around the practical aspects of construction, contractor's working site and the extent of temporary works required. | 33% | 5.0 | 2.5 | 10.0 | 7.5 |
| 3.3 | Construction impact on port operations i.e. access to existing slipways and Old Tug Jetty and the impact on operations during construction e.g. closing of entire area versus partial works being done and partial handover. | 34% | 5.0 | 2.5 | 10.0 | 7.5 |
| **4** | **Localisation** | **100%** | **7.5** | **2.5** | **10.0** | **1.0** |
| 4.1 | Whether material, plant and skills can be locally sourced for construction. | 100% | 7.5 | 2.5 | 10.0 | 1.0 |
| **5** | **Maintainability** | **100%** | **7.5** | **3.4** | **10.0** | **3.4** |
| 5.1 | Maintenance cost | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.2 | Personal required for maintenance i.e. skills and material | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.3 | Design service life | 34% | 7.5 | 5.0 | 10.0 | 5.0 |
| **6** | **Capital cost** | **100%** | **8.5** | **10.0** | **6.9** | **5.6** |
| 6.1 | Capital cost | 100% | 8.5 | 10.0 | 6.9 | 5.6 |
| **7** | **Upgradeability (flexibility and adaptability)** | **100%** | **7.5** | **5.0** | **10.0** | **2.5** |
| 7.1 | Provision for future increased berth depth and the structure's capacity for increased loading (vertical and lateral).<br>The adaptability for future change of use. | 100% | 7.5 | 5.0 | 10.0 | 2.5 |

| | |
|---|---|
| Excellent | 10 |
| Good | 7.5 |
| Average | 5 |
| Fair | 2.5 |
| Poor | 1 |

| | PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REFURBISHMENT OPTIONS ASSESSMENT | | | | | |
|---|---|---|---|---|---|---|
| | **Multi-criteria analysis for selection of preferred option - Weightings skewed towards upgradeability** | | | | | |
| | **TOTAL** | | **Option 1: Deck-on-pile** | **Option 2: Offset sheet pile wall** | **Option 3: Counterfort deck-on-pile hybrid** | **Option 4: Steel tubular combi-wall** |
| **Ref.** | **Criteria** | **Weighting** | | | | |
| 1 | **Health and safety considerations** | 12% | 8% | 11% | 5% | 10% |
| 2 | **Environmental considerations** | 12% | 4% | 5% | 9% | 10% |
| 3 | **Constructability** | 12% | 8% | 3% | 10% | 9% |
| 4 | **Localisation** | 12% | 9% | 3% | 12% | 1% |
| 5 | **Maintainability** | 12% | 9% | 4% | 12% | 4% |
| 6 | **Capital cost** | 12% | 10% | 12% | 8% | 7% |
| 7 | **Upgradeability (flexibility and adaptability)** | 30% | 23% | 15% | 30% | 8% |
| | **Total** | **100%** | **70%** | **52%** | **85%** | **48%** |
| **1** | **Health and safety considerations** | **100%** | **7.1** | **9.4** | **4.4** | **8.8** |
| 1.1 | Safety of personnel during construction, considering the extent of dive work and time working over water. | 25% | 7.5 | 7.5 | 2.5 | 10.0 |
| 1.2 | Redundancy of the structure, whether damage is localised and the ease of repair i.e. is damage localised or does it place the complete facility at risk. | 25% | 1.0 | 10.0 | 5.0 | 10.0 |
| 1.3 | Risk of partial or catastophic collapse of existing infrastructure during construction. | 50% | 10.0 | 10.0 | 5.0 | 7.5 |
| **2** | **Environmental considerations** | **100%** | **3.8** | **4.4** | **7.5** | **8.8** |
| 2.1 | Increased footprint of facility due to rehabilitation and the permit or authorisation requirements. | 25% | 2.5 | 5.0 | 5.0 | 10.0 |
| 2.2 | Permanent impact on port operations i.e. access to slipways and Old Tug Jetty. | 50% | 2.5 | 5.0 | 7.5 | 10.0 |
| 2.3 | Construction impact on environment i.e. use of green materials and construction methods. Also considers carbon footprint by accounting the quantum of material needed for each option. | 25% | 7.5 | 2.5 | 10.0 | 5.0 |
| **3** | **Constructability** | **100%** | **6.7** | **2.5** | **8.4** | **7.5** |
| 3.1 | Considering the construction schedule and the risk of delays due to ground conditions. | 33% | 10.0 | 2.5 | 5.0 | 7.5 |
| 3.2 | Considerations around the practical aspects of construction, contractor's working site and the extent of temporary works required. | 33% | 5.0 | 2.5 | 10.0 | 7.5 |
| 3.3 | Construction impact on port operations i.e. access to existing slipways and Old Tug Jetty and the impact on operations during construction e.g. closing of entire area versus partial works being done and partial handover. | 34% | 5.0 | 2.5 | 10.0 | 7.5 |
| **4** | **Localisation** | **100%** | **7.5** | **2.5** | **10.0** | **1.0** |
| 4.1 | Whether material, plant and skills can be locally sourced for construction. | 100% | 7.5 | 2.5 | 10.0 | 1.0 |
| **5** | **Maintainability** | **100%** | **7.5** | **3.4** | **10.0** | **3.4** |
| 5.1 | Maintenance cost | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.2 | Personal required for maintenance i.e. skills and material | 33% | 7.5 | 2.5 | 10.0 | 2.5 |
| 5.3 | Design service life | 34% | 7.5 | 5.0 | 10.0 | 5.0 |
| **6** | **Capital cost** | **100%** | **8.5** | **10.0** | **6.9** | **5.6** |
| 6.1 | Capital cost | 100% | 8.5 | 10.0 | 6.9 | 5.6 |
| **7** | **Upgradeability (flexibility and adaptability)** | **100%** | **7.5** | **5.0** | **10.0** | **2.5** |
| 7.1 | Provision for future increased berth depth and the structure's capacity for increased loading (vertical and lateral).<br>The adaptability for future change of use. | 100% | 7.5 | 5.0 | 10.0 | 2.5 |

| | |
|---|---|
| Excellent | 10 |
| Good | 7.5 |
| Average | 5 |
| Fair | 2.5 |
| Poor | 1 |

| PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE WALL (S2001-109) REFURBISHMENT OPTIONS ASSESSMENT | | | | |
|---|---|---|---|---|
| Multi-criteria analysis for selection of preferred option - Summary of sensitivity analysis | | | | |
| | | | | |
| **Weighting bias** | **Option 1:** Deck-on-pile | **Option 2:** Offset sheet pile wall | **Option 3:** Counterfort deck-on-pile hybrid | **Option 4:** Steel tubular combi-wall |
| **Base case** | 68% | 58% | 78% | 61% |
| **Equal** | 69% | 53% | 82% | 54% |
| **Health and safety considerations** | 70% | 60% | 75% | 60% |
| **Environmental considerations** | 64% | 51% | 80% | 60% |
| **Constructability** | 69% | 48% | 82% | 57% |
| **Capital cost** | 72% | 62% | 79% | 54% |
| **Upgradeability (flexibility and adaptability)** | 70% | 52% | 85% | 48% |
| | | | | |
| **Average score:** | **69%** | **55%** | **80%** | **56%** |
| **Overall rank:** | **2** | **4** | **1** | **3** |

**ANNEXURE C |** DRAWINGS

A1 DO NOT SCALE - IF IN DOUBT ASK

| CLIENT DRAWING NO. | | | | PRDW DRAWING NO. | | | | | | | DOCUMENT |
|---|---|---|---|---|---|---|---|---|---|---|---|
| PROJECT NO. | | SHEET NO. | REV. | PROJ NO. | SUB NO.. | TYPE | DISCRIP. | NO. | SHEET | REV. | TITLE |
| PEH 51V | 9046 | 01 | 00 | S2001 | 109 | DR | GA | 101 | S1 | 00 | DRAWING LIST |
| PEH 51V | 9046 | 02 | 00 | S2001 | 109 | DR | GA | 102 | S1 | 00 | LOCALITY PLAN |
| PEH 51V | 9046 | 03 | 00 | S2001 | 109 | DR | GA | 201 | S1 | 00 | EXISTING INFRASTRUCTURE |
| PEH 51V | 9046 | 04 | 00 | S2001 | 109 | DR | ST | 101 | S1 | 00 | PHASE 1 - COUNTERFORT WALL - PLAN AND TYPICAL CROSS SECTION |
| PEH 51V | 9046 | 05 | 00 | S2001 | 109 | DR | ST | 102 | S1 | 00 | PHASE 2 - DECK ON PILE - PLAN AND TYPICAL CROSS SECTION |

REFERENCE DRAWINGS

| DRAWING NO. | REFERENCE |
|---|---|

NOTES:

| NO. | DESCRIPTION | STATUS | BY | CHK'D | DATE |
|---|---|---|---|---|---|
| 0 | ISSUED FOR INFORMATION | C | UE | PES | 31/01/2019 |

STATUS CODE: (A) PRELIMINARY (B) PROPOSAL OR QUOTE (C) FOR APPROVAL (D) APPROVED FOR CONSTRUCTION (E) SUPERSEDED (F) AS BUILT

REVISIONS

| | NAME | SIGNED | DATE |
|---|---|---|---|
| DRAWN BY | UE | | 31/01/2019 |
| DRAWING CHECKED | YH | | 31/01/2019 |
| DESIGN CHECKED | PES | | 31/01/2019 |
| APPROVED | AEL | | 31/01/2019 |

FILE NAME: S2001-109-DR-GA-101-S1-R0.dwg

TIME STAMP: 27 MARCH 2019 11:17 AM

CLIENT: TNPA

TRANSNET

PRDW Consulting Port and Coastal Engineers www.prdw.com

PROJECT: PORT ELIZABETH HARBOUR OLD TUG JETTY SHEETPILE REHABILITATIONT FEL 2

DRAWING TITLE: DRAWING LIST

SCALE: AS SHOWN

S2001 - 109 - DR - GA - 101 - S1 - R0

PEH 51V - 9046 - 01 - 00



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A1 DO NOT SCALE - IF IN DOUBT ASK


SITE PLAN

REFERENCE DRAWINGS

| DRAWING NO. | REFERENCE |
|---|---|
| | |

NOTES:

| NO. | DESCRIPTION | STATUS | BY | CHK'D | DATE |
|---|---|---|---|---|---|
| 0 | ISSUED FOR INFORMATION | C | UE | PES | 31/01/2019 |

STATUS CODE: (A) PRELIMINARY (B) PROPOSAL OR QUOTE (C) FOR APPROVAL (D) APPROVED FOR CONSTRUCTION (E) SUPERSEDED (F) AS BUILT

REVISIONS

| | NAME | SIGNED | DATE |
|---|---|---|---|
| DRAWN BY | UE | | 31/01/2019 |
| DRAWING CHECKED | YH | | 31/01/2019 |
| DESIGN CHECKED | PES | | 31/01/2019 |
| APPROVED | AEL | | 31/01/2019 |

FILE NAME: S2001-109-DR-GA-102-S1-R0.dwg

TIME STAMP: 27 MARCH 2019 11:26 AM

CLIENT: TNPA

TRANSNET

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PROJECT: PORT ELIZABETH HARBOUR OLD TUG JETTY SHEETPILE REHABILITATION FEL 2

DRAWING TITLE: LOCALITY PLAN

SCALE: AS SHOWN

S2001 - 109 - DR - GA - 102 - S1 - R0

PEH 51V - 9046 - 02 - 00



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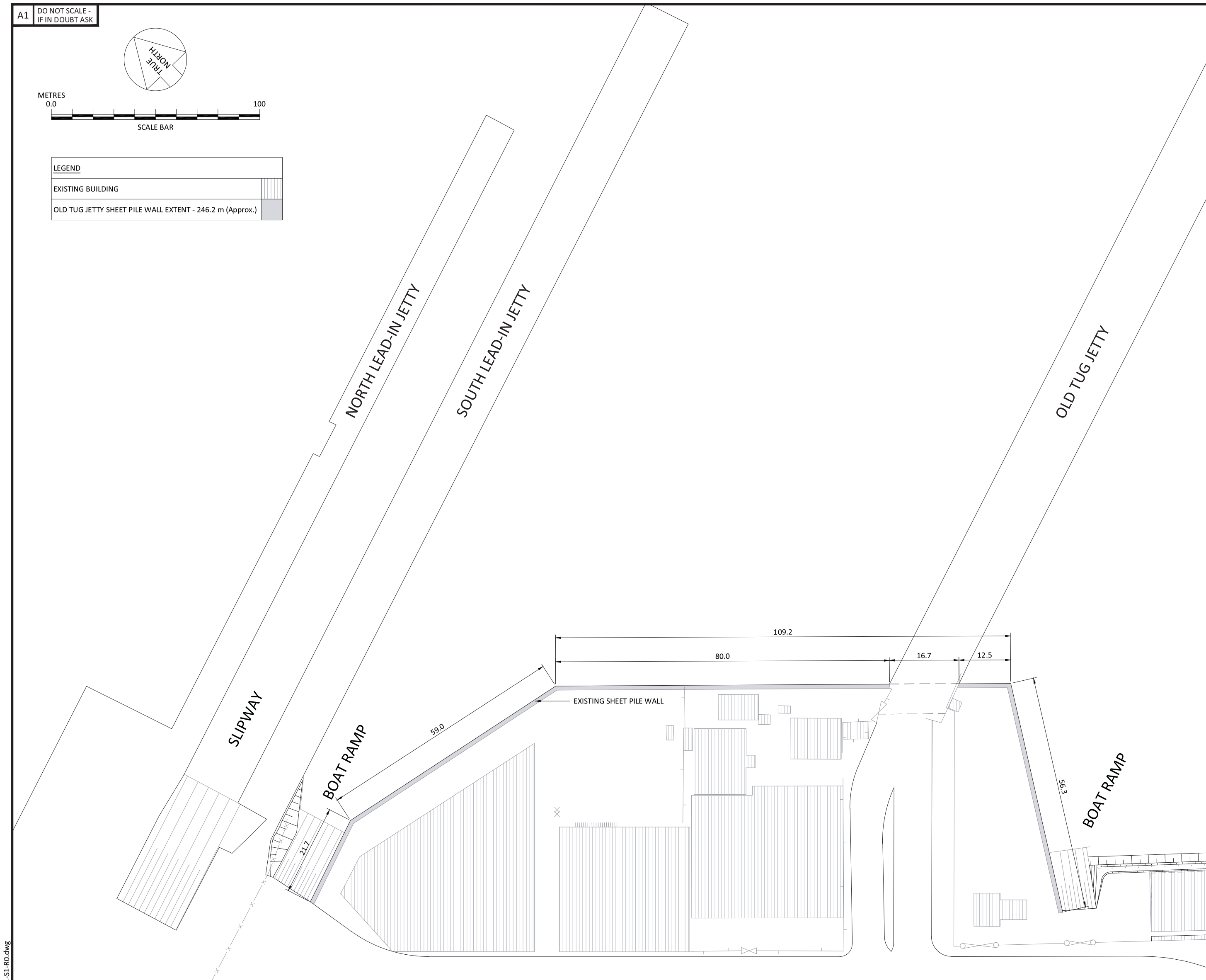
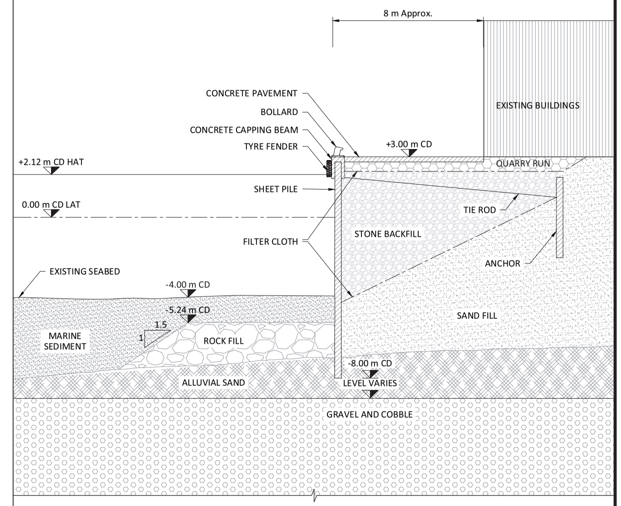
A1 DO NOT SCALE - IF IN DOUBT ASK




TYPICAL SECTION

SCALE: 1:25

| REFERENCE DRAWINGS | |
|---|---|
| DRAWING NO. | REFERENCE |

NOTES:

GENERAL

- DO NOT SCALE DRAWINGS - ONLY DIMENSIONS SHOWN TO BE USED.
- ALL LEVELS IN METRES AND REFERENCED TO CHART DATUM (CD), UNLESS NOTED OTHERWISE.
- ALL DIMENSIONS IN METRES (m), UNLESS NOTED OTHERWISE.
- ALL SECTIONS AND DETAILS REFERENCED TO PRDW DRAWING NUMBERS.
- EXISTING INFRASTRUCTURE DETAILS BASED ON AS-BUILT DRAWINGS PROVIDED BY TNPA (PEH-S1-V-1109)

| NO. | DESCRIPTION | STATUS | BY | CHK'D | DATE |
|---|---|---|---|---|---|
| 0 | ISSUED FOR INFORMATION | C | UE | PES | 31/01/2019 |

STATUS CODE: (A) PRELIMINARY (B) PROPOSAL OR QUOTE (C) FOR APPROVAL (D) APPROVED FOR CONSTRUCTION (E) SUPERSEDED (F) AS BUILT

REVISIONS

| | NAME | SIGNED | DATE |
|---|---|---|---|
| DRAWN BY | UE | | 31/01/2019 |
| DRAWING CHECKED | YH | | 31/01/2019 |
| DESIGN CHECKED | PES | | 31/01/2019 |
| APPROVED | AEL | | 31/01/2019 |
| FILE NAME | S2001-109-DR-GA-201-S1-R0.dwg | | |
| TIME STAMP | 27 MARCH 2019 11:24 AM | | |

CLIENT

TNPA

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PROJECT

PORT ELIZABETH HARBOUR
OLD TUG JETTY SHEETPILE
REHABILITATION FEL 2

DRAWING TITLE

# EXISTING INFRASTRUCTURE

SCALE: AS SHOWN

S2001 - 109 - DR - GA - 201 - S1 - R0

PEH 51V - 9046 - 03 - 00



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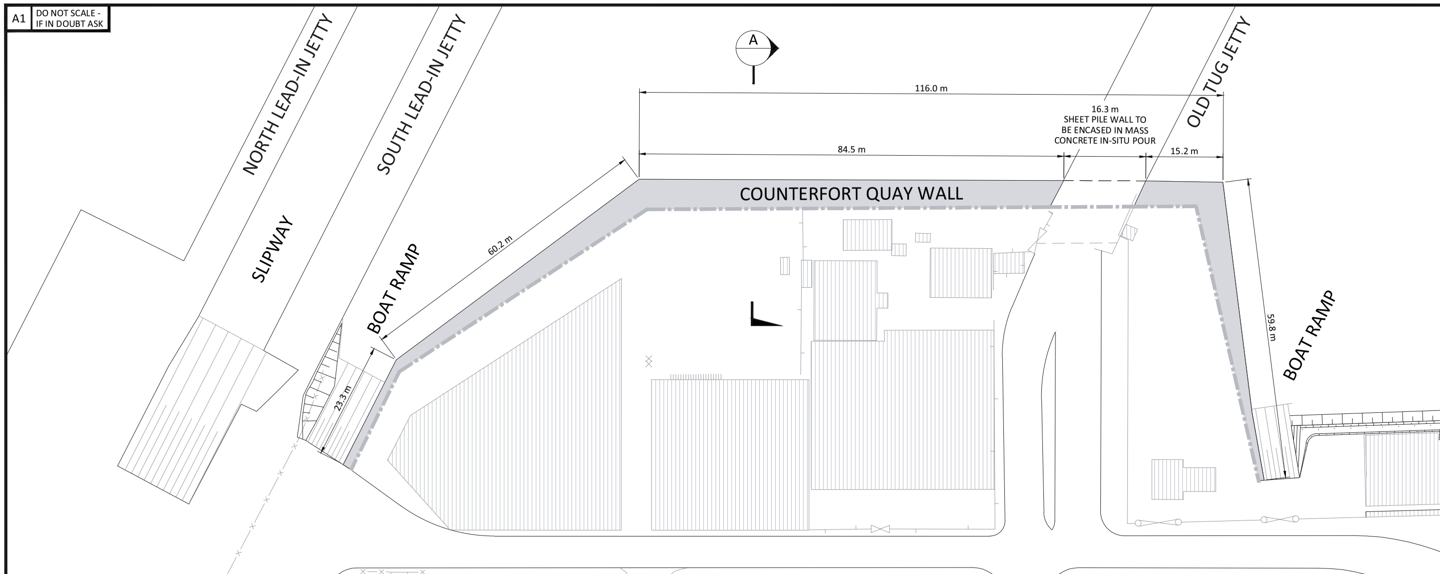
A1 DO NOT SCALE - IF IN DOUBT ASK

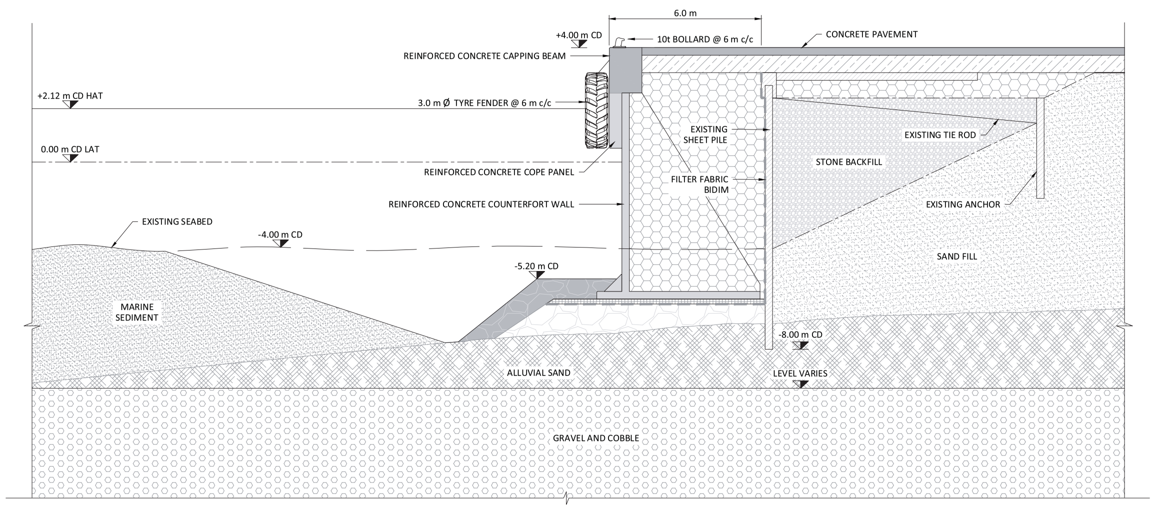



TRUE NORTH

METRES 0.0 100

SCALE BAR

LEGEND
- EXISTING BUILDING
- EXISTING SHEET PILE WALL- 246.2 m (Approx.)
- PHASE 1 COUNTERFORT WALL - 259.3 m (Approx.) - RECLAIMED AREA = 1003 m²




LEGEND
- LAYER WORKS
- SAND FILL
- STONE BED
- QUARRY RUN
- SCOUR PROTECTION
- EXISTING ROCK FILL
- IN-SITU CONCRETE
- PRECAST CONCRETE
- EXISTING INFRASTRUCTURE
- GROUND AND COBBLE
- ALLUVIAL SAND
- SAND FILL

## PHASE 1 - SECTION A

1:20

| REFERENCE DRAWINGS | |
|---|---|
| DRAWING NO. | REFERENCE |

NOTES:

GENERAL

- DO NOT SCALE DRAWINGS - ONLY DIMENSIONS SHOWN TO BE USED.
- ALL LEVELS IN METRES AND REFERENCED TO CHART DATUM (CD), UNLESS NOTED OTHERWISE.
- ALL DIMENSIONS IN METRES(m), UNLESS NOTED OTHERWISE.

| NO. | DESCRIPTION | STATUS | BY | CHK'D | DATE |
|---|---|---|---|---|---|
| 0 | ISSUED FOR INFORMATION | C | UE | PES | 31/01/2019 |

STATUS CODE: (A) PRELIMINARY (B) PROPOSAL OR QUOTE (C) FOR APPROVAL (D) APPROVED FOR CONSTRUCTION (E) SUPERSEDED (F) AS BUILT

REVISIONS

| | NAME | SIGNED | DATE |
|---|---|---|---|
| DRAWN BY | UE | | 31/01/2019 |
| DRAWING CHECKED | YH | | 31/01/2019 |
| DESIGN CHECKED | PES | | 31/01/2019 |
| APPROVED | AEL | | 31/01/2019 |
| FILE NAME | S2001-109-DR-ST-101-S1-R0.dwg | | |
| TIME STAMP | 27 MARCH 2019 11:28 AM | | |

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PROJECT

PORT ELIZABETH HARBOUR
OLD TUG JETTY SHEETPILE
REHABILITATION FEL 2

DRAWING TITLE

PHASE 1
COUNTERFORT WALL
PLAN AND TYPICAL
CROSS SECTION

SCALE: AS SHOWN

S2001 - 109 - DR - ST - 101 - S1 - R0

PEH 51V - 9046 - 04 - 00



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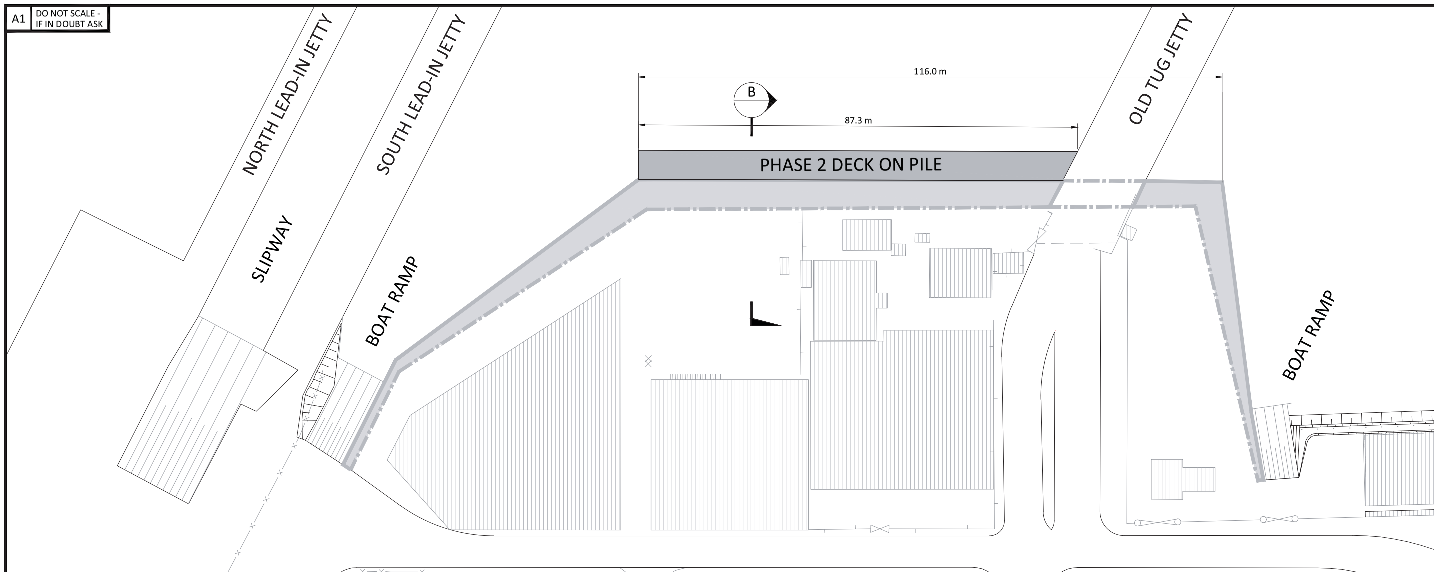
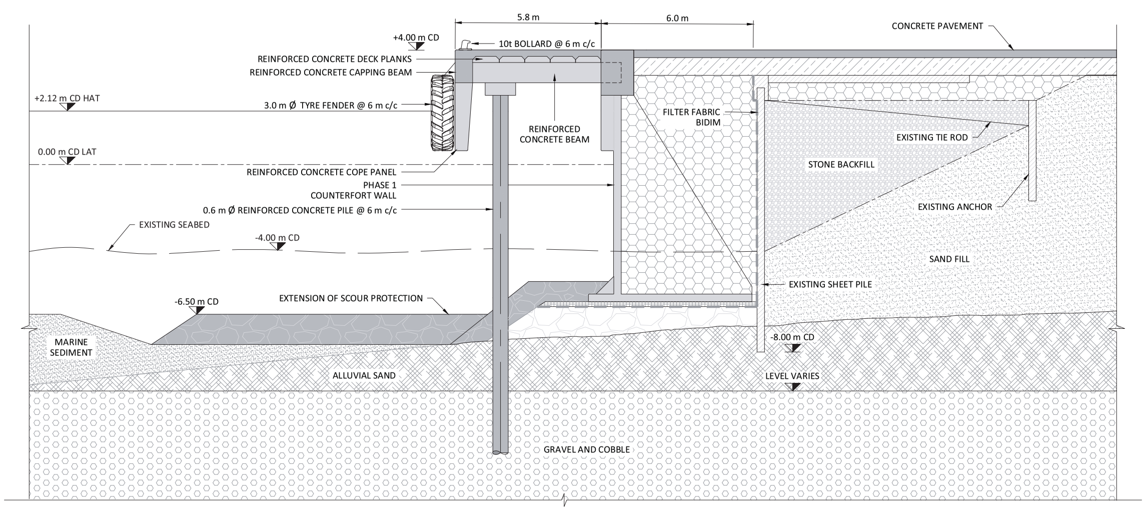
A1 DO NOT SCALE - IF IN DOUBT ASK




| LEGEND | |
|---|---|
| EXISTING BUILDING | |
| EXISTING SHEET PILE WALL- 246.2 m (Approx.) | |
| PHASE 1 COUNTERFORT WALL - 259.3 m (Approx.) - RECLAIMED AREA = 1003 m² | |
| PHASE 2 DECK ON PILE - 87.3 m (Approx.) - RECLAIMED AREA = 498 m² | |




PHASE 2 - SECTION B

1:20

LEGEND

- LAYER WORKS
- SAND FILL
- STONE BED
- QUARRY RUN
- SCOUR PROTECTION
- EXISTING ROCK FILL
- IN-SITU CONCRETE
- PRECAST CONCRETE
- EXISTING INFRASTRUCTURE
- GROUND AND COBBLE
- ALLUVIAL SAND
- SAND FILL

| REFERENCE DRAWINGS | |
|---|---|
| DRAWING NO. | REFERENCE |

NOTES:

GENERAL

- DO NOT SCALE DRAWINGS - ONLY DIMENSIONS SHOWN TO BE USED.
- ALL LEVELS IN METRES AND REFERENCED TO CHART DATUM (CD), UNLESS NOTED OTHERWISE.
- ALL DIMENSIONS IN METRES (m), UNLESS NOTED OTHERWISE.

| NO. | DESCRIPTION | STATUS | BY | CHK'D | DATE |
|---|---|---|---|---|---|
| 0 | ISSUED FOR INFORMATION | C | UE | PES | 31/01/2019 |

STATUS CODE: (A) PRELIMINARY (B) PROPOSAL OR QUOTE (C) FOR APPROVAL (D) APPROVED FOR CONSTRUCTION (E) SUPERSEDED (F) AS BUILT

REVISIONS

| | NAME | SIGNED | DATE |
|---|---|---|---|
| DRAWN BY | UE | | 31/01/2019 |
| DRAWING CHECKED | YH | | 31/01/2019 |
| DESIGN CHECKED | PES | | 31/01/2019 |
| APPROVED | AEL | | 31/01/2019 |

FILE NAME: S2001-109-DR-ST-102-S1-R0.dwg

TIME STAMP: 27 MARCH 2019 11:22 AM

CLIENT: TNPA

TRANSNET

PRDW Consulting Port and Coastal Engineers www.prdw.com

PROJECT: PORT ELIZABETH HARBOUR OLD TUG JETTY SHEETPILE REHABILITATION FEL 2

DRAWING TITLE: PHASE 2 DECK ON PILE PLAN AND TYPICAL CROSS SECTION

SCALE: AS SHOWN

S2001 - 109 - DR - ST - 102 - S1 - R0

PEH 51V - 9046 - 05 - 00



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**ANNEXURE D |** CAPITAL COST ESTIMATE

PRDW
Consulting Port and Coastal Engineers

| | | |
|---|---|---|
| 1 | **PROJECT NO.**<br>S2001-109 | |
| 2 | **TITLE**<br>Port of Port Elizabeth - Old Tug Jetty Sheetpile Refurbishment | |
| 3 | **ESTIMATE PREPARED BY:**<br>**PRDW** | **DATE:**<br>**Feb-19** |

**4** **SCOPE**

**Description**

FEL 2 capital construction cost estimate for refurbishment of the Old Tug Jetty Sheetpile

**Scope Items**

Phase 1 - Counterfort Wall
- Counterfort Quay wall (259.3m long)
- Scour Protection
- Dredging
- Cope and quay furniture
- Paving

Phase 2 - Deck on pile structure
- Deck on Pile Quay wall (87.3m long)
- Scour Protection
- Dredging
- Cope and quay furniture

**5** **ASSUMPTIONS AND EXCLUSIONS**

**Assumptions**

| | | |
|---|---|---|
| Cost base as at: | | Feb-19 |
| Exchange Rate (Dollar) - $ 1.00 : | R | 13.90 |
| Exchange Rate (Euro) - 1.00 € : | R | 15.90 |
| Exchange Rate (Pound) - £ 1.00 : | R | 17.90 |

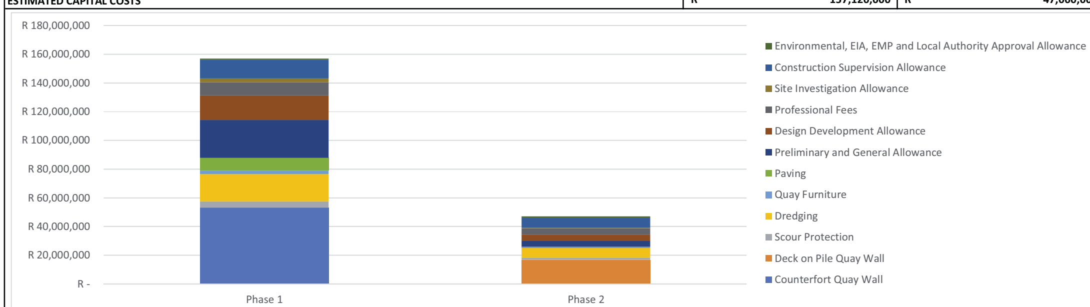
Contractor has unrestricted access to the berth and use of existing quay during construction
Existing founding material is suitable for the proposed structure
All construction for Phase 1 will be completed using marine equipment
All construction for Phase 2 will be complete using land-based equipment
All fill and scour material is to be imported from a commercial source within 30km radius from the construction site
Dredged material to be disposed onshore dewatered and taken to a landfill site
Counterfort units can be loaded from an existing quay

**Exclusions**

Landside facilities i.e. Buildings, Structures and services
Allowance for purchase/lease of land and third party compensation due to disruption or relocation;
Allowance for compensation to third parties
Allowance for market adjustment due to local and international demand, availability of skills, resources and materials
Allowance for rate of exchange adjustments
Allowance for owner's costs
Allowance for pre-tender and post contract escalation
Allowance in respect of post contract contingencies (10% recommended)
Value Added Tax or other South African or Foreign taxes, royalties and duties

**6** **CAPEX (Including P&G's, Design Development Allowance and Professional Fee)**

| Item | Description | Phase 1 | | Phase 2 | |
|---|---|---|---|---|---|
| 1 | Counterfort Quay Wall | R | 53,100,000 | R | - |
| 2 | Deck on Pile Quay Wall | R | - | R | 16,700,000 |
| 3 | Scour Protection | R | 4,480,000 | R | 1,510,000 |
| 4 | Dredging | R | 18,920,000 | R | 6,790,000 |
| 5 | Quay Furniture | R | 2,430,000 | R | 800,000 |
| 6 | Paving | R | 8,920,000 | R | - |
| 7 | Preliminary and General Allowance | R | 26,300,000 | R | 4,080,000 |
| 8 | Design Development Allowance | R | 17,130,000 | R | 4,490,000 |
| 9 | Professional Fees | R | 9,190,000 | R | 4,470,000 |
| 10 | Site Investigation Allowance | R | 2,650,000 | R | 220,000 |
| 11 | Construction Supervision Allowance | R | 13,000,000 | R | 7,000,000 |
| 12 | Environmental, EIA, EMP and Local Authority Approval Allowance | R | 1,000,000 | R | 1,000,000 |
| **ESTIMATED CAPITAL COSTS** | | **R** | **157,120,000** | **R** | **47,060,000** |




**7** **SOURCE OF ESTIMATE**

Rates are largely based upon PRDW's internal rates data base

**8** **LEVEL OF ACCURACY**

| **Rough Order of Magnitude**<br>**Class 5** | | **Pre-feasibility /Conceptual**<br>**Class 4** | | **Feasibility / Budget**<br>**Class 3** | | **Definitive Control Budget**<br>**Class 2** | | **Definitive Control Budget**<br>**Class 1** | |
|---|---|---|---|---|---|---|---|---|---|
| | | Accuracy<br>-30 % to +50 % | ✓ | | | | | | |
| (No Dwg, No BoM), Thumb suck | | Basis Captured on GA Dwgs | | Detailed Design Dwgs 30%, Construction Dwgs, Site investigations | | Construction Started | | Construction Started | |

**9** **RISKS IDENTIFIED AND COMMENTS**

Limited geotechnical information available

| | |
|---|---|
| Project: | **Port of Port Elizabeth - Old Tug Jetty Sheetpile Refurbishment** |
| Project No.: | **S2001-109** |
| Title: | **FEL 2 capital construction cost estimate for refurbishment of the Old Tug Jetty Sheetpile** |
| Section: | **Phase 1 - Counterfort Wall** |

| ITEM | REF | DESCRIPTION | UNIT | QTY | RATE | AMOUNT | COMMENT |
|---|---|---|---|---|---|---|---|
| | | **Phase 1 - Counterfort Wall** | | | | | |
| 1 | | Precast yard, mobilisation, demobilisation of counterfort unit placing kit | Sum | 1 | 18,020,000.00 | R 18,020,000 | |
| 2 | | Supply and place concrete counterfort wall | Sum | 1 | 26,320,000.00 | R 26,320,000 | |
| 3 | | Backfill to counterfort wall | Sum | 1 | 6,970,000.00 | R 6,970,000 | |
| 4 | | Quay furniture | Sum | 1 | 2,430,000.00 | R 2,430,000 | |
| 5 | | Scour Protection | Sum | 1 | 4,480,000.00 | R 4,480,000 | |
| 6 | | Paving | Sum | 1 | 8,920,000.00 | R 8,920,000 | |
| 7 | | Services | Sum | 1 | 1,790,000.00 | R 1,790,000 | |
| 8 | | Dredging | Sum | 1 | 14,820,000.00 | R 14,820,000 | |
| 9 | | Mobilisation/ demobilisation of dredge equipment | Sum | 1 | 4,100,000.00 | R 4,100,000 | |
| | | **SUB-TOTAL:** | | | | **R 87,850,000** | |
| | | Preliminary and General Allowance - Quay wall | 40% | | | R 26,300,000 | |
| | | Design Development and Construction Risk Allowance | 15% | | | R 17,130,000 | |
| | | Professional Fee Allowance | 7% | | | R 9,190,000 | |
| | | **SUB-TOTAL CARRIED FORWARD TO SUMMARY:** | | | | **R 140,470,000** | |

| | |
|---|---|
| Project: | **Port of Port Elizabeth - Old Tug Jetty Sheetpile Refurbishment** |
| Project No.: | **S2001-109** |
| Title: | **FEL 2 capital construction cost estimate for refurbishment of the Old Tug Jetty Sheetpile** |
| Section: | **Phase 2 - Deck on pile structure** |

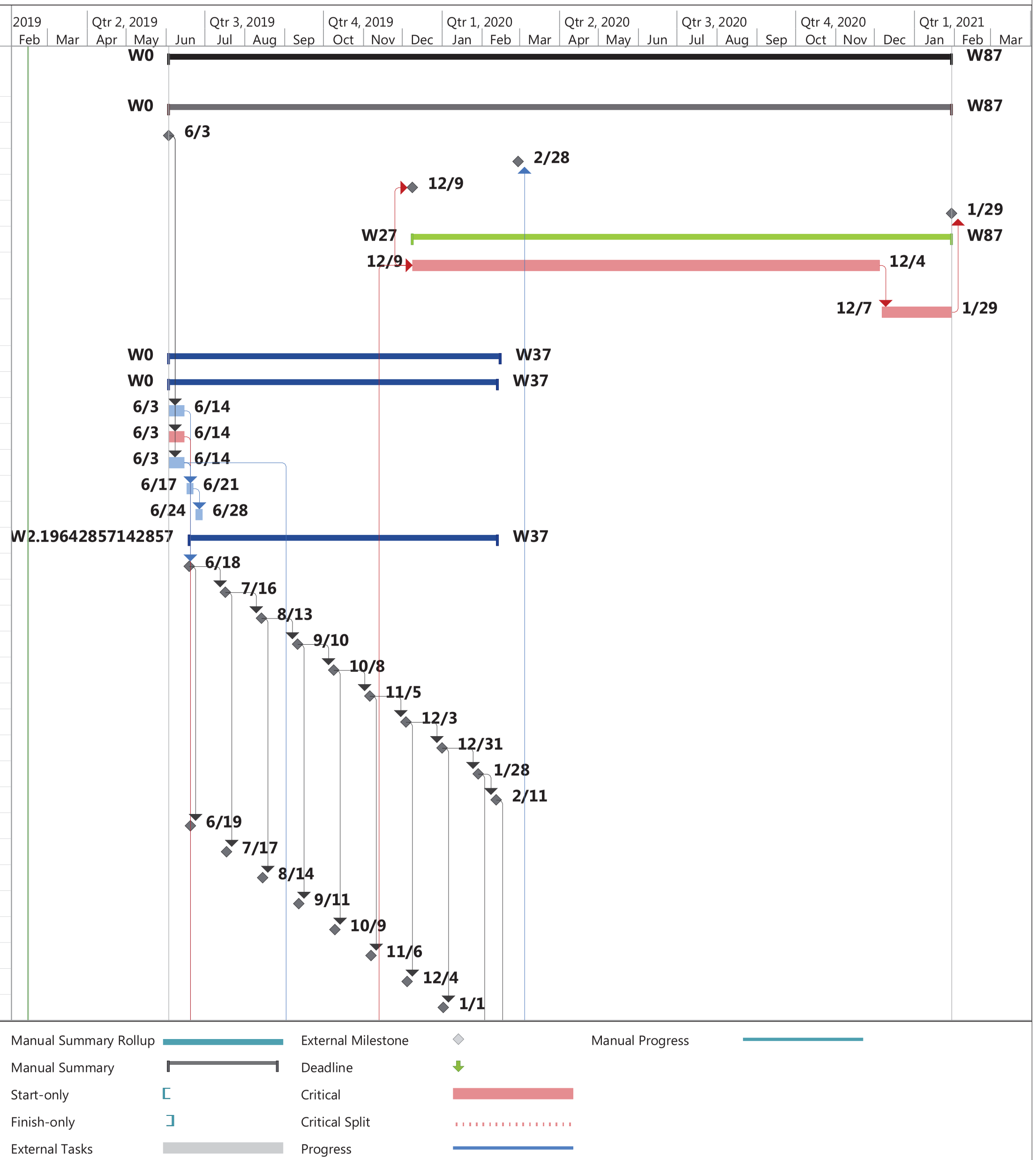
| ITEM | REF | DESCRIPTION | UNIT | QTY | RATE | AMOUNT | COMMENT |
|---|---|---|---|---|---|---|---|
| | | **<u>Phase 2 - Deck on pile structure</u>** | | | | | |
| 1 | | Precast yard | Sum | 1 | 5,000,000.00 | R 5,000,000 | |
| 2 | | Mobilisation/ demobilisation of piling equipment | Sum | 1 | 3,120,000.00 | R 3,120,000 | |
| 3 | | Supply and place piling | Sum | 1 | 4,550,000.00 | R 4,550,000 | |
| 4 | | Supply and place concrete deck | Sum | 1 | 3,200,000.00 | R 3,200,000 | |
| 5 | | Quay furniture | Sum | 1 | 800,000.00 | R 800,000 | |
| 6 | | Scour Protection | Sum | 1 | 1,510,000.00 | R 1,510,000 | |
| 7 | | Services | Sum | 1 | 830,000.00 | R 830,000 | |
| 8 | | Dredging | Sum | 1 | 2,690,000.00 | R 2,690,000 | |
| 9 | | Mobilisation/ demobilisation of dredge equipment | Sum | 1 | 4,100,000.00 | R 4,100,000 | |
| | | **SUB-TOTAL:** | | | | **R 25,800,000** | |
| | | Preliminary and General Allowance - Quay wall | 30% | | | R 4,080,000 | |
| | | Design Development and Construction Risk Allowance | 15% | | | R 4,490,000 | |
| | | Professional Fee Allowance | 13% | | | R 4,470,000 | |
| | | **SUB-TOTAL CARRIED FORWARD TO SUMMARY:** | | | | **R 38,840,000** | |

**ANNEXURE E |** FEL 3 PROJECT SCHEDULE

PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE REFURBISHMENT

Doc number: S2001-109-PS-GA-001-R1

| ID | Task Name | Duration | Cost |
|---|---|---|---|
| 1 | **Old Tug Jetty Sheet Pile Rehabilitation Project - Phase 1** | **87 wks** | **R 9,650,000.00** |
| 2 | **Milestones** | **87 wks** | **R 0.00** |
| 3 | Commencement of FEL3 Engineering Study | 0 days | R 0.00 |
| 4 | Completion of FEL3 Engineering Study | 0 wks | R 0.00 |
| 5 | Submission of EIA | 0 wks | R 0.00 |
| 6 | Environmental RoD | 0 wks | R 0.00 |
| 7 | **Environemental & Local Authority Authorizations** | **60 wks** | **R 870,000.00** |
| 8 | Full Scoping and EIA including local authority authorisation | 52 wks | R 870,000.00 |
| 9 | Time Risk Allowances for dealing with authorization risks | 8 wks | R 0.00 |
| 10 | **FEL3 Engineering Study** | **37 wks** | **R 8,740,000.00** |
| 11 | **Project Management & Coordination** | **36.6 wks** | **R 1,154,280.00** |
| 12 | Appoint Environmental Practitioner | 2 wks | R 45,180.00 |
| 13 | Appoint Geotechnical Subcontractor | 2 wks | R 45,180.00 |
| 14 | Project Set-up and Kick-off | 2 wks | R 84,000.00 |
| 15 | Prepare and Submit HSE File for Approval | 1 wk | R 8,800.00 |
| 16 | HSE File review and approval by TNPA | 1 wk | R 0.00 |
| 17 | **Meetings** | **34.2 wks** | **R 971,120.00** |
| 18 | Internal Progress Meeting No. 1 | 0 wks | R 54,254.00 |
| 19 | Internal Progress Meeting No. 2 | 0 wks | R 54,254.00 |
| 20 | Internal Progress Meeting No. 3 | 0 wks | R 54,254.00 |
| 21 | Internal Progress Meeting No. 4 | 0 wks | R 54,254.00 |
| 22 | Internal Progress Meeting No. 5 | 0 wks | R 54,254.00 |
| 23 | Internal Progress Meeting No. 6 | 0 wks | R 54,254.00 |
| 24 | Internal Progress Meeting No. 7 | 0 wks | R 54,254.00 |
| 25 | Internal Progress Meeting No. 8 | 0 wks | R 54,254.00 |
| 26 | Internal Progress Meeting No. 9 | 0 wks | R 54,254.00 |
| 27 | Internal Progress Meeting No. 10 | 0 wks | R 43,894.00 |
| 28 | Client Progress Meeting No. 1 | 0 wks | R 43,894.00 |
| 29 | Client Progress Meeting No. 2 | 0 wks | R 43,894.00 |
| 30 | Client Progress Meeting No. 3 | 0 wks | R 43,894.00 |
| 31 | Client Progress Meeting No. 4 | 0 wks | R 43,894.00 |
| 32 | Client Progress Meeting No. 5 | 0 wks | R 43,894.00 |
| 33 | Client Progress Meeting No. 6 | 0 wks | R 43,894.00 |
| 34 | Client Progress Meeting No. 7 | 0 wks | R 43,894.00 |
| 35 | Client Progress Meeting No. 8 | 0 wks | R 43,894.00 |

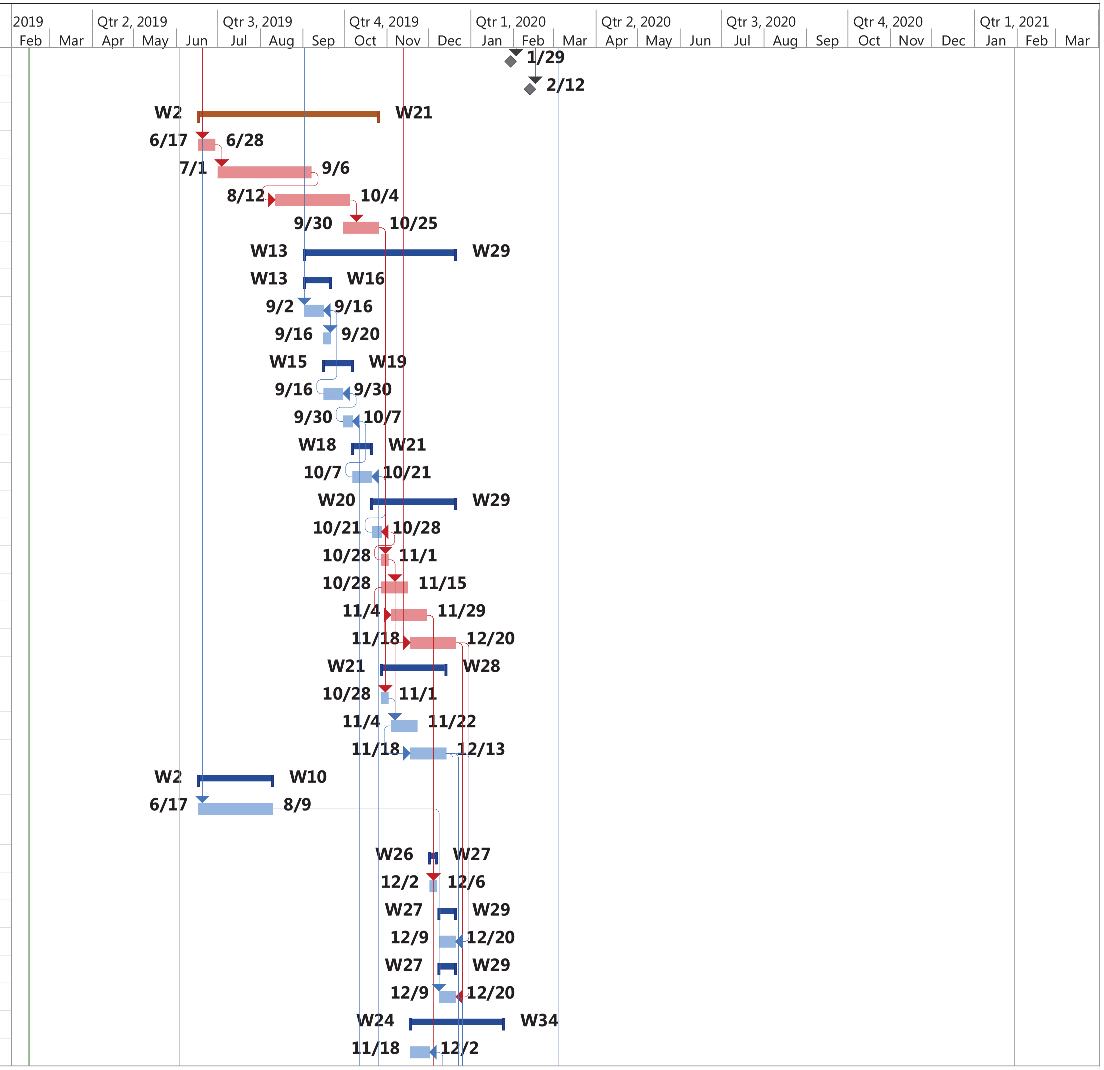



Project: FEL3 Programme
Date: Thu 2/14/19

# PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE REFURBISHMENT

Doc number: S2001-109-PS-GA-001-R1

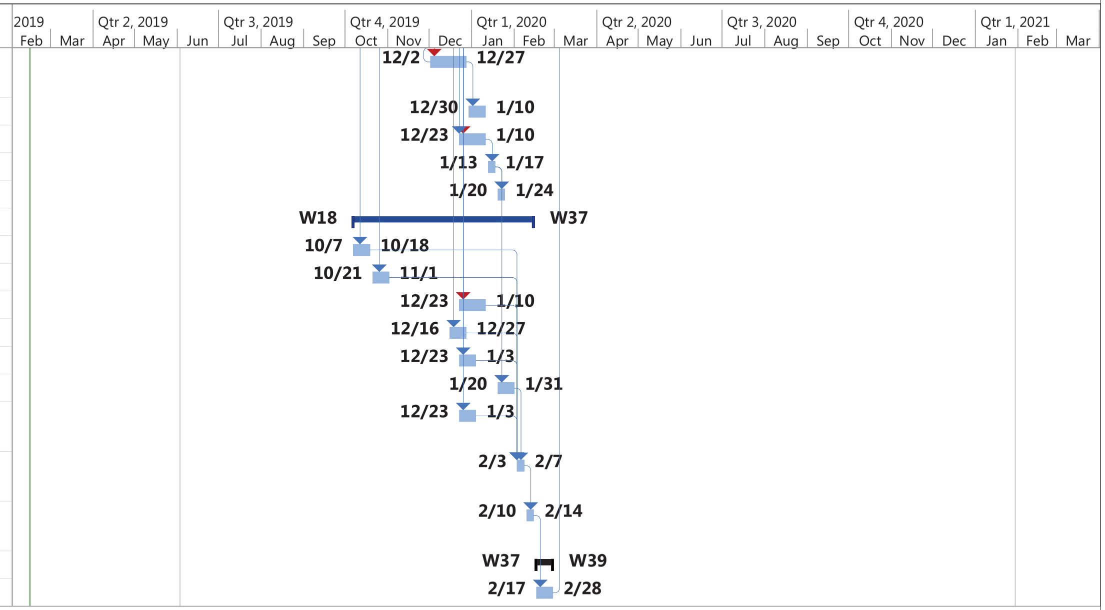
| ID | Task Name | Duration | Cost |
|---|---|---|---|
| 36 | Client Progress Meeting No. 9 | 0 wks | R 43,894.00 |
| 37 | Client Progress Meeting No. 10 | 0 wks | R 43,894.00 |
| 38 | **Site Investigations** | **19 wks** | **R 2,716,295.00** |
| 39 | Mobilize to site | 2 wks | R 500,000.00 |
| 40 | Field work (Geotech & Hydorgraphic Surveys) | 10 wks | R 1,866,295.00 |
| 41 | Lab Testing | 8 wks | R 200,000.00 |
| 42 | Site Investigation Report (Factual & Interpretive) | 4 wks | R 150,000.00 |
| 43 | **Feasibility Design** | **16 wks** | **R 3,205,821.00** |
| 44 | **Design Basis** | **3 wks** | **R 72,000.00** |
| 45 | Prepare and submit Design Basis for Approval | 2 wks | R 72,000.00 |
| 46 | Design Basis review and approval by TNPA | 1 wk | R 0.00 |
| 47 | **Coastal Processes Study** | **3 wks** | **R 39,600.00** |
| 48 | Collate model inputs (Desktop Study) | 2 wks | R 19,800.00 |
| 49 | Prepare and run coastal processes model | 1 wk | R 19,800.00 |
| 50 | **Navigation Study** | **2 wks** | **R 50,000.00** |
| 51 | Navigation designs | 2 wks | R 50,000.00 |
| 52 | **Structural Design** | **9 wks** | **R 1,883,370.00** |
| 53 | Model setup (load cases, etc.) | 1 wk | R 65,000.00 |
| 54 | Review Site Investigation reports | 1 wk | R 71,700.00 |
| 55 | Stability Assessment | 3 wks | R 85,000.00 |
| 56 | Numerical modelling and Structural Designs | 4 wks | R 269,400.00 |
| 57 | Prepare Structural Drawings | 5 wks | R 1,392,270.00 |
| 58 | **Coastal Structures Design** | **7 wks** | **R 1,160,851.00** |
| 59 | Review Site Investigation reports | 1 wk | R 40,000.00 |
| 60 | Scour Protection designs | 3 wks | R 185,000.00 |
| 61 | Prepare Scour Protection drawings | 4 wks | R 935,851.00 |
| 62 | **Environmental Management** | **8 wks** | **R 100,000.00** |
| 63 | Identify Environmental Authorization requirements & Risks | 8 wks | R 100,000.00 |
| 64 | **Health & Safety Management** | **1 wk** | **R 80,000.00** |
| 65 | Safey in Design Review | 1 wk | R 80,000.00 |
| 66 | **Construction Management** | **2 wks** | **R 82,900.00** |
| 67 | Constructability Review & Schedule | 2 wks | R 82,900.00 |
| 68 | **Risk Management** | **2 wks** | **R 157,054.00** |
| 69 | Project Risk Analysis | 2 wks | R 157,054.00 |
| 70 | **Procurement Documentation** | **10 wks** | **R 893,650.00** |
| 71 | Obtain Transnet general specifications (H&S, etc.) | 2 wks | R 20,000.00 |




Project: FEL3 Programme
Date: Thu 2/14/19

Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Critical
Critical Split
Progress
Manual Progress

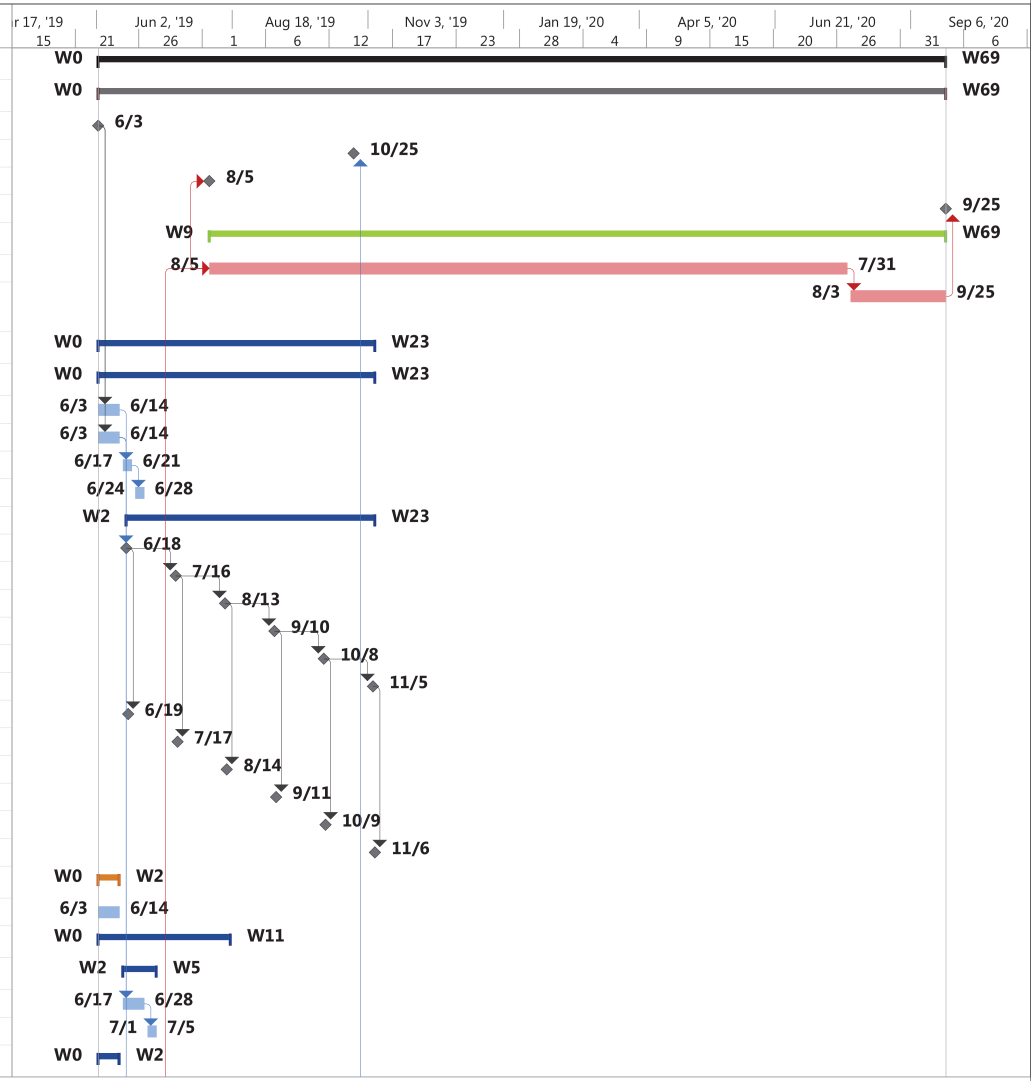
| ID | Task Name | Duration | Cost |
|---|---|---|---|
| 72 | Prepare Works information (Incl. Technical Specifications) | 4 wks | R 462,400.00 |
| 73 | Prepare Site Information | 2 wks | R 169,700.00 |
| 74 | Prepare Bill of Quantities & Pricing Assumptions | 3 wks | R 191,550.00 |
| 75 | Complie Tender documentation submission | 1 wk | R 50,000.00 |
| 76 | TNPA reivew and approval of tender documentation | 1 wk | R 0.00 |
| 77 | **Feasibility Report** | **19 wks** | **R 350,000.00** |
| 78 | Coastal Process inputs into FEL3 Study Report | 2 wks | R 15,000.00 |
| 79 | Navigation inputs into FEL3 Study Report | 2 wks | R 15,000.00 |
| 80 | Structural inputs into FEL3 Study Report | 3 wks | R 90,000.00 |
| 81 | Coastal Structures inputs into FEL3 Study Report | 2 wks | R 70,000.00 |
| 82 | Risk Management inputs into FEL3 Study Report | 2 wks | R 40,000.00 |
| 83 | Procurement inputs into FEL3 Study Report | 2 wks | R 50,000.00 |
| 84 | Environmental subconsultant inputs into FEL3 Report | 2 wks | R 30,000.00 |
| 85 | Internal Review & Submission of Feasibility Study Report | 1 wk | R 40,000.00 |
| 86 | TNPA Review and approval of Feasibility Study Report | 1 wk | R 0.00 |
| 87 | **TNPA Approvals** | **2 wks** | **R 40,000.00** |
| 88 | FEL 3 Gate Review | 2 wks | R 40,000.00 |




Project: FEL3 Programme
Date: Thu 2/14/19

Task
Split
Milestone
Summary
Project Summary
Inactive Task
Inactive Milestone
Inactive Summary
Manual Task
Duration-only
Manual Summary Rollup
Manual Summary
Start-only
Finish-only
External Tasks
External Milestone
Deadline
Critical
Critical Split
Progress
Manual Progress

| ID | Task Name | Duration | Cost |
|---|---|---|---|
| 1 | **Old Tug Jetty Sheet Pile Rehabilitation Project - Phase 2** | **69 wks** | **R 4,500,000.00** |
| 2 | **Milestones** | **69 wks** | **R 0.00** |
| 3 | Commencement of FEL3 Engineering Study | 0 days | R 0.00 |
| 4 | Completion of FEL3 Engineering Study | 0 wks | R 0.00 |
| 5 | Submission of EIA | 0 wks | R 0.00 |
| 6 | Environmental RoD | 0 wks | R 0.00 |
| 7 | **Environemental & Local Authority Authorizations** | **60 wks** | **R 870,000.00** |
| 8 | Full Scoping and EIA including local authority approval | 52 wks | R 870,000.00 |
| 9 | Time Risk Allowances for dealing with authorization risks | 8 wks | R 0.00 |
| 10 | **FEL3 Engineering Study** | **22.6 wks** | **R 3,630,000.00** |
| 11 | **Project Management & Coordination** | **22.6 wks** | **R 481,000.00** |
| 12 | Appoint Environmental Practitioner | 2 wks | R 45,000.00 |
| 13 | Project Set-up and Kick-off | 2 wks | R 83,000.00 |
| 14 | Prepare and Submit HSE File for Approval | 1 wk | R 9,000.00 |
| 15 | HSE File review and approval by TNPA | 1 wk | R 0.00 |
| 16 | **Meetings** | **20.2 wks** | **R 344,000.00** |
| 17 | Internal Progress Meeting No. 1 | 0 wks | R 28,000.00 |
| 18 | Internal Progress Meeting No. 2 | 0 wks | R 28,000.00 |
| 19 | Internal Progress Meeting No. 3 | 0 wks | R 28,000.00 |
| 20 | Internal Progress Meeting No. 4 | 0 wks | R 28,000.00 |
| 21 | Internal Progress Meeting No. 5 | 0 wks | R 28,000.00 |
| 22 | Internal Progress Meeting No. 6 | 0 wks | R 28,000.00 |
| 23 | Client Progress Meeting No. 1 | 0 wks | R 32,000.00 |
| 24 | Client Progress Meeting No. 2 | 0 wks | R 28,000.00 |
| 25 | Client Progress Meeting No. 3 | 0 wks | R 28,000.00 |
| 26 | Client Progress Meeting No. 4 | 0 wks | R 28,000.00 |
| 27 | Client Progress Meeting No. 5 | 0 wks | R 28,000.00 |
| 28 | Client Progress Meeting No. 6 | 0 wks | R 32,000.00 |
| 29 | **Site Investigation** | **2 wks** | **R 220,000.00** |
| 30 | Bathymetric survey | 2 wks | R 220,000.00 |
| 31 | **Feasibility Design** | **11 wks** | **R 1,539,100.00** |
| 32 | **Design Basis** | **3 wks** | **R 72,000.00** |
| 33 | Prepare and submit Design Basis for Approval | 2 wks | R 72,000.00 |
| 34 | Design Basis review and approval by TNPA | 1 wk | R 0.00 |
| 35 | **Navigation Study** | **2 wks** | **R 30,000.00** |




Project: FEL3 Programme
Date: Thu 2/14/19

| | | | | |
|---|---|---|---|---|
| Task | Inactive Task | Manual Summary Rollup | External Milestone | Manual Progress |
| Split | Inactive Milestone | Manual Summary | Deadline | |
| Milestone | Inactive Summary | Start-only | Critical | |
| Summary | Manual Task | Finish-only | Critical Split | |
| Project Summary | Duration-only | External Tasks | Progress | |

| ID | Task Name | Duration | Cost |
|---|---|---|---|
| 36 | Navigation designs | 2 wks | R 30,000.00 |
| 37 | **Structural Design** | **9 wks** | **R 1,012,100.00** |
| 38 | Model setup (load cases, etc.) | 1 wk | R 65,000.00 |
| 39 | Review Site Investigation reports | 1 wk | R 71,700.00 |
| 40 | Stability Assessment | 3 wks | R 85,000.00 |
| 41 | Numerical modelling and Structural Designs | 4 wks | R 240,400.00 |
| 42 | Prepare Structural Drawings | 5 wks | R 550,000.00 |
| 43 | **Coastal Structures Design** | **10 wks** | **R 425,000.00** |
| 44 | Review Site Investigation reports | 1 wk | R 40,000.00 |
| 45 | Scour Protection designs | 3 wks | R 135,000.00 |
| 46 | Prepare Scour Protection drawings | 4 wks | R 250,000.00 |
| 47 | **Environmental Management** | **8 wks** | **R 100,000.00** |
| 48 | Identify Environmental Authorization requirements & Risks | 8 wks | R 100,000.00 |
| 49 | **Health & Safety Management** | **1 wk** | **R 70,000.00** |
| 50 | Safey in Design Review | 1 wk | R 70,000.00 |
| 51 | **Construction Management** | **2 wks** | **R 82,900.00** |
| 52 | Constructability Review & Schedule | 2 wks | R 82,900.00 |
| 53 | **Risk Management** | **2 wks** | **R 124,000.00** |
| 54 | Project Risk Analysis | 2 wks | R 124,000.00 |
| 55 | **Procurement Documentation** | **10 wks** | **R 643,000.00** |
| 56 | Obtain Transnet general specifications (H&S, etc.) | 2 wks | R 20,000.00 |
| 57 | Prepare Works information (Incl. Technical Specifications) | 4 wks | R 356,000.00 |
| 58 | Prepare Site Information | 2 wks | R 50,000.00 |
| 59 | Prepare Bill of Quantities & Pricing Assumptions | 3 wks | R 167,000.00 |
| 60 | Complie Tender documentation submission | 1 wk | R 50,000.00 |
| 61 | TNPA reivew and approval of tender documentation | 1 wk | R 0.00 |
| 62 | **Feasibility Report** | **17 wks** | **R 330,000.00** |
| 63 | Navigation inputs into FEL3 Study Report | 2 wks | R 10,000.00 |
| 64 | Structural inputs into FEL3 Study Report | 3 wks | R 90,000.00 |
| 65 | Coastal Structures inputs into FEL3 Study Report | 2 wks | R 70,000.00 |
| 66 | Risk Management inputs into FEL3 Study Report | 2 wks | R 40,000.00 |
| 67 | Procurement inputs into FEL3 Study Report | 2 wks | R 50,000.00 |
| 68 | Environmental subconsultant inputs into FEL3 Report | 2 wks | R 30,000.00 |

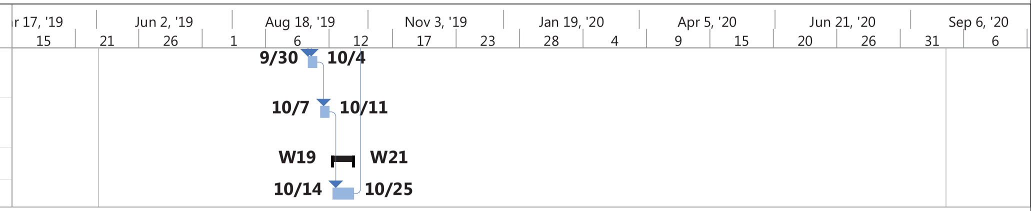

Project: FEL3 Programme
Date: Thu 2/14/19

Task | Inactive Task | Manual Summary Rollup | External Milestone | Manual Progress
Split | Inactive Milestone | Manual Summary | Deadline
Milestone | Inactive Summary | Start-only | Critical
Summary | Manual Task | Finish-only | Critical Split
Project Summary | Duration-only | External Tasks | Progress

PORT OF PORT ELIZABETH - OLD TUG JETTY SHEETPILE REFURBISHMENT



| ID | Task Name | Duration | Cost |
|---|---|---|---|
| 69 | Internal Review & Submission of Feasibility Study Report | 1 wk | R 40,000.00 |
| 70 | TNPA Review and approval of Feasibility Study Report | 1 wk | R 0.00 |
| 71 | **TNPA Approvals** | **2 wks** | **R 40,000.00** |
| 72 | FEL 3 Gate Review | 2 wks | R 40,000.00 |




Project: FEL3 Programme
Date: Thu 2/14/19

| | | | | |
|---|---|---|---|---|
| Task | Inactive Task | Manual Summary Rollup | External Milestone | Manual Progress |
| Split | Inactive Milestone | Manual Summary | Deadline | |
| Milestone | Inactive Summary | Start-only | Critical | |
| Summary | Manual Task | Finish-only | Critical Split | |
| Project Summary | Duration-only | External Tasks | Progress | |

**ANNEXURE F |** CALCULATION SHEETS

| | PORT OF PORT ELIZABETH OLD TUG JETTY SHEET PILE REFURBISHMENT (FEL 2 STUDY) | | |
|---|---|---|---|
| PRDW Consulting Port and Coastal Engineers | COUNTERFORT WALL | Rev | TRANSNET national ports authority |
| | GLOBAL STABILITY VERIFICATION | R1 | |

CALCULATION SHEET REGISTER

| |
|---|
| S2001-109-CS-GT-101 – OVERTURNING AND SLIDING ASSESSMENT (MAXIMUM WALL HEIGHT) |
| S2001-109-CS-GT-102 – OVERTURNING AND SLIDING ASSESSMENT (INTERMEDIATE WALL HEIGHT) |
| S2001-109-CS-GT-103 – BEARING ASSESSMENT |
| S2001-109-CS-GT-104 – SLIP ASSESSMENT |

REVIEW REGISTER

| **Author** | **Reviewed** | **Approved** |
|---|---|---|
| Yusuf Hargey | Philip E. Smith | Philip E. Smith |
| Signature: | Signature: PE Smith | Signature: PE Smith |

DOCUMENT CHANGE RECORD

| **Rev** | **Date** | **Description of Revision** | **Status** |
|---|---|---|---|
| 0 | 01/02/2019 | None | For approval |
| 1 | 14/02/2019 | Updated according to Client's comments | For approval |

TOTAL NUMBER OF PAGES INCLUDING APPENDICES: [240]

## 1. INTRODUCTION AND DESIGN PREMISE

This calculation note describes the global stability design verification checks undertaken for the counterfort wall. The design has been undertaken in accordance with the BS EN 1997-1:2004, Design Approach 1. The counterfort wall height varies from a berth depth of -5.2 m CD along the north western face sloping up and tying into the extents of the boat ramps as it approaches the shore. Therefore, the wall has been assessed at its maximum retained height and at an intermediate retained height.

The following design checks/modes of failure were assessed:

- Overturning
- Sliding
- Slip
- Bearing

This calculation note should be read in conjunction with the basis of design document (see Annexure A) and the FEL 2 study report.

## 2. TYPICAL MODELLED DESIGN SECTION

The counterfort wall has been modelled using Fine GEO 5© software and PRDW verified bearing assessment spreadsheets. The wall has been modelled as a precast block structure ignoring inter-block forces. Loading on the back of the wall has been determined using the virtual back theory as outlined in Craig's Soil Mechanics (7$^{th}$ edition). The virtual back of the counterfort wall corresponds with a theoretical vertical plane at its heel where, the soil material friction back of this plane is assumed to be ($\delta$ =) 0° and the soil mass in front of it is assumed to act as part of the wall.

The critical load combinations have been determined by applying the design loads with their respective partial and combination factors (refer to Section 4 and 5 of the FEL 2 study) in various realistic combinations at HAT and LAT that produce the largest design utilization ratio. In addition, a tidal lag of 0.5 m has been applied to the back of the wall in accordance with the recommendations of the Port Engineer Handbook (Portnet, 1994). An illustration of the maximum counterfort modelled height is presented in Figure 2-1 below. The figure illustrates design material properties and live loads (applied variable actions).

In addition, regarding the block densities illustrated in Figure 2-1;

- Block 1 density equal to the density of the reinforced concrete counterfort base
- Block 2 density accounts for the weight of the reinforced concrete counterfort buttress, wall and back fill material, block modelled as a rectangle rather than a trapezoid in accordance with the virtual back theory.
- Block 3 density accounts for the weight of the reinforced concrete cope panel and capping beam

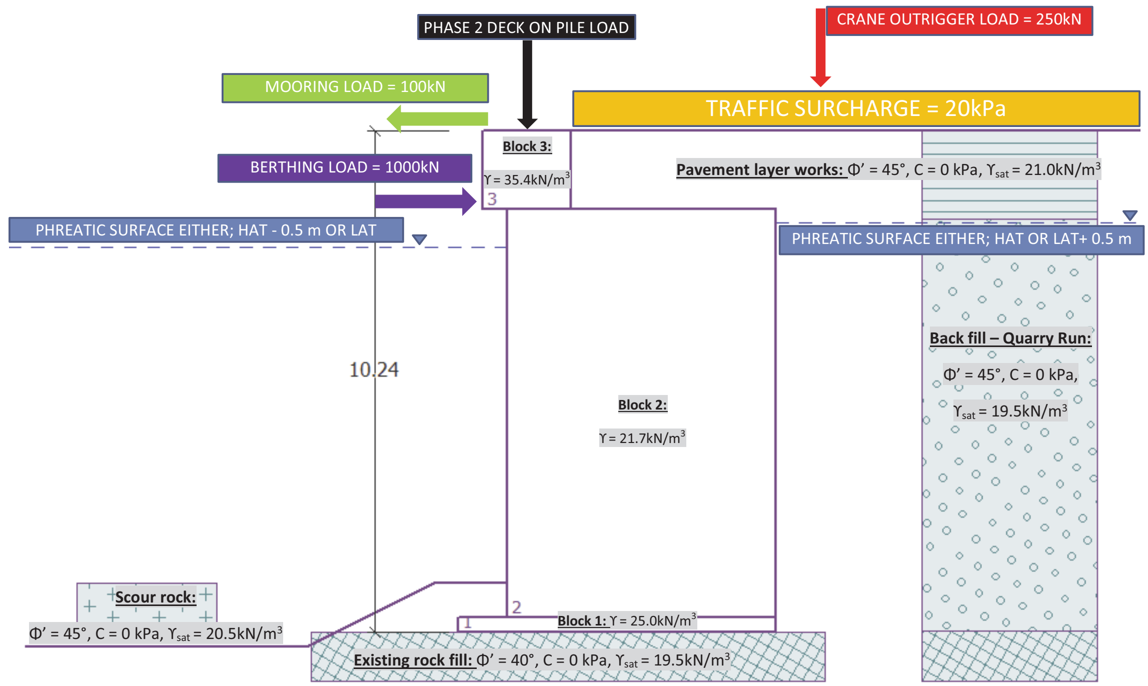



***Figure 2-1 GEO 5 model representation of counterfort wall***

## 3. CALCULATION DESCRIPTIONS

The following calculations sheets have been included:

- S2001-109-CS-GT-101 – OVERTURNING AND SLIDING ASSESSMENT (MAXIMUM WALL HEIGHT): this calculation presents the output sheets for sliding and overturning checks undertaken in GEO 5© for the maximum counterfort wall retained height for constructions phases 1 and 2. Results are provided for all the critical load combinations assumed.
- S2001-109-CS-GT-102 – OVERTURNING AND SLIDING ASSESSMENT (INTERMEDIATE WALL HEIGHT): this calculation presents the output sheets for sliding and overturning checks undertaken in GEO 5© for the intermediate counterfort wall retained height for construction phase 1. Results are provided for all the critical load combinations assumed.
- S2001-109-CS-GT-103 – BEARING ASSESSMENT: this calculation presents the output sheets for bearing checks undertaken using the verified PRDW in house developed spreadsheets for the maximum and intermediate counterfort wall retained height. Results are provided only for the critical load combinations.
- S2001-109-CS-GT-104 – SLIP ASSESSMENT: this calculation presents the output sheets for slip checks undertaken in GEO 5© for the maximum counterfort wall retained height for constructions phases 1 and 2. Results are provided only for the critical load combinations.

Refer to the FEL 2 Study report for a summary of the critical global stability results.

# Prefab wall analysis

## Input data

### Project

Task : Global Stability - Overturning and Sliding Verification
Part : Counterfort Wall
Description : Phase 2 Operational Load - Mooring and Traffic Surcharge
Customer : TNPA
Author : YH
Date : 1/23/2019
Project ID : Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment
Project number : S2001-109

### Settings

(input for current task)

### Materials and standards

Concrete structures : EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1 : standard

### Wall analysis

Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Coulomb
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Calculate as skew
Allowable eccentricity : 0.333
Verification methodology : according to EN 1997
Design approach : 1 - reduction of actions and soil parameters

| Partial factors on actions (A) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Permanent design situation | | | | | | | | | |
| | | Combination 1 | | | | Combination 2 | | | |
| | | Unfavourable | | Favourable | | Unfavourable | | Favourable | |
| Permanent actions : | $\gamma_G$ = | 1.35 | [–] | 1.00 | [–] | 1.00 | [–] | 1.00 | [–] |
| Variable actions : | $\gamma_Q$ = | 1.50 | [–] | 0.00 | [–] | 1.30 | [–] | 0.00 | [–] |
| Water load : | $\gamma_w$ = | 1.35 | [–] | | | 1.00 | [–] | | |

| Partial factors for soil parameters (M) | | | | | |
|---|---|---|---|---|---|
| Permanent design situation | | | | | |
| | | Combination 1 | | Combination 2 | |
| Partial factor on internal friction : | $\gamma_\phi$ = | 1.00 | [–] | 1.25 | [–] |
| Partial factor on effective cohesion : | $\gamma_c$ = | 1.00 | [–] | 1.25 | [–] |
| Partial factor on undrained shear strength : | $\gamma_{cu}$ = | 1.00 | [–] | 1.40 | [–] |
| Partial factor on Poisson's ratio : | $\gamma_v$ = | 1.00 | [–] | 1.00 | [–] |

| Partial factors for variable actions | | | |
|---|---|---|---|
| Permanent design situation | | | |
| Factor for combination value : | $\psi_0$ = | 0.70 | [–] |
| Factor for frequent value : | $\psi_1$ = | 0.50 | [–] |
| Factor for quasi-permanent value : | $\psi_2$ = | 0.30 | [–] |

### Geometry of structure

Slope of wall = 0.00 °

| No. | Width b [m] | Height h [m] | Offset k [m] | Offs.(L) $o_1$ [m] | Offs.(R) $o_2$ [m] | Self w. [kN/m$^3$] | Friction [–] | Cohesion [kPa] | Shear bear.cap. $R_s$ [kN/m] |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 1.80 | 1.60 | -0.50 | 0.00 | 0.00 | 35.40 | 1.000 | 0.00 | 0.00 |
| 2 | 5.50 | 8.34 | 1.00 | 0.00 | 0.00 | 21.70 | 1.000 | 1000.00 | 0.00 |
| 1 | 6.50 | 0.30 | 0.00 | 0.00 | 0.00 | 25.00 | - | - | - |

Note: Blocks are ordered from bottom to the top

## Basic soil parameters

| No. | Name | Pattern | $\varphi_{ef}$ [°] | $c_{ef}$ [kPa] | $\gamma$ [kN/m$^3$] | $\gamma_{su}$ [kN/m$^3$] | $\delta$ [°] |
|---|---|---|---|---|---|---|---|
| 1 | Backfill Quarry Run | | 45.00 | 0.00 | 18.50 | 9.50 | 0.00 |
| 2 | Existing Scour Rock (Quarry Run) | | 40.00 | 0.00 | 18.50 | 9.50 | 0.00 |
| 3 | Scour Rock | | 45.00 | 0.00 | 19.50 | 10.50 | 0.00 |
| 4 | Pavement Layers | | 45.00 | 0.00 | 20.00 | 11.00 | 0.00 |

All soils are considered as cohesionless for at rest pressure analysis.

## Soil parameters

**Backfill Quarry Run**

Unit weight : $\gamma$ = 18.50 kN/m$^3$
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 45.00 °
Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 19.50 kN/m$^3$

**Existing Scour Rock (Quarry Run)**

Unit weight : $\gamma$ = 18.50 kN/m$^3$
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 40.00 °
Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 19.50 kN/m$^3$

**Scour Rock**

Unit weight : $\gamma$ = 19.50 kN/m$^3$
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 45.00 °
Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 20.50 kN/m$^3$

**Pavement Layers**

Unit weight : $\gamma$ = 20.00 kN/m$^3$
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 45.00 °

Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 21.00 kN/m3

## Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 8.40 | Backfill Quarry Run | |
| 3 | 3.80 | Existing Scour Rock (Quarry Run) | |
| 4 | - | Existing Scour Rock (Quarry Run) | |

## Foundation

Type of foundation : strip foundation
Soil of foundation - Existing Scour Rock (Quarry Run)

**Geometry**

Foundation thickness $h$ = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

## Terrain profile

Terrain behind the structure is flat.

## Water influence

GWT behind the structure lies at a depth of 1.88 m
GWT in front of the structure lies at a depth of 2.38 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

## Input surface surcharges

| No. | Surcharge | | Action | Mag.1 | Mag.2 | Ord.x | Length | Depth |
|---|---|---|---|---|---|---|---|---|
| | new | change | | [kN/m2] | [kN/m2] | x [m] | l [m] | z [m] |
| 1 | Yes | | variable | 20.00 | | | | on terrain |
| 2 | Yes | | permanent | 7.50 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Traffic Surcharge |
| 2 | Pavement |

## Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour Rock
Angle of friction struc.-soil $\delta$ = 30.00 °
Soil thickness in front of structure $h$ = 1.00 m

## Terrain shape in front of structure

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | -1.00 |

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 3 | -1.50 | -1.00 |
| 4 | -4.10 | 0.30 |
| 5 | -5.10 | 0.30 |

Origin [0,0] is located in bottom left edge of construction.
Positive coordinate +z has downward direction.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Yes | | Mooring Load | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |
| 2 | Yes | | Deck on Pile Dead Load | permanent | 0.00 | 80.20 | 0.00 | -1.10 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 1)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

**Active pressure behind the structure - partial results**

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 0.08 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 7.56 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

**Active pressure distribution behind the structure (without surcharge)**

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 19.99 | 19.99 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 25.34 | 25.34 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 25.42 | 25.42 | 0.00 |

**Water pressure distribution**

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

**Pressure profile due to surcharge - Traffic Surcharge**

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 1.88 | 3.43 | 0.00 |
| 6 | 2.38 | 3.43 | 0.00 |
| 7 | 9.94 | 3.43 | 0.00 |
| 8 | 10.20 | 3.43 | 0.00 |
| 9 | 10.20 | 4.35 | 0.00 |
| 10 | 10.24 | 4.35 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 1.88 | 1.29 | 0.00 |
| 6 | 2.38 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 116.99 | -3.74 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 35.17 | -5.11 | 13.26 | 6.17 | 1.500 | 1.500 | 1.500 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.500 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 1.050 | 1.050 | 1.050 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.350 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3379.40 kNm/m
Overturning moment $M_{ovr}$ = 1416.19 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 780.65 kN/m
Active horizontal force $H_{act}$ = 246.65 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 250.92 kPa

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 0.08 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 7.56 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 26.92 | 26.92 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 33.12 | 33.12 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 33.23 | 33.23 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 1.88 | 4.62 | 0.00 |
| 6 | 2.38 | 4.62 | 0.00 |
| 7 | 9.94 | 4.62 | 0.00 |
| 8 | 10.20 | 4.62 | 0.00 |
| 9 | 10.20 | 5.68 | 0.00 |
| 10 | 10.24 | 5.68 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 5 | 1.88 | 1.73 | 0.00 |
| 6 | 2.38 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 157.44 | -3.74 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 47.31 | -5.11 | 13.35 | 6.17 | 1.300 | 1.300 | 1.300 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.300 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 0.910 | 0.910 | 0.910 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.000 |

### Verification of complete wall

**Check for overturning stability**
Resisting moment $M_{res}$ = 3338.45 kNm/m
Overturning moment $M_{ovr}$ = 1362.11 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**
Resisting horizontal force $H_{res}$ = 634.06 kN/m
Active horizontal force $H_{act}$ = 262.10 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 228.54 kPa

## Verification No. 2 (Stage of construction 1)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 0.08 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 7.56 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 5 | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 19.99 | 19.99 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 25.34 | 25.34 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 25.42 | 25.42 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 1.88 | 3.43 | 0.00 |
| 6 | 2.38 | 3.43 | 0.00 |
| 7 | 9.94 | 3.43 | 0.00 |
| 8 | 10.20 | 3.43 | 0.00 |
| 9 | 10.20 | 4.35 | 0.00 |
| 10 | 10.24 | 4.35 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 1.88 | 1.29 | 0.00 |
| 6 | 2.38 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

## Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 116.99 | -3.74 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 35.17 | -5.11 | 13.26 | 6.17 | 1.050 | 1.050 | 1.050 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.050 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 1.500 | 1.500 | 1.500 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.350 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3342.61 kNm/m
Overturning moment $M_{ovr}$ = 1405.74 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 775.65 kN/m
Active horizontal force $H_{act}$ = 237.70 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 247.60 kPa

## Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

## Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 0.08 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 7.56 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 26.92 | 26.92 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 33.12 | 33.12 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 33.23 | 33.23 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

## Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 1.88 | 4.62 | 0.00 |
| 6 | 2.38 | 4.62 | 0.00 |
| 7 | 9.94 | 4.62 | 0.00 |
| 8 | 10.20 | 4.62 | 0.00 |
| 9 | 10.20 | 5.68 | 0.00 |
| 10 | 10.24 | 5.68 | 0.00 |

## Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 1.88 | 1.73 | 0.00 |
| 6 | 2.38 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

## Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 157.44 | -3.74 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 47.31 | -5.11 | 13.35 | 6.17 | 0.910 | 0.910 | 0.910 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 0.910 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 1.300 | 1.300 | 1.300 |

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.000 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3306.35 kNm/m
Overturning moment $M_{ovr}$ = 1328.91 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 630.57 kN/m
Active horizontal force $H_{act}$ = 249.62 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 224.95 kPa

## Bearing capacity of foundation soil (Stage of construction 1)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 720.93 | 1366.15 | 186.89 | 0.081 | 250.92 |
| 2 | 1060.41 | 930.35 | 246.65 | 0.175 | 220.44 |
| 3 | 1093.47 | 944.56 | 262.10 | 0.178 | 225.72 |
| 4 | 1018.19 | 1036.52 | 262.10 | 0.151 | 228.54 |
| 5 | 753.94 | 1328.35 | 177.95 | 0.087 | 247.60 |
| 6 | 1067.37 | 924.38 | 237.70 | 0.178 | 220.58 |
| 7 | 1075.46 | 939.35 | 249.62 | 0.176 | 223.11 |
| 8 | 1022.76 | 1003.73 | 249.62 | 0.157 | 224.95 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 699.76 | 994.70 | 168.54 |
| 2 | 757.67 | 923.95 | 168.54 |
| 3 | 699.76 | 994.70 | 168.54 |
| 4 | 757.67 | 923.95 | 168.54 |

## Input data (Stage of construction 2)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 8.40 | Backfill Quarry Run | |
| 3 | 3.80 | Existing Scour Rock (Quarry Run) | |

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 4 | - | Existing Scour Rock (Quarry Run) | |

## Foundation

Type of foundation : strip foundation
Soil of foundation - Existing Scour Rock (Quarry Run)

**Geometry**

Foundation thickness $h = 1.00$ m
Offset left $b_l = 3.00$ m
Offset right $b_p = 1.00$ m

## Terrain profile

Terrain behind the structure is flat.

## Water influence

GWT behind the structure lies at a depth of 3.50 m
GWT in front of the structure lies at a depth of 4.00 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

## Input surface surcharges

| No. | Surcharge | | Action | Mag.1 | Mag.2 | Ord.x | Length | Depth |
|---|---|---|---|---|---|---|---|---|
| | new | change | | [kN/m²] | [kN/m²] | x [m] | l [m] | z [m] |
| 1 | No | No | variable | 20.00 | | | | on terrain |
| 2 | No | No | permanent | 7.50 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Traffic Surcharge |
| 2 | Pavement |

## Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour Rock
Angle of friction struc.-soil $\delta = 30.00$ °
Soil thickness in front of structure $h = 1.00$ m

## Terrain shape in front of structure

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | -1.00 |
| 3 | -1.50 | -1.00 |
| 4 | -4.10 | 0.30 |
| 5 | -5.10 | 0.30 |

Origin [0,0] is located in bottom left edge of construction.
Positive coordinate +z has downward direction.

## Applied forces acting on the structure

| No. | Force | | Name | Action | $F_x$ | $F_z$ | M | x | z |
|---|---|---|---|---|---|---|---|---|---|
| | new | edit | | | [kN/m] | [kN/m] | [kNm/m] | [m] | [m] |
| 1 | No | No | Mooring Load | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 2 | No | No | Deck on Pile Dead Load | permanent | 0.00 | 80.20 | 0.00 | -1.10 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 2)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $φ_d$ [°] | $c_d$ [kPa] | γ [kN/m$^3$] | $δ_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $σ_z$ [kPa] | $σ_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $φ_d$ [°] | $c_d$ [kPa] | γ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $σ_z$ [kPa] | $σ_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $φ_d$ [°] | $c_d$ [kPa] | γ [kN/m$^3$] | $δ_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 1.70 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 5.94 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

**Active pressure distribution behind the structure (without surcharge)**

| Layer No. | Start [m] / End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 22.49 | 22.49 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 28.51 | 28.51 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 28.59 | 28.59 | 0.00 |

**Water pressure distribution**

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

**Pressure profile due to surcharge - Traffic Surcharge**

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 3.50 | 3.43 | 0.00 |
| 6 | 4.00 | 3.43 | 0.00 |
| 7 | 9.94 | 3.43 | 0.00 |
| 8 | 10.20 | 3.43 | 0.00 |
| 9 | 10.20 | 4.35 | 0.00 |
| 10 | 10.24 | 4.35 | 0.00 |

## Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 3.50 | 1.29 | 0.00 |
| 6 | 4.00 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

## Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 135.91 | -3.75 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 35.17 | -5.11 | 13.26 | 6.17 | 1.500 | 1.500 | 1.500 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.500 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 1.050 | 1.050 | 1.050 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.350 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3713.53 kNm/m
Overturning moment $M_{ovr}$ = 1432.98 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 855.42 kN/m
Active horizontal force $H_{act}$ = 261.24 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 265.71 kPa

## Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 1.70 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 5.94 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 5 | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 30.28 | 30.28 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 37.26 | 37.26 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 37.37 | 37.37 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 3.50 | 4.62 | 0.00 |
| 6 | 4.00 | 4.62 | 0.00 |
| 7 | 9.94 | 4.62 | 0.00 |
| 8 | 10.20 | 4.62 | 0.00 |
| 9 | 10.20 | 5.68 | 0.00 |
| 10 | 10.24 | 5.68 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 3.50 | 1.73 | 0.00 |
| 6 | 4.00 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 182.90 | -3.75 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 47.31 | -5.11 | 13.35 | 6.17 | 1.300 | 1.300 | 1.300 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.300 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 0.910 | 0.910 | 0.910 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.000 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3672.58 kNm/m

Overturning moment $M_{ovr}$ = 1399.34 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 693.87 kN/m

Active horizontal force $H_{act}$ = 279.46 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 239.30 kPa

## Verification No. 2 (Stage of construction 2)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

## Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

## Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

## Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 1.70 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 5.94 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

## Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 22.49 | 22.49 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 28.51 | 28.51 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 28.59 | 28.59 | 0.00 |

## Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 3.50 | 3.43 | 0.00 |
| 6 | 4.00 | 3.43 | 0.00 |
| 7 | 9.94 | 3.43 | 0.00 |
| 8 | 10.20 | 3.43 | 0.00 |
| 9 | 10.20 | 4.35 | 0.00 |
| 10 | 10.24 | 4.35 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 3.50 | 1.29 | 0.00 |
| 6 | 4.00 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 135.91 | -3.75 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 35.17 | -5.11 | 13.26 | 6.17 | 1.050 | 1.050 | 1.050 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.050 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 1.500 | 1.500 | 1.500 |

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.350 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3676.73 kNm/m

Overturning moment $M_{ovr}$ = 1422.53 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 850.41 kN/m

Active horizontal force $H_{act}$ = 252.30 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 262.20 kPa

## Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

## Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

## Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

## Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

**Active pressure behind the structure - partial results**

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 1.70 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 5.94 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

**Active pressure distribution behind the structure (without surcharge)**

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 30.28 | 30.28 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 37.26 | 37.26 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 37.37 | 37.37 | 0.00 |

**Water pressure distribution**

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

**Pressure profile due to surcharge - Traffic Surcharge**

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 3.50 | 4.62 | 0.00 |
| 6 | 4.00 | 4.62 | 0.00 |
| 7 | 9.94 | 4.62 | 0.00 |
| 8 | 10.20 | 4.62 | 0.00 |
| 9 | 10.20 | 5.68 | 0.00 |
| 10 | 10.24 | 5.68 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 182.90 | -3.75 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 47.31 | -5.11 | 13.35 | 6.17 | 0.910 | 0.910 | 0.910 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 0.910 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 1.300 | 1.300 | 1.300 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.000 |

### Verification of complete wall

**Check for overturning stability**
Resisting moment $M_{res}$ = 3640.47 kNm/m
Overturning moment $M_{ovr}$ = 1366.14 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**
Resisting horizontal force $H_{res}$ = 690.38 kN/m
Active horizontal force $H_{act}$ = 266.98 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 235.44 kPa

## Bearing capacity of foundation soil (Stage of construction 2)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 673.23 | 1486.44 | 197.70 | 0.070 | 265.71 |
| 2 | 1032.66 | 1019.45 | 261.24 | 0.156 | 227.86 |
| 3 | 1086.15 | 1033.66 | 279.46 | 0.162 | 235.01 |
| 4 | 1010.87 | 1125.62 | 279.46 | 0.138 | 239.30 |
| 5 | 706.24 | 1448.64 | 188.76 | 0.075 | 262.20 |

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 6 | 1039.61 | 1013.48 | 252.30 | 0.158 | 227.83 |
| 7 | 1068.14 | 1028.45 | 266.98 | 0.160 | 232.53 |
| 8 | 1015.44 | 1092.83 | 266.98 | 0.143 | 235.44 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 667.65 | 1083.80 | 179.35 |
| 2 | 725.56 | 1013.05 | 179.35 |
| 3 | 667.65 | 1083.80 | 179.35 |
| 4 | 725.56 | 1013.05 | 179.35 |

## Input data (Stage of construction 3)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 8.40 | Backfill Quarry Run | |
| 3 | 3.80 | Existing Scour Rock (Quarry Run) | |
| 4 | - | Existing Scour Rock (Quarry Run) | |

### Foundation

Type of foundation : strip foundation
Soil of foundation - Existing Scour Rock (Quarry Run)

**Geometry**

Foundation thickness $h = 1.00$ m
Offset left $b_l = 3.00$ m
Offset right $b_p = 1.00$ m

### Terrain profile

Terrain behind the structure is flat.

### Water influence

GWT behind the structure lies at a depth of 1.88 m
GWT in front of the structure lies at a depth of 2.38 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

### Input surface surcharges

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m$^2$] | Mag.2 [kN/m$^2$] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 1 | No | No | permanent | 7.50 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Pavement |

### Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest

Soil on front face of the structure - Scour Rock
Angle of friction struc.-soil $\delta$ = 30.00 °
Soil thickness in front of structure h = 1.00 m

### Terrain shape in front of structure

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | -1.00 |
| 3 | -1.50 | -1.00 |
| 4 | -4.10 | 0.30 |
| 5 | -5.10 | 0.30 |

Origin [0,0] is located in bottom left edge of construction.
Positive coordinate +z has downward direction.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | No | No | Mooring Load | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |
| 2 | No | No | Deck on Pile Dead Load | permanent | 0.00 | 80.20 | 0.00 | -1.10 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 3)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 0.08 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 7.56 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 19.99 | 19.99 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 25.34 | 25.34 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 25.42 | 25.42 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 1.88 | 1.29 | 0.00 |
| 6 | 2.38 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 116.99 | -3.74 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 1.500 | 1.500 | 1.500 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.350 |

### Verification of complete wall

**Check for overturning stability**
Resisting moment $M_{res}$ = 3256.75 kNm/m
Overturning moment $M_{ovr}$ = 1216.84 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**
Resisting horizontal force $H_{res}$ = 763.97 kN/m
Active horizontal force $H_{act}$ = 200.77 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 228.59 kPa

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 0.08 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 7.56 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 5 | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 26.92 | 26.92 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 33.12 | 33.12 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 33.23 | 33.23 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 1.88 | 1.73 | 0.00 |
| 6 | 2.38 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 157.44 | -3.74 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 1.300 | 1.300 | 1.300 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.000 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3231.43 kNm/m
Overturning moment $M_{ovr}$ = 1108.86 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**
Resisting horizontal force $H_{res}$ = 622.42 kN/m
Active horizontal force $H_{act}$ = 206.57 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 202.52 kPa

## Bearing capacity of foundation soil (Stage of construction 3)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 666.47 | 1240.16 | 141.01 | 0.083 | 228.59 |
| 2 | 919.09 | 910.46 | 200.77 | 0.155 | 203.18 |
| 3 | 890.85 | 927.21 | 206.57 | 0.148 | 202.52 |
| 4 | 890.85 | 927.21 | 206.57 | 0.148 | 202.52 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 616.46 | 910.70 | 133.36 |

## Input data (Stage of construction 4)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 8.40 | Backfill Quarry Run | |
| 3 | 3.80 | Existing Scour Rock (Quarry Run) | |
| 4 | - | Existing Scour Rock (Quarry Run) | |

### Foundation

Type of foundation : strip foundation
Soil of foundation - Existing Scour Rock (Quarry Run)

**Geometry**
Foundation thickness $h$ = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

### Terrain profile

Terrain behind the structure is flat.

### Water influence

GWT behind the structure lies at a depth of 3.50 m

GWT in front of the structure lies at a depth of 4.00 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

### Input surface surcharges

| No. | Surcharge | | Action | Mag.1 [kN/m$^2$] | Mag.2 [kN/m$^2$] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| | new | change | | | | | | |
| 1 | No | No | permanent | 7.50 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Pavement |

### Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour Rock
Angle of friction struc.-soil $\delta$ = 30.00 °
Soil thickness in front of structure h = 1.00 m

### Terrain shape in front of structure

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | -1.00 |
| 3 | -1.50 | -1.00 |
| 4 | -4.10 | 0.30 |
| 5 | -5.10 | 0.30 |

Origin [0,0] is located in bottom left edge of construction.
Positive coordinate +z has downward direction.

### Applied forces acting on the structure

| No. | Force | | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| | new | edit | | | | | | | |
| 1 | No | No | Mooring Load | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |
| 2 | No | No | Deck on Pile Dead Load | permanent | 0.00 | 80.20 | 0.00 | -1.10 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 4)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

**Pressure at rest on front face of the structure - partial results**

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

**Pressure at rest distribution on front face of the structure**

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

**Active pressure behind the structure - partial results**

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 1.70 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 5.94 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

**Active pressure distribution behind the structure (without surcharge)**

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 22.49 | 22.49 | 0.00 |

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 7 | 10.20 | 131.10 | 5.00 | 28.51 | 28.51 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 28.59 | 28.59 | 0.00 |

## Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

## Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 3.50 | 1.29 | 0.00 |
| 6 | 4.00 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

## Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 135.91 | -3.75 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 1.500 | 1.500 | 1.500 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.350 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3590.88 kNm/m
Overturning moment $M_{ovr}$ = 1233.63 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 838.73 kN/m
Active horizontal force $H_{act}$ = 215.37 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 243.36 kPa

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 1.70 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 5.94 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 30.28 | 30.28 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 37.26 | 37.26 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 37.37 | 37.37 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 3.50 | 1.73 | 0.00 |
| 6 | 4.00 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 182.90 | -3.75 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -10.24 | 0.00 | 0.50 | 1.300 | 1.300 | 1.300 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.000 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3565.56 kNm/m
Overturning moment $M_{ovr}$ = 1146.09 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 682.23 kN/m
Active horizontal force $H_{act}$ = 223.93 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 213.45 kPa

## Bearing capacity of foundation soil (Stage of construction 4)

**Design load acting at the center of footing bottom**

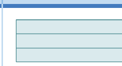
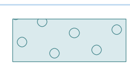
| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 618.77 | 1360.44 | 151.83 | 0.070 | 243.36 |
| 2 | 891.34 | 999.56 | 215.37 | 0.137 | 211.93 |
| 3 | 883.54 | 1016.31 | 223.93 | 0.134 | 213.45 |
| 4 | 883.54 | 1016.31 | 223.93 | 0.134 | 213.45 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 584.35 | 999.80 | 144.18 |

## Input data (Stage of construction 5)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers |  |
| 2 | 8.40 | Backfill Quarry Run |  |

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 3 | 3.80 | Existing Scour Rock (Quarry Run) | |
| 4 | - | Existing Scour Rock (Quarry Run) | |

## Foundation

Type of foundation : strip foundation
Soil of foundation - Existing Scour Rock (Quarry Run)

**Geometry**

Foundation thickness $h$ = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

## Terrain profile

Terrain behind the structure is flat.

## Water influence

GWT behind the structure lies at a depth of 1.88 m
GWT in front of the structure lies at a depth of 2.38 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

## Input surface surcharges

| No. | Surcharge | | Action | Mag.1 [kN/m2] | Mag.2 [kN/m2] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| | new | change | | | | | | |
| 1 | No | No | permanent | 7.50 | | | | on terrain |
| 2 | Yes | | variable | 20.00 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Pavement |
| 2 | Traffic |

## Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour Rock
Angle of friction struc.-soil $\delta$ = 30.00 °
Soil thickness in front of structure h = 1.00 m

## Terrain shape in front of structure

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | -1.00 |
| 3 | -1.50 | -1.00 |
| 4 | -4.10 | 0.30 |
| 5 | -5.10 | 0.30 |

Origin [0,0] is located in bottom left edge of construction.
Positive coordinate +z has downward direction.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | No | No | Deck on Pile Dead Load | permanent | 0.00 | 80.20 | 0.00 | -1.10 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 5)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 0.08 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 5 | 7.56 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

**Active pressure distribution behind the structure (without surcharge)**

| Layer No. | Start [m] / End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 19.99 | 19.99 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 25.34 | 25.34 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 25.42 | 25.42 | 0.00 |

**Water pressure distribution**

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

**Pressure profile due to surcharge - Pavement**

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 1.88 | 1.29 | 0.00 |
| 6 | 2.38 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

## Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 116.99 | -3.74 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Traffic | 35.17 | -5.11 | 13.26 | 6.17 | 1.500 | 1.500 | 1.500 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.500 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.350 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3379.40 kNm/m
Overturning moment $M_{ovr}$ = 1251.68 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 780.65 kN/m
Active horizontal force $H_{act}$ = 230.58 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 240.29 kPa

## Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

## Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

## Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 0.08 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 7.56 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 26.92 | 26.92 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 33.12 | 33.12 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 33.23 | 33.23 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 1.88 | 1.73 | 0.00 |
| 6 | 2.38 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 1.88 | 4.62 | 0.00 |
| 6 | 2.38 | 4.62 | 0.00 |
| 7 | 9.94 | 4.62 | 0.00 |
| 8 | 10.20 | 4.62 | 0.00 |
| 9 | 10.20 | 5.68 | 0.00 |
| 10 | 10.24 | 5.68 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 157.44 | -3.74 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Traffic | 47.31 | -5.11 | 13.35 | 6.17 | 1.300 | 1.300 | 1.300 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.300 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.000 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3338.45 kNm/m
Overturning moment $M_{ovr}$ = 1219.54 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 634.06 kN/m
Active horizontal force $H_{act}$ = 248.18 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 215.47 kPa

## Bearing capacity of foundation soil (Stage of construction 5)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 556.42 | 1366.15 | 170.82 | 0.063 | 240.29 |
| 2 | 895.91 | 930.35 | 230.58 | 0.148 | 203.40 |
| 3 | 950.90 | 944.56 | 248.18 | 0.155 | 210.53 |
| 4 | 875.61 | 1036.52 | 248.18 | 0.130 | 215.47 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 543.09 | 994.70 | 153.24 |
| 2 | 601.00 | 923.95 | 153.24 |

## Input data (Stage of construction 6)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 8.40 | Backfill Quarry Run | |
| 3 | 3.80 | Existing Scour Rock (Quarry Run) | |
| 4 | - | Existing Scour Rock (Quarry Run) | |

### Foundation

Type of foundation : strip foundation
Soil of foundation - Existing Scour Rock (Quarry Run)

**Geometry**

Foundation thickness $h$ = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

### Terrain profile

Terrain behind the structure is flat.

### Water influence

GWT behind the structure lies at a depth of 3.50 m
GWT in front of the structure lies at a depth of 4.00 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

### Input surface surcharges

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m$^2$] | Mag.2 [kN/m$^2$] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 1 | No | No | permanent | 7.50 | | | | on terrain |
| 2 | No | No | variable | 20.00 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Pavement |
| 2 | Traffic |

### Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour Rock
Angle of friction struc.-soil $\delta$ = 30.00 °
Soil thickness in front of structure h = 1.00 m

### Terrain shape in front of structure

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | -1.00 |
| 3 | -1.50 | -1.00 |
| 4 | -4.10 | 0.30 |
| 5 | -5.10 | 0.30 |

Origin [0,0] is located in bottom left edge of construction.
Positive coordinate +z has downward direction.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | No | No | Deck on Pile Dead Load | permanent | 0.00 | 80.20 | 0.00 | -1.10 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 6)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 1.70 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 5.94 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 5 | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 22.49 | 22.49 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 28.51 | 28.51 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 28.59 | 28.59 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 3.50 | 1.29 | 0.00 |
| 6 | 4.00 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 3.50 | 3.43 | 0.00 |
| 6 | 4.00 | 3.43 | 0.00 |
| 7 | 9.94 | 3.43 | 0.00 |
| 8 | 10.20 | 3.43 | 0.00 |
| 9 | 10.20 | 4.35 | 0.00 |
| 10 | 10.24 | 4.35 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 135.91 | -3.75 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Traffic | 35.17 | -5.11 | 13.26 | 6.17 | 1.500 | 1.500 | 1.500 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.500 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.350 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3713.53 kNm/m
Overturning moment $M_{ovr}$ = 1268.48 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 855.42 kN/m
Active horizontal force $H_{act}$ = 245.18 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 255.60 kPa

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 1.70 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 5.94 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 30.28 | 30.28 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 37.26 | 37.26 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 37.37 | 37.37 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 3.50 | 1.73 | 0.00 |
| 6 | 4.00 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 3.50 | 4.62 | 0.00 |
| 6 | 4.00 | 4.62 | 0.00 |
| 7 | 9.94 | 4.62 | 0.00 |
| 8 | 10.20 | 4.62 | 0.00 |
| 9 | 10.20 | 5.68 | 0.00 |
| 10 | 10.24 | 5.68 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 182.90 | -3.75 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Traffic | 47.31 | -5.11 | 13.35 | 6.17 | 1.300 | 1.300 | 1.300 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.300 |
| Deck on Pile Dead Load | 0.00 | -10.24 | 80.20 | 1.20 | 1.000 | 1.000 | 1.000 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3672.58 kNm/m
Overturning moment $M_{ovr}$ = 1256.77 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 693.87 kN/m
Active horizontal force $H_{act}$ = 265.54 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 227.07 kPa

## Bearing capacity of foundation soil (Stage of construction 6)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 508.72 | 1486.44 | 181.64 | 0.053 | 255.60 |
| 2 | 868.15 | 1019.45 | 245.18 | 0.131 | 212.53 |
| 3 | 943.58 | 1033.66 | 265.54 | 0.140 | 221.14 |
| 4 | 868.29 | 1125.62 | 265.54 | 0.119 | 227.07 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 510.98 | 1083.80 | 164.05 |
| 2 | 568.89 | 1013.05 | 164.05 |

# Prefab wall analysis

## Input data

### Project

Task : Global Stability - Overturning and Sliding Verification
Part : Counterfort Wall
Description : Phase 1 - Mooring and Traffic Surcharge
Customer : TNPA
Author : YH
Date : 1/23/2019
Project ID : Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment
Project number : S2001-109

### Settings

(input for current task)

### Materials and standards

Concrete structures : EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1 : standard

### Wall analysis

Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Coulomb
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Calculate as skew
Allowable eccentricity : 0.333
Verification methodology : according to EN 1997
Design approach : 1 - reduction of actions and soil parameters

**Partial factors on actions (A)**
**Permanent design situation**

| | | Combination 1 | | | | Combination 2 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Unfavourable | | Favourable | | Unfavourable | | Favourable | |
| Permanent actions : | $\gamma_G$ = | 1.35 | [–] | 1.00 | [–] | 1.00 | [–] | 1.00 | [–] |
| Variable actions : | $\gamma_Q$ = | 1.50 | [–] | 0.00 | [–] | 1.30 | [–] | 0.00 | [–] |
| Water load : | $\gamma_w$ = | 1.35 | [–] | | | 1.00 | [–] | | |

**Partial factors for soil parameters (M)**
**Permanent design situation**

| | | Combination 1 | | Combination 2 | |
|---|---|---|---|---|---|
| Partial factor on internal friction : | $\gamma_\phi$ = | 1.00 | [–] | 1.25 | [–] |
| Partial factor on effective cohesion : | $\gamma_c$ = | 1.00 | [–] | 1.25 | [–] |
| Partial factor on undrained shear strength : | $\gamma_{cu}$ = | 1.00 | [–] | 1.40 | [–] |
| Partial factor on Poisson's ratio : | $\gamma_v$ = | 1.00 | [–] | 1.00 | [–] |

**Partial factors for variable actions**
**Permanent design situation**

| | | | |
|---|---|---|---|
| Factor for combination value : | $\psi_0$ = | 0.70 | [–] |
| Factor for frequent value : | $\psi_1$ = | 0.50 | [–] |
| Factor for quasi-permanent value : | $\psi_2$ = | 0.30 | [–] |

### Geometry of structure

Slope of wall = 0.00 °

| No. | Width b [m] | Height h [m] | Offset k [m] | Offs.(L) $o_1$ [m] | Offs.(R) $o_2$ [m] | Self w. [kN/m³] | Friction [–] | Cohesion [kPa] | Shear bear.cap. $R_s$ [kN/m] |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 1.80 | 1.60 | -0.50 | 0.00 | 0.00 | 35.40 | 1.000 | 0.00 | 0.00 |
| 2 | 5.50 | 8.34 | 1.00 | 0.00 | 0.00 | 21.70 | 1.000 | 1000.00 | 0.00 |
| 1 | 6.50 | 0.30 | 0.00 | 0.00 | 0.00 | 25.00 | - | - | - |

Note: Blocks are ordered from bottom to the top

## Basic soil parameters

| No. | Name | Pattern | $\varphi_{ef}$ [°] | $c_{ef}$ [kPa] | $\gamma$ [kN/m³] | $\gamma_{su}$ [kN/m³] | $\delta$ [°] |
|---|---|---|---|---|---|---|---|
| 1 | Backfill Quarry Run | | 45.00 | 0.00 | 18.50 | 9.50 | 0.00 |
| 2 | Existing Scour Rock (Quarry Run) | | 40.00 | 0.00 | 18.50 | 9.50 | 0.00 |
| 3 | Scour Rock | | 45.00 | 0.00 | 19.50 | 10.50 | 0.00 |
| 4 | Pavement Layers | | 45.00 | 0.00 | 20.00 | 11.00 | 0.00 |

All soils are considered as cohesionless for at rest pressure analysis.

## Soil parameters

**Backfill Quarry Run**
Unit weight : $\gamma$ = 18.50 kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 45.00 °
Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 19.50 kN/m³

**Existing Scour Rock (Quarry Run)**
Unit weight : $\gamma$ = 18.50 kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 40.00 °
Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 19.50 kN/m³

**Scour Rock**
Unit weight : $\gamma$ = 19.50 kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 45.00 °
Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 20.50 kN/m³

**Pavement Layers**
Unit weight : $\gamma$ = 20.00 kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 45.00 °

Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 21.00 kN/m$^3$

## Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 8.40 | Backfill Quarry Run | |
| 3 | 3.80 | Existing Scour Rock (Quarry Run) | |
| 4 | - | Existing Scour Rock (Quarry Run) | |

## Foundation

Type of foundation : strip foundation
Soil of foundation - Existing Scour Rock (Quarry Run)

**Geometry**

Foundation thickness h = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

## Terrain profile

Terrain behind the structure is flat.

## Water influence

GWT behind the structure lies at a depth of 1.88 m
GWT in front of the structure lies at a depth of 2.38 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

## Input surface surcharges

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m$^2$] | Mag.2 [kN/m$^2$] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 1 | Yes | | variable | 20.00 | | | | on terrain |
| 2 | Yes | | permanent | 7.50 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Traffic Surcharge |
| 2 | Pavement |

## Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour Rock
Angle of friction struc.-soil $\delta$ = 30.00 °
Soil thickness in front of structure h = 1.00 m

## Terrain shape in front of structure

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | -1.00 |

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 3 | -1.50 | -1.00 |
| 4 | -4.10 | 0.30 |
| 5 | -5.10 | 0.30 |

Origin [0,0] is located in bottom left edge of construction.
Positive coordinate +z has downward direction.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Yes | | Mooring Load | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |
| 2 | Yes | | Deck on Pile Dead Load | permanent | 0.00 | 80.20 | 0.00 | -1.10 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Input data (Stage of construction 7)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 8.40 | Backfill Quarry Run | |
| 3 | 3.80 | Existing Scour Rock (Quarry Run) | |
| 4 | - | Existing Scour Rock (Quarry Run) | |

### Foundation

Type of foundation : strip foundation
Soil of foundation - Existing Scour Rock (Quarry Run)

**Geometry**

Foundation thickness h = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

### Terrain profile

Terrain behind the structure is flat.

### Water influence

GWT behind the structure lies at a depth of 1.88 m
GWT in front of the structure lies at a depth of 2.38 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

### Input surface surcharges

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m$^2$] | Mag.2 [kN/m$^2$] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 1 | No | No | permanent | 7.50 | | | | on terrain |

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m²] | Mag.2 [kN/m²] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 2 | No | No | variable | 20.00 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Pavement |
| 2 | Traffic |

### Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour Rock
Angle of friction struc.-soil $\delta$ = 30.00 °
Soil thickness in front of structure h = 1.00 m

### Terrain shape in front of structure

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | -1.00 |
| 3 | -1.50 | -1.00 |
| 4 | -4.10 | 0.30 |
| 5 | -5.10 | 0.30 |

Origin [0,0] is located in bottom left edge of construction.
Positive coordinate +z has downward direction.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Yes | | Mooring 2 | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 7)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 0.08 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 7.56 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 19.99 | 19.99 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 25.34 | 25.34 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 25.42 | 25.42 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 1.88 | 1.29 | 0.00 |
| 6 | 2.38 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 1.88 | 3.43 | 0.00 |
| 6 | 2.38 | 3.43 | 0.00 |
| 7 | 9.94 | 3.43 | 0.00 |
| 8 | 10.20 | 3.43 | 0.00 |
| 9 | 10.20 | 4.35 | 0.00 |
| 10 | 10.24 | 4.35 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 116.99 | -3.74 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Traffic | 35.17 | -5.11 | 13.26 | 6.17 | 1.500 | 1.500 | 1.500 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.500 |

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Mooring 2 | 15.30 | -10.24 | 0.00 | 0.50 | 1.050 | 1.050 | 1.050 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3283.16 kNm/m
Overturning moment $M_{ovr}$ = 1416.19 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 713.36 kN/m
Active horizontal force $H_{act}$ = 246.65 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 220.42 kPa

## Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

## Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

## Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

## Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 0.08 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 7.56 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 26.92 | 26.92 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 33.12 | 33.12 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 33.23 | 33.23 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 1.88 | 1.73 | 0.00 |
| 6 | 2.38 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 1.88 | 4.62 | 0.00 |
| 6 | 2.38 | 4.62 | 0.00 |
| 7 | 9.94 | 4.62 | 0.00 |
| 8 | 10.20 | 4.62 | 0.00 |
| 9 | 10.20 | 5.68 | 0.00 |
| 10 | 10.24 | 5.68 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 157.44 | -3.74 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Traffic | 47.31 | -5.11 | 13.35 | 6.17 | 1.300 | 1.300 | 1.300 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.300 |
| Mooring 2 | 15.30 | -10.24 | 0.00 | 0.50 | 0.910 | 0.910 | 0.910 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3242.21 kNm/m
Overturning moment $M_{ovr}$ = 1362.11 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 580.23 kN/m
Active horizontal force $H_{act}$ = 262.10 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 202.85 kPa

## Verification No. 2 (Stage of construction 7)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $φ_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $δ_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $σ_z$ [kPa] | $σ_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $φ_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $σ_z$ [kPa] | $σ_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $φ_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $δ_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 0.08 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 7.56 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 19.57 | 19.57 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 19.99 | 19.99 | 0.00 |
| 7 | 10.20 | 116.52 | 5.00 | 25.34 | 25.34 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 25.42 | 25.42 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 1.88 | 1.29 | 0.00 |
| 6 | 2.38 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 5 | 1.88 | 3.43 | 0.00 |
| 6 | 2.38 | 3.43 | 0.00 |
| 7 | 9.94 | 3.43 | 0.00 |
| 8 | 10.20 | 3.43 | 0.00 |
| 9 | 10.20 | 4.35 | 0.00 |
| 10 | 10.24 | 4.35 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 116.99 | -3.74 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Traffic | 35.17 | -5.11 | 13.26 | 6.17 | 1.050 | 1.050 | 1.050 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.050 |
| Mooring 2 | 15.30 | -10.24 | 0.00 | 0.50 | 1.500 | 1.500 | 1.500 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3246.37 kNm/m
Overturning moment $M_{ovr}$ = 1405.74 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 708.35 kN/m
Active horizontal force $H_{act}$ = 237.70 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 216.79 kPa

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

## Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

## Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

## Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 0.08 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 7.56 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

## Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| 6 | 9.94 | 114.05 | 5.00 | 26.35 | 26.35 | 0.00 |
| | 10.20 | 116.52 | 5.00 | 26.92 | 26.92 | 0.00 |

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 7 | 10.20 | 116.52 | 5.00 | 33.12 | 33.12 | 0.00 |
| | 10.24 | 116.90 | 5.00 | 33.23 | 33.23 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 1.88 | 1.73 | 0.00 |
| 6 | 2.38 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 1.88 | 4.62 | 0.00 |
| 6 | 2.38 | 4.62 | 0.00 |
| 7 | 9.94 | 4.62 | 0.00 |
| 8 | 10.20 | 4.62 | 0.00 |
| 9 | 10.20 | 5.68 | 0.00 |
| 10 | 10.24 | 5.68 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.23 | 710.78 | 3.39 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Active pressure | 157.44 | -3.74 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 40.55 | -4.06 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Traffic | 47.31 | -5.11 | 13.35 | 6.17 | 0.910 | 0.910 | 0.910 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 0.910 |
| Mooring 2 | 15.30 | -10.24 | 0.00 | 0.50 | 1.300 | 1.300 | 1.300 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3210.11 kNm/m
Overturning moment $M_{ovr}$ = 1328.91 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 576.73 kN/m
Active horizontal force $H_{act}$ = 249.62 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 198.99 kPa

## Bearing capacity of foundation soil (Stage of construction 7)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 498.97 | 1257.88 | 186.89 | 0.061 | 220.42 |
| 2 | 896.00 | 850.15 | 246.65 | 0.162 | 193.56 |
| 3 | 929.06 | 864.36 | 262.10 | 0.165 | 198.69 |
| 4 | 853.78 | 956.32 | 262.10 | 0.137 | 202.85 |
| 5 | 531.99 | 1220.08 | 177.95 | 0.067 | 216.79 |
| 6 | 902.96 | 844.18 | 237.70 | 0.165 | 193.59 |
| 7 | 911.05 | 859.15 | 249.62 | 0.163 | 196.19 |
| 8 | 858.35 | 923.53 | 249.62 | 0.143 | 198.99 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 535.35 | 914.50 | 168.54 |
| 2 | 593.26 | 843.75 | 168.54 |
| 3 | 535.35 | 914.50 | 168.54 |
| 4 | 593.26 | 843.75 | 168.54 |

# Input data (Stage of construction 8)

## Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 8.40 | Backfill Quarry Run | |
| 3 | 3.80 | Existing Scour Rock (Quarry Run) | |
| 4 | - | Existing Scour Rock (Quarry Run) | |

## Foundation

Type of foundation : strip foundation
Soil of foundation - Existing Scour Rock (Quarry Run)

**Geometry**

Foundation thickness $h$ = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

## Terrain profile

Terrain behind the structure is flat.

## Water influence

GWT behind the structure lies at a depth of 3.50 m
GWT in front of the structure lies at a depth of 4.00 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

## Input surface surcharges

| No. | Surcharge | | Action | Mag.1 | Mag.2 | Ord.x | Length | Depth |
|---|---|---|---|---|---|---|---|---|
| | new | change | | [kN/m2] | [kN/m2] | x [m] | l [m] | z [m] |
| 1 | No | No | permanent | 7.50 | | | | on terrain |
| 2 | No | No | variable | 20.00 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Pavement |
| 2 | Traffic |

## Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour Rock
Angle of friction struc.-soil $\delta$ = 30.00 °
Soil thickness in front of structure $h$ = 1.00 m

## Terrain shape in front of structure

| No. | Coordinate x[m] | Depth z[m] |
|---|---|---|
| 1 | 0.00 | 0.00 |
| 2 | 0.00 | -1.00 |
| 3 | -1.50 | -1.00 |
| 4 | -4.10 | 0.30 |
| 5 | -5.10 | 0.30 |

Origin [0,0] is located in bottom left edge of construction.
Positive coordinate +z has downward direction.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | No | No | Mooring 2 | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 8)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 3 | 1.70 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 5.94 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 22.49 | 22.49 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 28.51 | 28.51 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 28.59 | 28.59 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 3.50 | 1.29 | 0.00 |
| 6 | 4.00 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 10 | 10.24 | 1.63 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 3.50 | 3.43 | 0.00 |
| 6 | 4.00 | 3.43 | 0.00 |
| 7 | 9.94 | 3.43 | 0.00 |
| 8 | 10.20 | 3.43 | 0.00 |
| 9 | 10.20 | 4.35 | 0.00 |
| 10 | 10.24 | 4.35 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 135.91 | -3.75 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Traffic | 35.17 | -5.11 | 13.26 | 6.17 | 1.500 | 1.500 | 1.500 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.500 |
| Mooring 2 | 15.30 | -10.24 | 0.00 | 0.50 | 1.050 | 1.050 | 1.050 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3617.29 kNm/m

Overturning moment $M_{ovr}$ = 1432.98 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 788.12 kN/m

Active horizontal force $H_{act}$ = 261.24 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 235.78 kPa

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

## Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

## Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

## Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

## Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 1.70 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 5.94 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

## Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 30.28 | 30.28 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 37.26 | 37.26 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 37.37 | 37.37 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 3.50 | 1.73 | 0.00 |
| 6 | 4.00 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 3.50 | 4.62 | 0.00 |
| 6 | 4.00 | 4.62 | 0.00 |
| 7 | 9.94 | 4.62 | 0.00 |
| 8 | 10.20 | 4.62 | 0.00 |
| 9 | 10.20 | 5.68 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 10 | 10.24 | 5.68 | 0.00 |

**Forces acting on construction - combination 2**

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 182.90 | -3.75 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Traffic | 47.31 | -5.11 | 13.35 | 6.17 | 1.300 | 1.300 | 1.300 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.300 |
| Mooring 2 | 15.30 | -10.24 | 0.00 | 0.50 | 0.910 | 0.910 | 0.910 |

**Verification of complete wall**

**Check for overturning stability**

Resisting moment $M_{res}$ = 3576.34 kNm/m

Overturning moment $M_{ovr}$ = 1399.34 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 640.04 kN/m

Active horizontal force $H_{act}$ = 279.46 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 214.20 kPa

## Verification No. 2 (Stage of construction 8)

**Passive pressure on front face of the structure - partial results**

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |
| 2 | 0.00 | 89.92(30.00) | 45.00 | 0.00 | 10.50 | -30.00 | 5.495 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -30.00 | 22.869 | |

**Passive pressure distribution on front face of the structure**

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 168.09 | 145.57 | -84.04 |
| 2 | 0.70 | 7.35 | 0.00 | 40.39 | 20.24 | 34.95 |
| | 0.70 | 7.36 | 0.00 | 40.47 | 20.28 | 35.02 |
| 3 | 0.70 | 7.36 | 0.00 | 168.41 | 145.85 | -84.21 |
| | 1.00 | 10.50 | 0.00 | 240.13 | 207.96 | -120.06 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.92(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 1.70 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 5.94 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.26 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.04 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 22.07 | 22.07 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 22.49 | 22.49 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 28.51 | 28.51 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 28.59 | 28.59 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 3.50 | 1.29 | 0.00 |
| 6 | 4.00 | 1.29 | 0.00 |
| 7 | 9.94 | 1.29 | 0.00 |
| 8 | 10.20 | 1.29 | 0.00 |
| 9 | 10.20 | 1.63 | 0.00 |
| 10 | 10.24 | 1.63 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 3.50 | 3.43 | 0.00 |
| 6 | 4.00 | 3.43 | 0.00 |
| 7 | 9.94 | 3.43 | 0.00 |
| 8 | 10.20 | 3.43 | 0.00 |
| 9 | 10.20 | 4.35 | 0.00 |
| 10 | 10.24 | 4.35 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.350 |
| FF resistance | -52.67 | -0.33 | -29.93 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.350 |
| Active pressure | 135.91 | -3.75 | 10.60 | 6.28 | 1.350 | 1.350 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.350 | 1.350 | 1.000 |
| Pavement | 13.19 | -5.11 | 4.97 | 6.17 | 1.350 | 1.350 | 1.000 |
| Traffic | 35.17 | -5.11 | 13.26 | 6.17 | 1.050 | 1.050 | 1.050 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.350 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 1.050 |

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Mooring 2 | 15.30 | -10.24 | 0.00 | 0.50 | 1.500 | 1.500 | 1.500 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3580.49 kNm/m

Overturning moment $M_{ovr}$ = 1422.53 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 783.12 kN/m

Active horizontal force $H_{act}$ = 252.30 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 232.00 kPa

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |
| 2 | 0.00 | 89.92(30.00) | 38.66 | 0.00 | 10.50 | -25.77 | 3.743 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -25.77 | 11.894 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 87.42 | 78.72 | -38.01 |
| 2 | 0.70 | 7.35 | 0.00 | 27.51 | 12.00 | 24.76 |
| | 0.70 | 7.36 | 0.00 | 27.57 | 12.02 | 24.81 |
| 3 | 0.70 | 7.36 | 0.00 | 87.59 | 78.87 | -38.08 |
| | 1.00 | 10.50 | 0.00 | 124.88 | 112.46 | -54.30 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.92(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

## Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 1.70 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 5.94 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.26 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.04 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

## Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| 6 | 9.94 | 128.63 | 5.00 | 29.71 | 29.71 | 0.00 |
| | 10.20 | 131.10 | 5.00 | 30.28 | 30.28 | 0.00 |
| 7 | 10.20 | 131.10 | 5.00 | 37.26 | 37.26 | 0.00 |
| | 10.24 | 131.48 | 5.00 | 37.37 | 37.37 | 0.00 |

## Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 9.94 | 5.00 | 0.00 |
| 7 | 10.20 | 5.00 | 0.00 |
| 8 | 10.24 | 5.00 | 0.00 |

## Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 3.50 | 1.73 | 0.00 |
| 6 | 4.00 | 1.73 | 0.00 |
| 7 | 9.94 | 1.73 | 0.00 |
| 8 | 10.20 | 1.73 | 0.00 |
| 9 | 10.20 | 2.13 | 0.00 |
| 10 | 10.24 | 2.13 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 3.50 | 4.62 | 0.00 |
| 6 | 4.00 | 4.62 | 0.00 |
| 7 | 9.94 | 4.62 | 0.00 |
| 8 | 10.20 | 4.62 | 0.00 |
| 9 | 10.20 | 5.68 | 0.00 |
| 10 | 10.24 | 5.68 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -5.44 | 799.88 | 3.43 | 1.000 | 1.000 | 1.000 |
| FF resistance | -29.05 | -0.33 | -13.53 | 0.49 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -9.42 | 123.79 | 4.24 | 1.000 | 1.000 | 1.000 |
| Active pressure | 182.90 | -3.75 | 10.68 | 6.28 | 1.000 | 1.000 | 1.000 |
| Water pressure | 32.45 | -3.25 | 0.00 | 5.84 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -16.25 | 4.33 | 1.000 | 1.000 | 1.000 |
| Pavement | 17.74 | -5.11 | 5.00 | 6.17 | 1.000 | 1.000 | 1.000 |
| Traffic | 47.31 | -5.11 | 13.35 | 6.17 | 0.910 | 0.910 | 0.910 |
| Pavement | 0.00 | -10.24 | 26.53 | 4.07 | 1.000 | 1.000 | 1.000 |
| Traffic | 0.00 | -10.24 | 70.74 | 4.07 | 0.000 | 0.000 | 0.910 |
| Mooring 2 | 15.30 | -10.24 | 0.00 | 0.50 | 1.300 | 1.300 | 1.300 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 3544.23 kNm/m
Overturning moment $M_{ovr}$ = 1366.14 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 636.54 kN/m
Active horizontal force $H_{act}$ = 266.98 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 210.13 kPa

## Bearing capacity of foundation soil (Stage of construction 8)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 451.27 | 1378.17 | 197.70 | 0.050 | 235.78 |
| 2 | 868.25 | 939.25 | 261.24 | 0.142 | 201.94 |
| 3 | 921.74 | 953.46 | 279.46 | 0.149 | 208.79 |
| 4 | 846.46 | 1045.42 | 279.46 | 0.125 | 214.20 |
| 5 | 484.29 | 1340.37 | 188.76 | 0.056 | 232.00 |
| 6 | 875.20 | 933.28 | 252.30 | 0.144 | 201.81 |
| 7 | 903.73 | 948.25 | 266.98 | 0.147 | 206.42 |
| 8 | 851.03 | 1012.63 | 266.98 | 0.129 | 210.13 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 503.24 | 1003.60 | 179.35 |
| 2 | 561.15 | 932.85 | 179.35 |
| 3 | 503.24 | 1003.60 | 179.35 |
| 4 | 561.15 | 932.85 | 179.35 |

# Prefab wall analysis

## Input data

### Project

Task : Global Stability - Overturning and Sliding Verification
Part : Counterfort Wall
Description : Shallow Berth Operational Load Case - Mooring and Traffic Surcharge
Customer : TNPA
Author : YH
Date : 1/23/2019
Project ID : Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment
Project number : S2001-109

### Settings

(input for current task)

### Materials and standards

Concrete structures : EN 1992-1-1 (EC2)
Coefficients EN 1992-1-1 : standard

### Wall analysis

Active earth pressure calculation : Coulomb
Passive earth pressure calculation : Coulomb
Earthquake analysis : Mononobe-Okabe
Shape of earth wedge : Calculate as skew
Allowable eccentricity : 0.333
Verification methodology : according to EN 1997
Design approach : 1 - reduction of actions and soil parameters

| Partial factors on actions (A) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Permanent design situation | | | | | | | | | |
| | | Combination 1 | | | | Combination 2 | | | |
| | | Unfavourable | | Favourable | | Unfavourable | | Favourable | |
| Permanent actions : | $\gamma_G$ = | 1.35 | [–] | 1.00 | [–] | 1.00 | [–] | 1.00 | [–] |
| Variable actions : | $\gamma_Q$ = | 1.50 | [–] | 0.00 | [–] | 1.30 | [–] | 0.00 | [–] |
| Water load : | $\gamma_w$ = | 1.35 | [–] | | | 1.00 | [–] | | |

| Partial factors for soil parameters (M) | | | | | |
|---|---|---|---|---|---|
| Permanent design situation | | | | | |
| | | Combination 1 | | Combination 2 | |
| Partial factor on internal friction : | $\gamma_\phi$ = | 1.00 | [–] | 1.25 | [–] |
| Partial factor on effective cohesion : | $\gamma_c$ = | 1.00 | [–] | 1.25 | [–] |
| Partial factor on undrained shear strength : | $\gamma_{cu}$ = | 1.00 | [–] | 1.40 | [–] |
| Partial factor on Poisson's ratio : | $\gamma_v$ = | 1.00 | [–] | 1.00 | [–] |

| Partial factors for variable actions | | | |
|---|---|---|---|
| Permanent design situation | | | |
| Factor for combination value : | $\psi_0$ = | 0.70 | [–] |
| Factor for frequent value : | $\psi_1$ = | 0.50 | [–] |
| Factor for quasi-permanent value : | $\psi_2$ = | 0.30 | [–] |

### Geometry of structure

Slope of wall = 0.00 °

| No. | Width b [m] | Height h [m] | Offset k [m] | Offs.(L) $o_1$ [m] | Offs.(R) $o_2$ [m] | Self w. [kN/m$^3$] | Friction [–] | Cohesion [kPa] | Shear bear.cap. $R_s$ [kN/m] |
|---|---|---|---|---|---|---|---|---|---|
| 3 | 1.80 | 1.60 | -0.50 | 0.00 | 0.00 | 35.40 | 1.000 | 0.00 | 0.00 |
| 2 | 3.80 | 6.10 | 0.50 | 0.00 | 0.00 | 21.70 | 1.000 | 1000.00 | 0.00 |
| 1 | 4.30 | 0.30 | 0.00 | 0.00 | 0.00 | 25.00 | - | - | - |

Note: Blocks are ordered from bottom to the top

## Basic soil parameters

| No. | Name | Pattern | $\varphi_{ef}$ [°] | $c_{ef}$ [kPa] | $\gamma$ [kN/m$^3$] | $\gamma_{su}$ [kN/m$^3$] | $\delta$ [°] |
|---|---|---|---|---|---|---|---|
| 1 | Backfill quarry Run | | 45.00 | 0.00 | 18.50 | 9.50 | 0.00 |
| 2 | Existing scour rock (Quarry Run) | | 40.00 | 0.00 | 18.50 | 9.50 | 0.00 |
| 3 | Scour rock | | 45.00 | 0.00 | 19.50 | 10.50 | 0.00 |
| 4 | Pavement Layers | | 45.00 | 0.00 | 20.00 | 11.00 | 0.00 |

All soils are considered as cohesionless for at rest pressure analysis.

## Soil parameters

**Backfill quarry Run**

Unit weight : $\gamma$ = 18.50 kN/m$^3$
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 45.00 °
Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 19.50 kN/m$^3$

**Existing scour rock (Quarry Run)**

Unit weight : $\gamma$ = 18.50 kN/m$^3$
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 40.00 °
Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 19.50 kN/m$^3$

**Scour rock**

Unit weight : $\gamma$ = 19.50 kN/m$^3$
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 45.00 °
Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 20.50 kN/m$^3$

**Pavement Layers**

Unit weight : $\gamma$ = 20.00 kN/m$^3$
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 45.00 °

Cohesion of soil : $c_{ef}$ = 0.00 kPa
Angle of friction struc.-soil : $\delta$ = 0.00 °
Soil : cohesionless
Saturated unit weight : $\gamma_{sat}$ = 21.00 kN/m$^3$

## Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 6.10 | Backfill quarry Run | |
| 3 | 6.10 | Existing scour rock (Quarry Run) | |
| 4 | - | Existing scour rock (Quarry Run) | |

## Foundation

Type of foundation : strip foundation
Soil of foundation - Existing scour rock (Quarry Run)

**Geometry**

Foundation thickness h = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

## Terrain profile

Terrain behind the structure is flat.

## Water influence

GWT behind the structure lies at a depth of 1.88 m
GWT in front of the structure lies at a depth of 2.38 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

## Input surface surcharges

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m$^2$] | Mag.2 [kN/m$^2$] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 1 | Yes | | variable | 20.00 | | | | on terrain |
| 2 | Yes | | permanent | 7.50 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Traffic Surcharge |
| 2 | Pavement |

## Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour rock
Angle of friction struc.-soil $\delta$ = 25.00 °
Soil thickness in front of structure h = 1.00 m

Terrain in front of structure is flat.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | Yes | | Mooring Load | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 1)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |
| 2 | 0.00 | 89.85(30.00) | 45.00 | 0.00 | 10.50 | -25.00 | 4.497 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 137.56 | 124.67 | -58.13 |
| 2 | 0.70 | 7.35 | 0.00 | 33.05 | 14.05 | 29.92 |
| | 0.70 | 7.36 | 0.00 | 33.12 | 14.08 | 29.98 |
| 3 | 0.70 | 7.36 | 0.00 | 137.82 | 124.91 | -58.25 |
| | 1.00 | 10.50 | 0.00 | 196.51 | 178.10 | -83.05 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.85(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 0.08 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 5.32 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 6 | 0.20 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.10 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

## Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| | 7.70 | 92.77 | 5.00 | 15.92 | 15.92 | 0.00 |
| 6 | 7.70 | 92.77 | 5.00 | 15.92 | 15.92 | 0.00 |
| | 7.90 | 94.67 | 5.00 | 16.24 | 16.24 | 0.00 |
| 7 | 7.90 | 94.67 | 5.00 | 20.59 | 20.59 | 0.00 |
| | 8.00 | 95.62 | 5.00 | 20.79 | 20.79 | 0.00 |

## Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

## Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 1.88 | 3.43 | 0.00 |
| 6 | 2.38 | 3.43 | 0.00 |
| 7 | 7.70 | 3.43 | 0.00 |
| 8 | 7.90 | 3.43 | 0.00 |
| 9 | 7.90 | 4.35 | 0.00 |
| 10 | 8.00 | 4.35 | 0.00 |

## Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 1.88 | 1.29 | 0.00 |
| 6 | 2.38 | 1.29 | 0.00 |
| 7 | 7.70 | 1.29 | 0.00 |
| 8 | 7.90 | 1.29 | 0.00 |
| 9 | 7.90 | 1.63 | 0.00 |
| 10 | 8.00 | 1.63 | 0.00 |

## Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.32 | 422.15 | 2.03 | 1.000 | 1.000 | 1.350 |
| FF resistance | -45.22 | -0.33 | -20.70 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.350 |
| Active pressure | 76.38 | -2.93 | 10.60 | 4.08 | 1.350 | 1.350 | 1.000 |
| Water pressure | 29.35 | -2.94 | 0.00 | 3.64 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 27.54 | -3.99 | 13.26 | 3.97 | 1.050 | 1.050 | 1.050 |
| Pavement | 10.33 | -3.99 | 4.97 | 3.97 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 1.050 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 1.500 | 1.500 | 1.500 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1228.77 kNm/m

Overturning moment $M_{ovr}$ = 799.27 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 423.79 kN/m

Active horizontal force $H_{act}$ = 163.33 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 296.95 kPa

## Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |
| 2 | 0.00 | 89.85(30.00) | 38.66 | 0.00 | 10.50 | -21.48 | 3.249 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 75.88 | 70.62 | -27.78 |
| 2 | 0.70 | 7.35 | 0.00 | 23.88 | 8.80 | 22.20 |
| | 0.70 | 7.36 | 0.00 | 23.93 | 8.82 | 22.24 |
| 3 | 0.70 | 7.36 | 0.00 | 76.03 | 70.75 | -27.84 |
| | 1.00 | 10.50 | 0.00 | 108.41 | 100.88 | -39.69 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.85(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 0.08 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 5.32 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.20 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.10 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |

| Layer No. | Start [m] End [m] | σz [kPa] | σw [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 5 | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| | 7.70 | 92.77 | 5.00 | 21.43 | 21.43 | 0.00 |
| 6 | 7.70 | 92.77 | 5.00 | 21.43 | 21.43 | 0.00 |
| | 7.90 | 94.67 | 5.00 | 21.87 | 21.87 | 0.00 |
| 7 | 7.90 | 94.67 | 5.00 | 26.91 | 26.91 | 0.00 |
| | 8.00 | 95.62 | 5.00 | 27.18 | 27.18 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 1.88 | 4.62 | 0.00 |
| 6 | 2.38 | 4.62 | 0.00 |
| 7 | 7.70 | 4.62 | 0.00 |
| 8 | 7.90 | 4.62 | 0.00 |
| 9 | 7.90 | 5.68 | 0.00 |
| 10 | 8.00 | 5.68 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 1.88 | 1.73 | 0.00 |
| 6 | 2.38 | 1.73 | 0.00 |
| 7 | 7.70 | 1.73 | 0.00 |
| 8 | 7.90 | 1.73 | 0.00 |
| 9 | 7.90 | 2.13 | 0.00 |
| 10 | 8.00 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.32 | 422.15 | 2.03 | 1.000 | 1.000 | 1.000 |
| FF resistance | -26.16 | -0.33 | -9.88 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.000 |
| Active pressure | 102.72 | -2.93 | 10.68 | 4.08 | 1.000 | 1.000 | 1.000 |
| Water pressure | 29.35 | -2.94 | 0.00 | 3.64 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 37.02 | -3.98 | 13.35 | 3.97 | 0.910 | 0.910 | 0.910 |
| Pavement | 13.88 | -3.98 | 5.00 | 3.97 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 0.910 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 1.300 | 1.300 | 1.300 |

### Verification of complete wall

**Check for overturning stability**
Resisting moment $M_{res}$ = 1202.77 kNm/m
Overturning moment $M_{ovr}$ = 757.82 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**
Resisting horizontal force $H_{res}$ = 344.04 kN/m
Active horizontal force $H_{act}$ = 173.37 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 295.17 kPa

## Verification No. 2 (Stage of construction 1)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |
| 2 | 0.00 | 89.85(30.00) | 45.00 | 0.00 | 10.50 | -25.00 | 4.497 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 137.56 | 124.67 | -58.13 |
| 2 | 0.70 | 7.35 | 0.00 | 33.05 | 14.05 | 29.92 |
| | 0.70 | 7.36 | 0.00 | 33.12 | 14.08 | 29.98 |
| 3 | 0.70 | 7.36 | 0.00 | 137.82 | 124.91 | -58.25 |
| | 1.00 | 10.50 | 0.00 | 196.51 | 178.10 | -83.05 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.85(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 0.08 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 5.32 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.20 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.10 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| | 7.70 | 92.77 | 5.00 | 15.92 | 15.92 | 0.00 |
| 6 | 7.70 | 92.77 | 5.00 | 15.92 | 15.92 | 0.00 |
| | 7.90 | 94.67 | 5.00 | 16.24 | 16.24 | 0.00 |
| 7 | 7.90 | 94.67 | 5.00 | 20.59 | 20.59 | 0.00 |
| | 8.00 | 95.62 | 5.00 | 20.79 | 20.79 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 1.88 | 3.43 | 0.00 |
| 6 | 2.38 | 3.43 | 0.00 |
| 7 | 7.70 | 3.43 | 0.00 |
| 8 | 7.90 | 3.43 | 0.00 |
| 9 | 7.90 | 4.35 | 0.00 |
| 10 | 8.00 | 4.35 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 1.88 | 1.29 | 0.00 |
| 6 | 2.38 | 1.29 | 0.00 |
| 7 | 7.70 | 1.29 | 0.00 |
| 8 | 7.90 | 1.29 | 0.00 |
| 9 | 7.90 | 1.63 | 0.00 |
| 10 | 8.00 | 1.63 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.32 | 422.15 | 2.03 | 1.000 | 1.000 | 1.350 |
| FF resistance | -45.22 | -0.33 | -20.70 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.350 |
| Active pressure | 76.38 | -2.93 | 10.60 | 4.08 | 1.350 | 1.350 | 1.000 |
| Water pressure | 29.35 | -2.94 | 0.00 | 3.64 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 27.54 | -3.99 | 13.26 | 3.97 | 1.500 | 1.500 | 1.500 |
| Pavement | 10.33 | -3.99 | 4.97 | 3.97 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 1.500 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.350 |

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 1.050 | 1.050 | 1.050 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1252.44 kNm/m
Overturning moment $M_{ovr}$ = 793.60 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 428.80 kN/m
Active horizontal force $H_{act}$ = 168.84 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 284.57 kPa

## Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |
| 2 | 0.00 | 89.85(30.00) | 38.66 | 0.00 | 10.50 | -21.48 | 3.249 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |

## Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 75.88 | 70.62 | -27.78 |
| 2 | 0.70 | 7.35 | 0.00 | 23.88 | 8.80 | 22.20 |
| | 0.70 | 7.36 | 0.00 | 23.93 | 8.82 | 22.24 |
| 3 | 0.70 | 7.36 | 0.00 | 76.03 | 70.75 | -27.84 |
| | 1.00 | 10.50 | 0.00 | 108.41 | 100.88 | -39.69 |

## Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.85(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

## Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

## Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 0.08 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 5.32 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.20 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.10 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

## Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| | 7.70 | 92.77 | 5.00 | 21.43 | 21.43 | 0.00 |
| 6 | 7.70 | 92.77 | 5.00 | 21.43 | 21.43 | 0.00 |
| | 7.90 | 94.67 | 5.00 | 21.87 | 21.87 | 0.00 |
| 7 | 7.90 | 94.67 | 5.00 | 26.91 | 26.91 | 0.00 |
| | 8.00 | 95.62 | 5.00 | 27.18 | 27.18 | 0.00 |

## Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

## Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 1.88 | 4.62 | 0.00 |
| 6 | 2.38 | 4.62 | 0.00 |
| 7 | 7.70 | 4.62 | 0.00 |
| 8 | 7.90 | 4.62 | 0.00 |
| 9 | 7.90 | 5.68 | 0.00 |
| 10 | 8.00 | 5.68 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 1.88 | 1.73 | 0.00 |
| 6 | 2.38 | 1.73 | 0.00 |
| 7 | 7.70 | 1.73 | 0.00 |
| 8 | 7.90 | 1.73 | 0.00 |
| 9 | 7.90 | 2.13 | 0.00 |
| 10 | 8.00 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.32 | 422.15 | 2.03 | 1.000 | 1.000 | 1.000 |
| FF resistance | -26.16 | -0.33 | -9.88 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.000 |
| Active pressure | 102.72 | -2.93 | 10.68 | 4.08 | 1.000 | 1.000 | 1.000 |
| Water pressure | 29.35 | -2.94 | 0.00 | 3.64 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 37.02 | -3.98 | 13.35 | 3.97 | 1.300 | 1.300 | 1.300 |
| Pavement | 13.88 | -3.98 | 5.00 | 3.97 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 1.300 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 0.910 | 0.910 | 0.910 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1223.43 kNm/m
Overturning moment $M_{ovr}$ = 767.62 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 347.53 kN/m
Active horizontal force $H_{act}$ = 181.84 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 294.02 kPa

## Bearing capacity of foundation soil (Stage of construction 1)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 516.71 | 718.81 | 122.71 | 0.167 | 251.13 |
| 2 | 656.37 | 505.06 | 163.33 | 0.302 | 296.95 |
| 3 | 656.95 | 512.51 | 173.37 | 0.298 | 295.17 |
| 4 | 637.94 | 545.95 | 173.37 | 0.272 | 278.12 |
| 5 | 630.13 | 565.48 | 181.84 | 0.259 | 273.00 |
| 6 | 657.29 | 517.72 | 181.84 | 0.295 | 294.02 |
| 7 | 639.85 | 511.02 | 168.84 | 0.291 | 284.57 |
| 8 | 490.79 | 741.31 | 128.22 | 0.154 | 249.11 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 454.77 | 539.45 | 113.68 |
| 2 | 475.66 | 502.70 | 113.68 |
| 3 | 454.77 | 539.45 | 113.68 |
| 4 | 475.66 | 502.70 | 113.68 |

## Input data (Stage of construction 2)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 6.10 | Backfill quarry Run | |
| 3 | 6.10 | Existing scour rock (Quarry Run) | |
| 4 | - | Existing scour rock (Quarry Run) | |

### Foundation

Type of foundation : strip foundation
Soil of foundation - Existing scour rock (Quarry Run)

**Geometry**

Foundation thickness $h = 1.00$ m
Offset left $b_l = 3.00$ m
Offset right $b_p = 1.00$ m

### Terrain profile

Terrain behind the structure is flat.

### Water influence

GWT behind the structure lies at a depth of 3.50 m
GWT in front of the structure lies at a depth of 4.00 m
Subgrade at the heel is not permeable.

Uplift in foot. bottom due to different pressures is considered as linear.

### Input surface surcharges

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m$^2$] | Mag.2 [kN/m$^2$] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 1 | No | No | variable | 20.00 | | | | on terrain |
| 2 | No | No | permanent | 7.50 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Traffic Surcharge |
| 2 | Pavement |

### Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour rock
Angle of friction struc.-soil $\delta$ = 25.00 °
Soil thickness in front of structure h = 1.00 m

Terrain in front of structure is flat.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | No | No | Mooring Load | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 2)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |
| 2 | 0.00 | 89.85(30.00) | 45.00 | 0.00 | 10.50 | -25.00 | 4.497 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 137.56 | 124.67 | -58.13 |
| 2 | 0.70 | 7.35 | 0.00 | 33.05 | 14.05 | 29.92 |
| | 0.70 | 7.36 | 0.00 | 33.12 | 14.08 | 29.98 |
| 3 | 0.70 | 7.36 | 0.00 | 137.82 | 124.91 | -58.25 |
| | 1.00 | 10.50 | 0.00 | 196.51 | 178.10 | -83.05 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.85(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 1.70 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 3.70 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.20 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.10 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| | 7.70 | 107.35 | 5.00 | 18.42 | 18.42 | 0.00 |
| 6 | 7.70 | 107.35 | 5.00 | 18.42 | 18.42 | 0.00 |
| | 7.90 | 109.25 | 5.00 | 18.74 | 18.74 | 0.00 |
| 7 | 7.90 | 109.25 | 5.00 | 23.76 | 23.76 | 0.00 |
| | 8.00 | 110.20 | 5.00 | 23.96 | 23.96 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

## Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 3.50 | 3.43 | 0.00 |
| 6 | 4.00 | 3.43 | 0.00 |
| 7 | 7.70 | 3.43 | 0.00 |
| 8 | 7.90 | 3.43 | 0.00 |
| 9 | 7.90 | 4.35 | 0.00 |
| 10 | 8.00 | 4.35 | 0.00 |

## Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 3.50 | 1.29 | 0.00 |
| 6 | 4.00 | 1.29 | 0.00 |
| 7 | 7.70 | 1.29 | 0.00 |
| 8 | 7.90 | 1.29 | 0.00 |
| 9 | 7.90 | 1.63 | 0.00 |
| 10 | 8.00 | 1.63 | 0.00 |

## Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.38 | 483.71 | 2.07 | 1.000 | 1.000 | 1.350 |
| FF resistance | -45.22 | -0.33 | -20.70 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.350 |
| Active pressure | 89.73 | -2.89 | 10.60 | 4.08 | 1.350 | 1.350 | 1.000 |
| Water pressure | 21.25 | -2.13 | 0.00 | 3.64 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 27.54 | -3.99 | 13.26 | 3.97 | 1.050 | 1.050 | 1.050 |
| Pavement | 10.33 | -3.99 | 4.97 | 3.97 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 1.050 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 1.500 | 1.500 | 1.500 |

## Verification of complete wall

**Check for overturning stability**
Resisting moment $M_{res}$ = 1376.51 kNm/m
Overturning moment $M_{ovr}$ = 791.92 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**
Resisting horizontal force $H_{res}$ = 475.45 kN/m

Active horizontal force $H_{act}$ = 170.42 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 274.59 kPa

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |
| 2 | 0.00 | 89.85(30.00) | 38.66 | 0.00 | 10.50 | -21.48 | 3.249 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 75.88 | 70.62 | -27.78 |
| 2 | 0.70 | 7.35 | 0.00 | 23.88 | 8.80 | 22.20 |
| | 0.70 | 7.36 | 0.00 | 23.93 | 8.82 | 22.24 |
| 3 | 0.70 | 7.36 | 0.00 | 76.03 | 70.75 | -27.84 |
| | 1.00 | 10.50 | 0.00 | 108.41 | 100.88 | -39.69 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.85(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 1.70 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 3.70 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.20 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.10 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| | 7.70 | 107.35 | 5.00 | 24.80 | 24.80 | 0.00 |
| 6 | 7.70 | 107.35 | 5.00 | 24.80 | 24.80 | 0.00 |
| | 7.90 | 109.25 | 5.00 | 25.24 | 25.24 | 0.00 |
| 7 | 7.90 | 109.25 | 5.00 | 31.05 | 31.05 | 0.00 |
| | 8.00 | 110.20 | 5.00 | 31.32 | 31.32 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 3.50 | 4.62 | 0.00 |
| 6 | 4.00 | 4.62 | 0.00 |
| 7 | 7.70 | 4.62 | 0.00 |
| 8 | 7.90 | 4.62 | 0.00 |
| 9 | 7.90 | 5.68 | 0.00 |
| 10 | 8.00 | 5.68 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 5 | 3.50 | 1.73 | 0.00 |
| 6 | 4.00 | 1.73 | 0.00 |
| 7 | 7.70 | 1.73 | 0.00 |
| 8 | 7.90 | 1.73 | 0.00 |
| 9 | 7.90 | 2.13 | 0.00 |
| 10 | 8.00 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.38 | 483.71 | 2.07 | 1.000 | 1.000 | 1.000 |
| FF resistance | -26.16 | -0.33 | -9.88 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.000 |
| Active pressure | 120.68 | -2.89 | 10.68 | 4.08 | 1.000 | 1.000 | 1.000 |
| Water pressure | 21.25 | -2.13 | 0.00 | 3.64 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 37.02 | -3.98 | 13.35 | 3.97 | 0.910 | 0.910 | 0.910 |
| Pavement | 13.88 | -3.98 | 5.00 | 3.97 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 0.910 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 1.300 | 1.300 | 1.300 |

### Verification of complete wall

**Check for overturning stability**
Resisting moment $M_{res}$ = 1350.52 kNm/m
Overturning moment $M_{ovr}$ = 764.69 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**
Resisting horizontal force $H_{res}$ = 385.36 kN/m
Active horizontal force $H_{act}$ = 183.23 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 281.28 kPa

## Verification No. 2 (Stage of construction 2)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |
| 2 | 0.00 | 89.85(30.00) | 45.00 | 0.00 | 10.50 | -25.00 | 4.497 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 137.56 | 124.67 | -58.13 |
| 2 | 0.70 | 7.35 | 0.00 | 33.05 | 14.05 | 29.92 |
| | 0.70 | 7.36 | 0.00 | 33.12 | 14.08 | 29.98 |
| 3 | 0.70 | 7.36 | 0.00 | 137.82 | 124.91 | -58.25 |
| | 1.00 | 10.50 | 0.00 | 196.51 | 178.10 | -83.05 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.85(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 1.70 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 3.70 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.20 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.10 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 5 | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| | 7.70 | 107.35 | 5.00 | 18.42 | 18.42 | 0.00 |
| 6 | 7.70 | 107.35 | 5.00 | 18.42 | 18.42 | 0.00 |
| | 7.90 | 109.25 | 5.00 | 18.74 | 18.74 | 0.00 |
| 7 | 7.90 | 109.25 | 5.00 | 23.76 | 23.76 | 0.00 |
| | 8.00 | 110.20 | 5.00 | 23.96 | 23.96 | 0.00 |

## Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

## Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 3.50 | 3.43 | 0.00 |
| 6 | 4.00 | 3.43 | 0.00 |
| 7 | 7.70 | 3.43 | 0.00 |
| 8 | 7.90 | 3.43 | 0.00 |
| 9 | 7.90 | 4.35 | 0.00 |
| 10 | 8.00 | 4.35 | 0.00 |

## Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 3.50 | 1.29 | 0.00 |
| 6 | 4.00 | 1.29 | 0.00 |
| 7 | 7.70 | 1.29 | 0.00 |
| 8 | 7.90 | 1.29 | 0.00 |
| 9 | 7.90 | 1.63 | 0.00 |
| 10 | 8.00 | 1.63 | 0.00 |

## Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.38 | 483.71 | 2.07 | 1.000 | 1.000 | 1.350 |
| FF resistance | -45.22 | -0.33 | -20.70 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.350 |
| Active pressure | 89.73 | -2.89 | 10.60 | 4.08 | 1.350 | 1.350 | 1.000 |
| Water pressure | 21.25 | -2.13 | 0.00 | 3.64 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 27.54 | -3.99 | 13.26 | 3.97 | 1.500 | 1.500 | 1.500 |
| Pavement | 10.33 | -3.99 | 4.97 | 3.97 | 1.350 | 1.350 | 1.000 |
| Traffic Surcharge | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 1.500 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 1.050 | 1.050 | 1.050 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1400.19 kNm/m
Overturning moment $M_{ovr}$ = 786.25 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 480.45 kN/m
Active horizontal force $H_{act}$ = 175.93 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 267.01 kPa

## Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |
| 2 | 0.00 | 89.85(30.00) | 38.66 | 0.00 | 10.50 | -21.48 | 3.249 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |

## Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 75.88 | 70.62 | -27.78 |
| 2 | 0.70 | 7.35 | 0.00 | 23.88 | 8.80 | 22.20 |
| | 0.70 | 7.36 | 0.00 | 23.93 | 8.82 | 22.24 |
| 3 | 0.70 | 7.36 | 0.00 | 76.03 | 70.75 | -27.84 |
| | 1.00 | 10.50 | 0.00 | 108.41 | 100.88 | -39.69 |

## Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 2 | 0.00 | 89.85(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

**Pressure at rest distribution on front face of the structure**

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

**Active pressure behind the structure - partial results**

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 1.70 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 3.70 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.20 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.10 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

**Active pressure distribution behind the structure (without surcharge)**

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| | 7.70 | 107.35 | 5.00 | 24.80 | 24.80 | 0.00 |
| 6 | 7.70 | 107.35 | 5.00 | 24.80 | 24.80 | 0.00 |
| | 7.90 | 109.25 | 5.00 | 25.24 | 25.24 | 0.00 |
| 7 | 7.90 | 109.25 | 5.00 | 31.05 | 31.05 | 0.00 |
| | 8.00 | 110.20 | 5.00 | 31.32 | 31.32 | 0.00 |

**Water pressure distribution**

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Traffic Surcharge

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 3.50 | 4.62 | 0.00 |
| 6 | 4.00 | 4.62 | 0.00 |
| 7 | 7.70 | 4.62 | 0.00 |
| 8 | 7.90 | 4.62 | 0.00 |
| 9 | 7.90 | 5.68 | 0.00 |
| 10 | 8.00 | 5.68 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 3.50 | 1.73 | 0.00 |
| 6 | 4.00 | 1.73 | 0.00 |
| 7 | 7.70 | 1.73 | 0.00 |
| 8 | 7.90 | 1.73 | 0.00 |
| 9 | 7.90 | 2.13 | 0.00 |
| 10 | 8.00 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.38 | 483.71 | 2.07 | 1.000 | 1.000 | 1.000 |
| FF resistance | -26.16 | -0.33 | -9.88 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.000 |
| Active pressure | 120.68 | -2.89 | 10.68 | 4.08 | 1.000 | 1.000 | 1.000 |
| Water pressure | 21.25 | -2.13 | 0.00 | 3.64 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 37.02 | -3.98 | 13.35 | 3.97 | 1.300 | 1.300 | 1.300 |
| Pavement | 13.88 | -3.98 | 5.00 | 3.97 | 1.000 | 1.000 | 1.000 |
| Traffic Surcharge | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 1.300 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 0.910 | 0.910 | 0.910 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1371.17 kNm/m
Overturning moment $M_{ovr}$ = 774.49 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 388.86 kN/m
Active horizontal force $H_{act}$ = 191.70 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 281.19 kPa

## Bearing capacity of foundation soil (Stage of construction 2)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 629.42 | 607.51 | 183.23 | 0.241 | 272.69 |
| 2 | 648.43 | 574.07 | 183.23 | 0.263 | 281.28 |
| 3 | 633.63 | 566.62 | 170.42 | 0.260 | 274.59 |
| 4 | 490.49 | 801.92 | 127.96 | 0.142 | 260.64 |
| 5 | 621.61 | 627.04 | 191.70 | 0.231 | 270.59 |
| 6 | 648.76 | 579.28 | 191.70 | 0.260 | 281.19 |
| 7 | 617.11 | 572.58 | 175.93 | 0.251 | 267.01 |
| 8 | 464.57 | 824.42 | 133.47 | 0.131 | 259.82 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 433.94 | 601.01 | 118.93 |
| 2 | 454.83 | 564.26 | 118.93 |
| 3 | 433.94 | 601.01 | 118.93 |
| 4 | 454.83 | 564.26 | 118.93 |

## Input data (Stage of construction 3)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 6.10 | Backfill quarry Run | |
| 3 | 6.10 | Existing scour rock (Quarry Run) | |
| 4 | - | Existing scour rock (Quarry Run) | |

### Foundation

Type of foundation : strip foundation
Soil of foundation - Existing scour rock (Quarry Run)

**Geometry**

Foundation thickness $h$ = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

### Terrain profile

Terrain behind the structure is flat.

### Water influence

GWT behind the structure lies at a depth of 1.88 m
GWT in front of the structure lies at a depth of 2.38 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

### Input surface surcharges

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m²] | Mag.2 [kN/m²] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 1 | No | No | permanent | 7.50 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Pavement |

### Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour rock
Angle of friction struc.-soil $\delta$ = 25.00 °
Soil thickness in front of structure $h$ = 1.00 m

Terrain in front of structure is flat.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | No | No | Mooring Load | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 3)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |
| 2 | 0.00 | 89.85(30.00) | 45.00 | 0.00 | 10.50 | -25.00 | 4.497 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 137.56 | 124.67 | -58.13 |
| 2 | 0.70 | 7.35 | 0.00 | 33.05 | 14.05 | 29.92 |
| | 0.70 | 7.36 | 0.00 | 33.12 | 14.08 | 29.98 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 0.70 | 7.36 | 0.00 | 137.82 | 124.91 | -58.25 |
| | 1.00 | 10.50 | 0.00 | 196.51 | 178.10 | -83.05 |

**Pressure at rest on front face of the structure - partial results**

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.85(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

**Pressure at rest distribution on front face of the structure**

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

**Active pressure behind the structure - partial results**

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 0.08 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 5.32 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.20 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.10 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

**Active pressure distribution behind the structure (without surcharge)**

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| | 7.70 | 92.77 | 5.00 | 15.92 | 15.92 | 0.00 |
| 6 | 7.70 | 92.77 | 5.00 | 15.92 | 15.92 | 0.00 |
| | 7.90 | 94.67 | 5.00 | 16.24 | 16.24 | 0.00 |
| 7 | 7.90 | 94.67 | 5.00 | 20.59 | 20.59 | 0.00 |
| | 8.00 | 95.62 | 5.00 | 20.79 | 20.79 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 1.88 | 1.29 | 0.00 |
| 6 | 2.38 | 1.29 | 0.00 |
| 7 | 7.70 | 1.29 | 0.00 |
| 8 | 7.90 | 1.29 | 0.00 |
| 9 | 7.90 | 1.63 | 0.00 |
| 10 | 8.00 | 1.63 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.32 | 422.15 | 2.03 | 1.000 | 1.000 | 1.350 |
| FF resistance | -45.22 | -0.33 | -20.70 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.350 |
| Active pressure | 76.38 | -2.93 | 10.60 | 4.08 | 1.350 | 1.350 | 1.000 |
| Water pressure | 29.35 | -2.94 | 0.00 | 3.64 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.350 | 1.350 | 1.000 |
| Pavement | 10.33 | -3.99 | 4.97 | 3.97 | 1.350 | 1.350 | 1.000 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 1.500 | 1.500 | 1.500 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1173.54 kNm/m
Overturning moment $M_{ovr}$ = 683.97 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 412.11 kN/m
Active horizontal force $H_{act}$ = 134.41 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

**Maximumstressin footingbottom: 246.36 kPa**

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |
| 2 | 0.00 | 89.85(30.00) | 38.66 | 0.00 | 10.50 | -21.48 | 3.249 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 75.88 | 70.62 | -27.78 |
| 2 | 0.70 | 7.35 | 0.00 | 23.88 | 8.80 | 22.20 |
| | 0.70 | 7.36 | 0.00 | 23.93 | 8.82 | 22.24 |
| 3 | 0.70 | 7.36 | 0.00 | 76.03 | 70.75 | -27.84 |
| | 1.00 | 10.50 | 0.00 | 108.41 | 100.88 | -39.69 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.85(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 0.08 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 5.32 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.20 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.10 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| | 7.70 | 92.77 | 5.00 | 21.43 | 21.43 | 0.00 |
| 6 | 7.70 | 92.77 | 5.00 | 21.43 | 21.43 | 0.00 |
| | 7.90 | 94.67 | 5.00 | 21.87 | 21.87 | 0.00 |
| 7 | 7.90 | 94.67 | 5.00 | 26.91 | 26.91 | 0.00 |
| | 8.00 | 95.62 | 5.00 | 27.18 | 27.18 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 1.88 | 1.73 | 0.00 |
| 6 | 2.38 | 1.73 | 0.00 |
| 7 | 7.70 | 1.73 | 0.00 |
| 8 | 7.90 | 1.73 | 0.00 |
| 9 | 7.90 | 2.13 | 0.00 |
| 10 | 8.00 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.32 | 422.15 | 2.03 | 1.000 | 1.000 | 1.000 |
| FF resistance | -26.16 | -0.33 | -9.88 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.000 |
| Active pressure | 102.72 | -2.93 | 10.68 | 4.08 | 1.000 | 1.000 | 1.000 |

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Water pressure | 29.35 | -2.94 | 0.00 | 3.64 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.000 | 1.000 | 1.000 |
| Pavement | 13.88 | -3.98 | 5.00 | 3.97 | 1.000 | 1.000 | 1.000 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 1.300 | 1.300 | 1.300 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1154.58 kNm/m

Overturning moment $M_{ovr}$ = 623.57 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 335.89 kN/m

Active horizontal force $H_{act}$ = 139.68 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 235.75 kPa

## Bearing capacity of foundation soil (Stage of construction 3)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 448.66 | 666.31 | 93.79 | 0.157 | 225.61 |
| 2 | 566.38 | 491.14 | 134.41 | 0.268 | 246.36 |
| 3 | 544.78 | 500.37 | 139.68 | 0.253 | 235.75 |
| 4 | 544.78 | 500.37 | 139.68 | 0.253 | 235.75 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 389.96 | 489.45 | 86.14 |

## Input data (Stage of construction 4)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 6.10 | Backfill quarry Run | |
| 3 | 6.10 | Existing scour rock (Quarry Run) | |
| 4 | - | Existing scour rock (Quarry Run) | |

### Foundation

Type of foundation : strip foundation

Soil of foundation - Existing scour rock (Quarry Run)

**Geometry**

Foundation thickness $h$ = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

### Terrain profile

Terrain behind the structure is flat.

### Water influence

GWT behind the structure lies at a depth of 3.50 m
GWT in front of the structure lies at a depth of 4.00 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

### Input surface surcharges

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m2] | Mag.2 [kN/m2] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 1 | No | No | permanent | 7.50 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Pavement |

### Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour rock
Angle of friction struc.-soil $\delta$ = 25.00 °
Soil thickness in front of structure h = 1.00 m

Terrain in front of structure is flat.

### Applied forces acting on the structure

| No. | Force new | Force edit | Name | Action | $F_x$ [kN/m] | $F_z$ [kN/m] | M [kNm/m] | x [m] | z [m] |
|---|---|---|---|---|---|---|---|---|---|
| 1 | No | No | Mooring Load | variable | -15.30 | 0.00 | 0.00 | -1.80 | 0.00 |

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 4)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m3] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |
| 2 | 0.00 | 89.85(30.00) | 45.00 | 0.00 | 10.50 | -25.00 | 4.497 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 137.56 | 124.67 | -58.13 |
| 2 | 0.70 | 7.35 | 0.00 | 33.05 | 14.05 | 29.92 |
| | 0.70 | 7.36 | 0.00 | 33.12 | 14.08 | 29.98 |

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 0.70 | 7.36 | 0.00 | 137.82 | 124.91 | -58.25 |
| | 1.00 | 10.50 | 0.00 | 196.51 | 178.10 | -83.05 |

## Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.85(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

## Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

## Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 1.70 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 3.70 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.20 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.10 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

## Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| | 7.70 | 107.35 | 5.00 | 18.42 | 18.42 | 0.00 |
| 6 | 7.70 | 107.35 | 5.00 | 18.42 | 18.42 | 0.00 |
| | 7.90 | 109.25 | 5.00 | 18.74 | 18.74 | 0.00 |
| 7 | 7.90 | 109.25 | 5.00 | 23.76 | 23.76 | 0.00 |
| | 8.00 | 110.20 | 5.00 | 23.96 | 23.96 | 0.00 |

## Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

## Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.38 | 483.71 | 2.07 | 1.000 | 1.000 | 1.350 |
| FF resistance | -45.22 | -0.33 | -20.70 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.350 |
| Active pressure | 89.73 | -2.89 | 10.60 | 4.08 | 1.350 | 1.350 | 1.000 |
| Water pressure | 21.25 | -2.13 | 0.00 | 3.64 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.350 | 1.350 | 1.000 |
| Pavement | 10.33 | -3.99 | 4.97 | 3.97 | 1.350 | 1.350 | 1.000 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.350 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 1.500 | 1.500 | 1.500 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1321.28 kNm/m
Overturning moment $M_{ovr}$ = 676.62 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 463.77 kN/m
Active horizontal force $H_{act}$ = 141.50 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 236.93 kPa

## Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |
| 2 | 0.00 | 89.85(30.00) | 38.66 | 0.00 | 10.50 | -21.48 | 3.249 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |

## Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 75.88 | 70.62 | -27.78 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 2 | 0.70 | 7.35 | 0.00 | 23.88 | 8.80 | 22.20 |
| | 0.70 | 7.36 | 0.00 | 23.93 | 8.82 | 22.24 |
| 3 | 0.70 | 7.36 | 0.00 | 76.03 | 70.75 | -27.84 |
| | 1.00 | 10.50 | 0.00 | 108.41 | 100.88 | -39.69 |

## Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.85(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

## Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

## Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 1.70 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 3.70 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.20 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.10 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

## Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| | 7.70 | 107.35 | 5.00 | 24.80 | 24.80 | 0.00 |
| 6 | 7.70 | 107.35 | 5.00 | 24.80 | 24.80 | 0.00 |
| | 7.90 | 109.25 | 5.00 | 25.24 | 25.24 | 0.00 |

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 7 | 7.90 | 109.25 | 5.00 | 31.05 | 31.05 | 0.00 |
| | 8.00 | 110.20 | 5.00 | 31.32 | 31.32 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 3.50 | 1.73 | 0.00 |
| 6 | 4.00 | 1.73 | 0.00 |
| 7 | 7.70 | 1.73 | 0.00 |
| 8 | 7.90 | 1.73 | 0.00 |
| 9 | 7.90 | 2.13 | 0.00 |
| 10 | 8.00 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.38 | 483.71 | 2.07 | 1.000 | 1.000 | 1.000 |
| FF resistance | -26.16 | -0.33 | -9.88 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.000 |
| Active pressure | 120.68 | -2.89 | 10.68 | 4.08 | 1.000 | 1.000 | 1.000 |
| Water pressure | 21.25 | -2.13 | 0.00 | 3.64 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.000 | 1.000 | 1.000 |
| Pavement | 13.88 | -3.98 | 5.00 | 3.97 | 1.000 | 1.000 | 1.000 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.000 |
| Mooring Load | 15.30 | -8.00 | 0.00 | 0.00 | 1.300 | 1.300 | 1.300 |

### Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1302.32 kNm/m
Overturning moment $M_{ovr}$ = 630.44 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 377.21 kN/m

Active horizontal force $H_{act}$ = 149.54 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 234.98 kPa

## Bearing capacity of foundation soil (Stage of construction 4)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 422.44 | 749.42 | 99.04 | 0.131 | 236.21 |
| 2 | 543.64 | 552.70 | 141.50 | 0.229 | 236.93 |
| 3 | 536.26 | 561.93 | 149.54 | 0.222 | 234.98 |
| 4 | 536.26 | 561.93 | 149.54 | 0.222 | 234.98 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 369.13 | 551.01 | 91.39 |

## Input data (Stage of construction 5)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 6.10 | Backfill quarry Run | |
| 3 | 6.10 | Existing scour rock (Quarry Run) | |
| 4 | - | Existing scour rock (Quarry Run) | |

### Foundation

Type of foundation : strip foundation
Soil of foundation - Existing scour rock (Quarry Run)

**Geometry**

Foundation thickness $h$ = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

### Terrain profile

Terrain behind the structure is flat.

### Water influence

GWT behind the structure lies at a depth of 1.88 m
GWT in front of the structure lies at a depth of 2.38 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

### Input surface surcharges

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m2] | Mag.2 [kN/m2] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 1 | No | No | permanent | 7.50 | | | | on terrain |
| 2 | Yes | | variable | 20.00 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Pavement |
| 2 | Traffic |

### Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour rock
Angle of friction struc.-soil $\delta$ = 25.00 °
Soil thickness in front of structure h = 1.00 m

Terrain in front of structure is flat.

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 5)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m3] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |
| 2 | 0.00 | 89.85(30.00) | 45.00 | 0.00 | 10.50 | -25.00 | 4.497 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 137.56 | 124.67 | -58.13 |
| 2 | 0.70 | 7.35 | 0.00 | 33.05 | 14.05 | 29.92 |
| | 0.70 | 7.36 | 0.00 | 33.12 | 14.08 | 29.98 |
| 3 | 0.70 | 7.36 | 0.00 | 137.82 | 124.91 | -58.25 |
| | 1.00 | 10.50 | 0.00 | 196.51 | 178.10 | -83.05 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m3] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.85(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

## Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 0.08 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 5.32 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.20 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.10 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

## Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 6.43 | 6.43 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 7.25 | 7.25 | 0.00 |
| | 7.70 | 92.77 | 5.00 | 15.92 | 15.92 | 0.00 |
| 6 | 7.70 | 92.77 | 5.00 | 15.92 | 15.92 | 0.00 |
| | 7.90 | 94.67 | 5.00 | 16.24 | 16.24 | 0.00 |
| 7 | 7.90 | 94.67 | 5.00 | 20.59 | 20.59 | 0.00 |
| | 8.00 | 95.62 | 5.00 | 20.79 | 20.79 | 0.00 |

## Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

## Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 1.88 | 1.29 | 0.00 |
| 6 | 2.38 | 1.29 | 0.00 |
| 7 | 7.70 | 1.29 | 0.00 |
| 8 | 7.90 | 1.29 | 0.00 |
| 9 | 7.90 | 1.63 | 0.00 |
| 10 | 8.00 | 1.63 | 0.00 |

## Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 1.88 | 3.43 | 0.00 |
| 6 | 2.38 | 3.43 | 0.00 |
| 7 | 7.70 | 3.43 | 0.00 |
| 8 | 7.90 | 3.43 | 0.00 |
| 9 | 7.90 | 4.35 | 0.00 |
| 10 | 8.00 | 4.35 | 0.00 |

## Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.32 | 422.15 | 2.03 | 1.000 | 1.000 | 1.350 |
| FF resistance | -45.22 | -0.33 | -20.70 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.350 |
| Active pressure | 76.38 | -2.93 | 10.60 | 4.08 | 1.350 | 1.350 | 1.000 |
| Water pressure | 29.35 | -2.94 | 0.00 | 3.64 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.350 | 1.350 | 1.000 |
| Pavement | 10.33 | -3.99 | 4.97 | 3.97 | 1.350 | 1.350 | 1.000 |
| Traffic | 27.54 | -3.99 | 13.26 | 3.97 | 1.500 | 1.500 | 1.500 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.350 |
| Traffic | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 1.500 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1252.44 kNm/m

Overturning moment $M_{ovr}$ = 665.08 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 428.80 kN/m

Active horizontal force $H_{act}$ = 152.77 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

**Maximumstressin footingbottom: 223.11 kPa**

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |
| 2 | 0.00 | 89.85(30.00) | 38.66 | 0.00 | 10.50 | -21.48 | 3.249 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 75.88 | 70.62 | -27.78 |
| 2 | 0.70 | 7.35 | 0.00 | 23.88 | 8.80 | 22.20 |
| | 0.70 | 7.36 | 0.00 | 23.93 | 8.82 | 22.24 |
| 3 | 0.70 | 7.36 | 0.00 | 76.03 | 70.75 | -27.84 |
| | 1.00 | 10.50 | 0.00 | 108.41 | 100.88 | -39.69 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.85(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | α [°] | $\varphi_d$ [°] | $c_d$ [kPa] | γ [kN/m³] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 0.08 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 5.32 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.20 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.10 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| 4 | 1.88 | 37.48 | 0.00 | 8.66 | 8.66 | 0.00 |
| | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| 5 | 2.38 | 42.23 | 5.00 | 9.76 | 9.76 | 0.00 |
| | 7.70 | 92.77 | 5.00 | 21.43 | 21.43 | 0.00 |
| 6 | 7.70 | 92.77 | 5.00 | 21.43 | 21.43 | 0.00 |
| | 7.90 | 94.67 | 5.00 | 21.87 | 21.87 | 0.00 |
| 7 | 7.90 | 94.67 | 5.00 | 26.91 | 26.91 | 0.00 |
| | 8.00 | 95.62 | 5.00 | 27.18 | 27.18 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 1.88 | 0.00 | 0.00 |
| 5 | 2.38 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 1.88 | 1.73 | 0.00 |
| 6 | 2.38 | 1.73 | 0.00 |
| 7 | 7.70 | 1.73 | 0.00 |
| 8 | 7.90 | 1.73 | 0.00 |
| 9 | 7.90 | 2.13 | 0.00 |
| 10 | 8.00 | 2.13 | 0.00 |

### Forces acting on construction - combination 2

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.32 | 422.15 | 2.03 | 1.000 | 1.000 | 1.000 |
| FF resistance | -26.16 | -0.33 | -9.88 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.000 |
| Active pressure | 102.72 | -2.93 | 10.68 | 4.08 | 1.000 | 1.000 | 1.000 |

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Water pressure | 29.35 | -2.94 | 0.00 | 3.64 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.000 | 1.000 | 1.000 |
| Pavement | 13.88 | -3.98 | 5.00 | 3.97 | 1.000 | 1.000 | 1.000 |
| Traffic | 37.02 | -3.98 | 13.35 | 3.97 | 1.300 | 1.300 | 1.300 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.000 |
| Traffic | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 1.300 |

### Verification of complete wall

**Check for overturning stability**
Resisting moment $M_{res}$ = 1223.43 kNm/m
Overturning moment $M_{ovr}$ = 656.24 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**
Resisting horizontal force $H_{res}$ = 347.53 kN/m
Active horizontal force $H_{act}$ = 167.92 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 236.28 kPa

## Bearing capacity of foundation soil (Stage of construction 5)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 518.74 | 565.48 | 167.92 | 0.213 | 229.38 |
| 2 | 545.90 | 517.72 | 167.92 | 0.245 | 236.28 |
| 3 | 511.33 | 511.02 | 152.77 | 0.233 | 222.30 |
| 4 | 362.27 | 741.31 | 112.15 | 0.114 | 223.11 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 332.37 | 539.45 | 98.38 |
| 2 | 353.26 | 502.70 | 98.38 |

## Input data (Stage of construction 6)

### Geological profile and assigned soils

| No. | Layer [m] | Assigned soil | Pattern |
|---|---|---|---|
| 1 | 1.80 | Pavement Layers | |
| 2 | 6.10 | Backfill quarry Run | |
| 3 | 6.10 | Existing scour rock (Quarry Run) | |
| 4 | - | Existing scour rock (Quarry Run) | |

### Foundation

Type of foundation : strip foundation
Soil of foundation - Existing scour rock (Quarry Run)

**Geometry**

Foundation thickness $h$ = 1.00 m
Offset left $b_l$ = 3.00 m
Offset right $b_p$ = 1.00 m

### Terrain profile

Terrain behind the structure is flat.

### Water influence

GWT behind the structure lies at a depth of 3.50 m
GWT in front of the structure lies at a depth of 4.00 m
Subgrade at the heel is not permeable.
Uplift in foot. bottom due to different pressures is considered as linear.

### Input surface surcharges

| No. | Surcharge new | Surcharge change | Action | Mag.1 [kN/m²] | Mag.2 [kN/m²] | Ord.x x [m] | Length l [m] | Depth z [m] |
|---|---|---|---|---|---|---|---|---|
| 1 | No | No | permanent | 7.50 | | | | on terrain |
| 2 | No | No | variable | 20.00 | | | | on terrain |

| No. | Name |
|---|---|
| 1 | Pavement |
| 2 | Traffic |

### Resistance on front face of the structure

Resistance on front face of the structure: 1/2 pass., 1/2 at rest
Soil on front face of the structure - Scour rock
Angle of friction struc.-soil $\delta$ = 25.00 °
Soil thickness in front of structure h = 1.00 m

Terrain in front of structure is flat.

### Settings of the stage of construction

Design situation : permanent

## Verification No. 1 (Stage of construction 6)

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m³] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |
| 2 | 0.00 | 89.85(30.00) | 45.00 | 0.00 | 10.50 | -25.00 | 4.497 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | -25.00 | 18.715 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] / End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 137.56 | 124.67 | -58.13 |
| 2 | 0.70 | 7.35 | 0.00 | 33.05 | 14.05 | 29.92 |
| | 0.70 | 7.36 | 0.00 | 33.12 | 14.08 | 29.98 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 0.70 | 7.36 | 0.00 | 137.82 | 124.91 | -58.25 |
| | 1.00 | 10.50 | 0.00 | 196.51 | 178.10 | -83.05 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |
| 2 | 0.00 | 89.85(80.00) | 45.00 | 0.00 | 10.50 | 0.293 | MODIFIED |
| 3 | 0.30 | 0.00 | 45.00 | 0.00 | 10.50 | 0.293 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.15 | 2.15 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.37 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.26 | 0.37 | 7.25 |
| 3 | 0.70 | 7.36 | 0.00 | 2.16 | 2.16 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.08 | 3.08 | 0.00 |

### Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 45.00 | 0.00 | 20.00 | 45.00 | 0.448 | |
| 2 | 0.20 | 0.00 | 45.00 | 0.00 | 20.00 | 0.00 | 0.172 | |
| 3 | 1.70 | 0.00 | 45.00 | 0.00 | 18.50 | 0.00 | 0.172 | |
| 4 | 0.50 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 5 | 3.70 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 6 | 0.20 | 0.00 | 45.00 | 0.00 | 9.50 | 0.00 | 0.172 | |
| 7 | 0.10 | 0.00 | 40.00 | 0.00 | 9.50 | 0.00 | 0.217 | |

### Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 14.35 | 5.49 | 13.26 |
| 2 | 1.60 | 32.00 | 0.00 | 5.49 | 5.49 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 6.18 | 6.18 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 11.57 | 11.57 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 12.39 | 12.39 | 0.00 |
| | 7.70 | 107.35 | 5.00 | 18.42 | 18.42 | 0.00 |
| 6 | 7.70 | 107.35 | 5.00 | 18.42 | 18.42 | 0.00 |
| | 7.90 | 109.25 | 5.00 | 18.74 | 18.74 | 0.00 |
| 7 | 7.90 | 109.25 | 5.00 | 23.76 | 23.76 | 0.00 |
| | 8.00 | 110.20 | 5.00 | 23.96 | 23.96 | 0.00 |

### Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

### Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.29 | 3.11 |
| 2 | 1.60 | 1.29 | 3.11 |
| 3 | 1.60 | 1.29 | 0.00 |
| 4 | 1.80 | 1.29 | 0.00 |
| 5 | 3.50 | 1.29 | 0.00 |
| 6 | 4.00 | 1.29 | 0.00 |
| 7 | 7.70 | 1.29 | 0.00 |
| 8 | 7.90 | 1.29 | 0.00 |
| 9 | 7.90 | 1.63 | 0.00 |
| 10 | 8.00 | 1.63 | 0.00 |

### Pressure profile due to surcharge - Traffic

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 3.43 | 8.28 |
| 2 | 1.60 | 3.43 | 8.28 |
| 3 | 1.60 | 3.43 | 0.00 |
| 4 | 1.80 | 3.43 | 0.00 |
| 5 | 3.50 | 3.43 | 0.00 |
| 6 | 4.00 | 3.43 | 0.00 |
| 7 | 7.70 | 3.43 | 0.00 |
| 8 | 7.90 | 3.43 | 0.00 |
| 9 | 7.90 | 4.35 | 0.00 |
| 10 | 8.00 | 4.35 | 0.00 |

### Forces acting on construction - combination 1

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.38 | 483.71 | 2.07 | 1.000 | 1.000 | 1.350 |
| FF resistance | -45.22 | -0.33 | -20.70 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.350 |
| Active pressure | 89.73 | -2.89 | 10.60 | 4.08 | 1.350 | 1.350 | 1.000 |
| Water pressure | 21.25 | -2.13 | 0.00 | 3.64 | 1.350 | 1.350 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.350 | 1.350 | 1.000 |
| Pavement | 10.33 | -3.99 | 4.97 | 3.97 | 1.350 | 1.350 | 1.000 |
| Traffic | 27.54 | -3.99 | 13.26 | 3.97 | 1.500 | 1.500 | 1.500 |

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.350 |
| Traffic | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 1.500 |

## Verification of complete wall

**Check for overturning stability**

Resisting moment $M_{res}$ = 1400.19 kNm/m
Overturning moment $M_{ovr}$ = 657.73 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 480.45 kN/m
Active horizontal force $H_{act}$ = 159.86 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

Maximum stress in footing bottom : 236.58 kPa

### Passive pressure on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_p$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |
| 2 | 0.00 | 89.85(30.00) | 38.66 | 0.00 | 10.50 | -21.48 | 3.249 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | -21.48 | 10.324 | |

### Passive pressure distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 75.88 | 70.62 | -27.78 |
| 2 | 0.70 | 7.35 | 0.00 | 23.88 | 8.80 | 22.20 |
| | 0.70 | 7.36 | 0.00 | 23.93 | 8.82 | 22.24 |
| 3 | 0.70 | 7.36 | 0.00 | 76.03 | 70.75 | -27.84 |
| | 1.00 | 10.50 | 0.00 | 108.41 | 100.88 | -39.69 |

### Pressure at rest on front face of the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $K_r$ | Comment |
|---|---|---|---|---|---|---|---|
| 1 | 0.70 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |
| 2 | 0.00 | 89.85(80.00) | 38.66 | 0.00 | 10.50 | 0.375 | MODIFIED |
| 3 | 0.30 | 0.00 | 38.66 | 0.00 | 10.50 | 0.375 | |

### Pressure at rest distribution on front face of the structure

| Layer No. | Start [m] End [m] | $\sigma_Z$ [kPa] | $\sigma_W$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 0.70 | 7.35 | 0.00 | 2.76 | 2.76 | 0.00 |
| 2 | 0.70 | 7.35 | 0.00 | 7.25 | 0.48 | 7.24 |
| | 0.70 | 7.36 | 0.00 | 7.27 | 0.48 | 7.25 |

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 3 | 0.70 | 7.36 | 0.00 | 2.76 | 2.76 | 0.00 |
| | 1.00 | 10.50 | 0.00 | 3.94 | 3.94 | 0.00 |

## Active pressure behind the structure - partial results

| Layer No. | Thickness [m] | $\alpha$ [°] | $\varphi_d$ [°] | $c_d$ [kPa] | $\gamma$ [kN/m$^3$] | $\delta_d$ [°] | $K_a$ | Comment |
|---|---|---|---|---|---|---|---|---|
| 1 | 1.60 | 22.50 | 38.66 | 0.00 | 20.00 | 38.66 | 0.476 | |
| 2 | 0.20 | 0.00 | 38.66 | 0.00 | 20.00 | 0.00 | 0.231 | |
| 3 | 1.70 | 0.00 | 38.66 | 0.00 | 18.50 | 0.00 | 0.231 | |
| 4 | 0.50 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 5 | 3.70 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 6 | 0.20 | 0.00 | 38.66 | 0.00 | 9.50 | 0.00 | 0.231 | |
| 7 | 0.10 | 0.00 | 33.87 | 0.00 | 9.50 | 0.00 | 0.284 | |

## Active pressure distribution behind the structure (without surcharge)

| Layer No. | Start [m] End [m] | $\sigma_z$ [kPa] | $\sigma_w$ [kPa] | Pressure [kPa] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | 1.60 | 32.00 | 0.00 | 15.24 | 7.35 | 13.35 |
| 2 | 1.60 | 32.00 | 0.00 | 7.39 | 7.39 | 0.00 |
| | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| 3 | 1.80 | 36.00 | 0.00 | 8.32 | 8.32 | 0.00 |
| | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| 4 | 3.50 | 67.45 | 0.00 | 15.58 | 15.58 | 0.00 |
| | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| 5 | 4.00 | 72.20 | 5.00 | 16.68 | 16.68 | 0.00 |
| | 7.70 | 107.35 | 5.00 | 24.80 | 24.80 | 0.00 |
| 6 | 7.70 | 107.35 | 5.00 | 24.80 | 24.80 | 0.00 |
| | 7.90 | 109.25 | 5.00 | 25.24 | 25.24 | 0.00 |
| 7 | 7.90 | 109.25 | 5.00 | 31.05 | 31.05 | 0.00 |
| | 8.00 | 110.20 | 5.00 | 31.32 | 31.32 | 0.00 |

## Water pressure distribution

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 0.00 | 0.00 |
| 2 | 1.60 | 0.00 | 0.00 |
| 3 | 1.80 | 0.00 | 0.00 |
| 4 | 3.50 | 0.00 | 0.00 |
| 5 | 4.00 | 5.00 | 0.00 |
| 6 | 7.70 | 5.00 | 0.00 |
| 7 | 7.90 | 5.00 | 0.00 |
| 8 | 8.00 | 5.00 | 0.00 |

## Pressure profile due to surcharge - Pavement

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 1.72 | 3.13 |
| 2 | 1.60 | 1.72 | 3.13 |

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 3 | 1.60 | 1.73 | 0.00 |
| 4 | 1.80 | 1.73 | 0.00 |
| 5 | 3.50 | 1.73 | 0.00 |
| 6 | 4.00 | 1.73 | 0.00 |
| 7 | 7.70 | 1.73 | 0.00 |
| 8 | 7.90 | 1.73 | 0.00 |
| 9 | 7.90 | 2.13 | 0.00 |
| 10 | 8.00 | 2.13 | 0.00 |

**Pressure profile due to surcharge - Traffic**

| Point No. | Depth [m] | Hor. comp. [kPa] | Vert. comp. [kPa] |
|---|---|---|---|
| 1 | 0.00 | 4.59 | 8.34 |
| 2 | 1.60 | 4.59 | 8.34 |
| 3 | 1.60 | 4.62 | 0.00 |
| 4 | 1.80 | 4.62 | 0.00 |
| 5 | 3.50 | 4.62 | 0.00 |
| 6 | 4.00 | 4.62 | 0.00 |
| 7 | 7.70 | 4.62 | 0.00 |
| 8 | 7.90 | 4.62 | 0.00 |
| 9 | 7.90 | 5.68 | 0.00 |
| 10 | 8.00 | 5.68 | 0.00 |

**Forces acting on construction - combination 2**

| Name | $F_{hor}$ [kN/m] | App.Pt. z [m] | $F_{vert}$ [kN/m] | App.Pt. x [m] | Coeff. overtur. | Coeff. sliding | Coeff. stress |
|---|---|---|---|---|---|---|---|
| Weight - wall | 0.00 | -4.38 | 483.71 | 2.07 | 1.000 | 1.000 | 1.000 |
| FF resistance | -26.16 | -0.33 | -9.88 | 0.25 | 1.000 | 1.000 | 1.000 |
| Weight - earth wedge | 0.00 | -7.16 | 69.39 | 2.89 | 1.000 | 1.000 | 1.000 |
| Active pressure | 120.68 | -2.89 | 10.68 | 4.08 | 1.000 | 1.000 | 1.000 |
| Water pressure | 21.25 | -2.13 | 0.00 | 3.64 | 1.000 | 1.000 | 1.000 |
| Uplift pressure | 0.00 | 0.00 | -10.75 | 2.87 | 1.000 | 1.000 | 1.000 |
| Pavement | 13.88 | -3.98 | 5.00 | 3.97 | 1.000 | 1.000 | 1.000 |
| Traffic | 37.02 | -3.98 | 13.35 | 3.97 | 1.300 | 1.300 | 1.300 |
| Pavement | 0.00 | -8.00 | 13.78 | 2.72 | 1.000 | 1.000 | 1.000 |
| Traffic | 0.00 | -8.00 | 36.74 | 2.72 | 0.000 | 0.000 | 1.300 |

**Verification of complete wall**

**Check for overturning stability**

Resisting moment $M_{res}$ = 1371.17 kNm/m
Overturning moment $M_{ovr}$ = 663.11 kNm/m

**Wall for overturning is SATISFACTORY**

**Check for slip**

Resisting horizontal force $H_{res}$ = 388.86 kN/m
Active horizontal force $H_{act}$ = 177.78 kN/m

**Wall for slip is SATISFACTORY**

**Overall check - WALL is SATISFACTORY**

**Maximumstressin footingbottom: 236.96 kPa**

## Bearing capacity of foundation soil (Stage of construction 6)

**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] |
|---|---|---|---|---|---|
| 1 | 510.22 | 627.04 | 177.78 | 0.189 | 234.62 |
| 2 | 537.38 | 579.28 | 177.78 | 0.216 | 236.96 |
| 3 | 488.59 | 572.58 | 159.86 | 0.198 | 220.79 |
| 4 | 336.05 | 824.42 | 117.40 | 0.095 | 236.58 |

**Service load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] |
|---|---|---|---|
| 1 | 311.54 | 601.01 | 103.63 |
| 2 | 332.43 | 564.26 | 103.63 |

## GLOBAL STABILITY - BEARING STABILITY VERIFICATION
According BS EN 1997-1:2004_Design Approach 1

PRDW Consulting Port and Coastal Engineers

| S2001_109 | Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment | | Thursday, January 24, 2019 | | 01 of 04 |
|---|---|---|---|---|---|
| APPROVALS | INITIAL | SECTION | Counterfort Wall | | |
| DESIGN | YH | REFERENCE ITEMS | NA | | |
| CHECKED | PES | MODEL REF. | Geo 5 Model: S2001-109-CS-GT-101 | | |
| APPROVED | PES | CALCULATION No. | S2001-109-CS-GT-103 | REVISION | R 0 |

**Calc**

**Bearing on Stone Bed**
**Phase 2 - Mooring and Traffic Loads at HAT: Combo 2**
Bearing Capacity Spreadsheet : acc. to "*A Revised and Extended Formula for Bearing Capacity*"
by J. Brinch Hansen (Reprint of a Lecture in Japan, October 1968)

**Cell Notation**: Input | Calculation | Note

**Design Assumptions**

**Geo 5 Output**
**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] | | DUR |
|---|---|---|---|---|---|---|---|
| 1 | 720.93 | 1366.15 | 186.89 | 0.081 | 250.92 | | |
| 2 | 1060.41 | 930.35 | 246.65 | 0.175 | 220.44 | | |
| 3 | 1093.47 | 944.56 | 262.1 | 0.178 | 225.72 | | |
| 4 | 1018.19 | 1036.52 | 262.1 | 0.151 | 228.54 | PL = Traffic \| SL = Mooring Combo 2 | 0.97 |
| 5 | 753.94 | 1328.35 | 177.95 | 0.087 | 247.6 | | |
| 6 | 1067.37 | 924.38 | 237.7 | 0.178 | 220.58 | | |
| 7 | 1075.46 | 939.35 | 249.62 | 0.176 | 223.11 | | |
| 8 | 1022.76 | 1003.73 | 249.62 | 0.157 | 224.95 | PL = Mooring \| SL = Traffic Combo 2 | 0.96 |

**Output**

**TOTAL REACTION ON BASE**

Total Horizontal Force 249.62 kN
Total Vertical Force 1003.73 kN
Resultant Force 1034.30 kN @ 76 ° to horizontal
Eccentricity 1.02 m
Moment about centre 1022.76 kNm

Base width B 6.50 m — Effective Base width B' = 4.46 m
(Assume base of stone bed as structure base) — Base Stress = 224.95 kPa

Eccentricity Check 0.157
B/6 1.08 m

Stress under base
σmax (toe) 299.66 kPa
σmin (heel) 9.18 kPa

**BEARING CAPACITY**

Bearing Capacity Spreadsheet : acc. to "*A Revised and Extended Formula for Bearing Capacity*"
by J. Brinch Hansen (Reprint of a Lecture in Japan, October 1968)

$Q/A=1/2\gamma BN_\gamma s_\gamma d_\gamma i_\gamma b_\gamma g_\gamma+qN_q s_q d_q i_q b_q g_q+cN_c s_c d_c i_c b_c g_c=$ 236 kPa Bearing Capacity
V/A= 225 kPa Applied Pressure
**Design Utilization Ratio=** 0.96

| | | | |
|---|---|---|---|
| $\phi$= | 32 | frictional angle [deg] | arctan((tanØ)/1.25) |
| c= | 0 | Cohesion of soil/clay [kN/m$_2$] | |
| $\gamma$= | 10.00 | eff unit weight of underlying soil [kN/m$^3$] | |
| ν= | 0 | Slope of foundation from horizontal [deg] | |
| $\beta$= | 0 | Slope of ground from horizontal [deg] | 32.00655748 38 |
| D= | 0 | Depth to foundation [m] | |
| B= | 4.5 | Short side of foundation [m] | |
| L= | 200.0 | Long side of foundation [m] | |
| Q= | 0.00 | Applied surcharge at surface [kN/m$^2$] | |
| H= | 49924 | Horizontal Component of Force Base [kN] | |
| V= | 200746 | Component of Force Normal to Base [kN] | |
| q= | 0.00 | unit surcharge at level of base [kN/m$^2$] | |

| q | | c | | $\gamma$ | |
|---|---|---|---|---|---|
| $N_q$= | 23.18 | $N_c$= | 35.49 | $N_\gamma$= | 27.72 |
| $s_q$= | 1.01 | $s_c$= | 1.01 | $s_\gamma$= | 0.99 |
| $d_q$= | 1.00 | $d_c$= | 1.00 | $d_\gamma$= | 1.00 |
| $i_q$= | 0.54 | $i_c$= | 0.52 | $i_\gamma$= | 0.38 |
| $b_q$= | 1.00 | $b_c$= | 1.00 | $b_\gamma$= | 1.00 |
| $g_q$= | 1.00 | $g_c$= | 1.00 | $g_\gamma$= | 1.00 |
| $P_q$= | 12.65 | $P_c$= | 18.68 | $P_\gamma$= | 10.56 |
| $q * P_q$ = | 0.00 | $c * P_c$ = | 0.00 | $.5*B*\gamma*P_\gamma$= | 235.51 |

s= shape factors
d= depth factors
i= load inclination factors
b= base inclination factors
g= ground inclination factors
Product= N*s*d*i*b*g

# GLOBAL STABILITY - BEARING STABILITY VERIFICATION

According BS EN 1997-1:2004_Design Approach 1

| S2001_109 | Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment | | Thursday, January 24, 2019 | 02 of 04 |
|---|---|---|---|---|
| **APPROVALS** | **INITIAL** | **SECTION** | Counterfort Wall | |
| **DESIGN** | YH | **REFERENCE ITEMS** | NA | |
| **CHECKED** | PES | **MODEL REF.** | Geo 5 Model: S2001-109-CS-GT-101 | |
| **APPROVED** | PES | **CALCULATION No.** | S2001-109-CS-GT-103 | REVISION: R 0 |

**Calc**

**Bearing on Stone Bed**
**Phase 2 - Mooring and Traffic Loads at LAT: Combo 2**
Bearing Capacity Spreadsheet : acc. to "*A Revised and Extended Formula for Bearing Capacity*"
by J. Brinch Hansen (Reprint of a Lecture in Japan, October 1968)

**Cell Notation**

Input | Calculation | Note

**Design Assumptions**

**Geo 5 Output**
**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] | | DUR |
|---|---|---|---|---|---|---|---|
| 1 | 673.23 | 1486.44 | 197.7 | 0.07 | 265.71 | | |
| 2 | 1032.66 | 1019.45 | 261.24 | 0.156 | 227.86 | | |
| 3 | 1086.15 | 1033.66 | 279.46 | 0.162 | 235.01 | | |
| 4 | 1010.87 | 1125.62 | 279.46 | 0.138 | 239.3 | PL = Traffic \| SL = Mooring Combo 2 | 0.96 |
| 5 | 706.24 | 1448.64 | 188.76 | 0.075 | 262.2 | | |
| 6 | 1039.61 | 1013.48 | 252.3 | 0.158 | 227.83 | | |
| 7 | 1068.14 | 1028.45 | 266.98 | 0.16 | 232.53 | | |
| 8 | 1015.44 | 1092.83 | 266.98 | 0.143 | 235.44 | PL = Mooring \| SL = Traffic Combo 2 | 0.94 |

**Output**

**TOTAL REACTION ON BASE**

| | | |
|---|---|---|
| Total Horizontal Force | 279.46 | kN |
| Total Vertical Force | 1125.62 | kN |
| Resultant Force | 1159.79 | kN @ 76 ° to horizontal |
| Eccentricity | 0.90 | m |
| Moment about centre | 1010.87 | kNm |

Base width B 6.50 m — Effective Base width B' = 4.70 m
(Assume base of stone bed as structure base) — Base Stress = 239.30 kPa

Eccentricity Check 0.138
B/6 1.08 m

Stress under base
σmax (toe) 316.73 kPa
σmin (heel) 29.62 kPa

**BEARING CAPACITY**

Bearing Capacity Spreadsheet : acc. to "*A Revised and Extended Formula for Bearing Capacity*"
by J. Brinch Hansen (Reprint of a Lecture in Japan, October 1968)

| | | | |
|---|---|---|---|
| $Q/A=1/2\gamma BN_\gamma s_\gamma d_\gamma i_\gamma b_\gamma g_\gamma+qN_q s_q d_q i_q b_q g_q+cN_c s_c d_c i_c b_c g_c=$ | 249 | kPa | Bearing Capacity |
| V/A= | 239 | kPa | Applied Pressure |
| **Design Utilization Ratio=** | 0.96 | | |

| | | | |
|---|---|---|---|
| ϕ= | 32 | frictional angle [deg] | arctan((tanØ)/1.25) |
| c= | 0 | Cohesion of soil/clay [kN/m2] | |
| γ= | 10.00 | eff unit weight of underlying soil [kN/m$^3$] | |
| ν= | 0 | Slope of foundation from horizontal [deg] | |
| β= | 0 | Slope of ground from horizontal [deg] | 32.00655748 38 |
| D= | 0 | Depth to foundation [m] | |
| B= | 4.7 | Short side of foundation [m] | |
| L= | 200.0 | Long side of foundation [m] | |
| Q= | 0.00 | Applied surcharge at surface [kN/m$^2$] | |
| H= | 55892 | Horizontal Component of Force Base [kN] | |
| V= | 225124 | Component of Force Normal to Base [kN] | |
| q= | 0.00 | unit surcharge at level of base [kN/m$^2$] | |

| q | | c | | γ | |
|---|---|---|---|---|---|
| $N_q$= | 23.18 | $N_c$= | 35.49 | $N_\gamma$= | 27.72 |
| $s_q$= | 1.01 | $s_c$= | 1.02 | $s_\gamma$= | 0.99 |
| $d_q$= | 1.00 | $d_c$= | 1.00 | $d_\gamma$= | 1.00 |
| $i_q$= | 0.54 | $i_c$= | 0.52 | $i_\gamma$= | 0.38 |
| $b_q$= | 1.00 | $b_c$= | 1.00 | $b_\gamma$= | 1.00 |
| $g_q$= | 1.00 | $g_c$= | 1.00 | $g_\gamma$= | 1.00 |
| $P_q$= | 12.64 | $P_c$= | 18.66 | $P_\gamma$= | 10.57 |
| $q * P_q$ = | 0.00 | $c * P_c$ = | 0.00 | $.5*B*\gamma*P_\gamma$= | 248.59 |

s= shape factors
d= depth factors
i= load inclination factors
b= base inclination factors
g= ground inclination factors
Product= N*s*d*i*b*g

# GLOBAL STABILITY - BEARING STABILITY VERIFICATION

According BS EN 1997-1:2004_Design Approach 1

| S2001_109 | Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment | | | Thursday, January 24, 2019 | 03 of 04 |
|---|---|---|---|---|---|
| APPROVALS | INITIAL | | SECTION | Counterfort Wall | |
| DESIGN | YH | | REFERENCE ITEMS | NA | |
| CHECKED | PES | | MODEL REF. | Geo 5 Model: S2001-109-CS-GT-102 | |
| APPROVED | PES | | CALCULATION No. | S2001-109-CS-GT-103 | REVISION R 0 |

**Calc**

**Bearing on Stone Bed**
**Shallow Berth- Mooring and Traffic Loads at HAT: Combo 2**
Bearing Capacity Spreadsheet : acc. to "*A Revised and Extended Formula for Bearing Capacity*"
by J. Brinch Hansen (Reprint of a Lecture in Japan, October 1968)
and BS EN 1997-1:2004 - Design Approach 1

**Cell Notation**

Input | Calculation | Note

**Design Assumptions**

**Geo 5 Output**
**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] | | DUR |
|---|---|---|---|---|---|---|---|
| 1 | 516.71 | 718.81 | 122.71 | 0.167 | 251.13 | | |
| 2 | 656.37 | 505.06 | 163.33 | 0.302 | 296.95 | | 0.94 |
| 3 | 656.95 | 512.51 | 173.37 | 0.298 | 295.17 | PL = Mooring \| SL = Traffic Combo 2 | |
| 4 | 637.94 | 545.95 | 173.37 | 0.272 | 278.12 | | |
| 5 | 630.13 | 565.48 | 181.84 | 0.259 | 273 | | |
| 6 | 657.29 | 517.72 | 181.84 | 0.295 | 294.02 | PL = Traffic \| SL = Mooring Combo 2 | 0.97 |
| 7 | 639.85 | 511.02 | 168.84 | 0.291 | 284.57 | | |
| 8 | 490.79 | 741.31 | 128.22 | 0.154 | 249.11 | | |

**Output**

**TOTAL REACTION ON BASE**

| | | | |
|---|---|---|---|
| Total Horizontal Force | 173.37 | kN | |
| Total Vertical Force | 512.51 | kN | |
| Resultant Force | 541.04 | kN | @ 71 ° to horizontal |
| Eccentricity | 1.28 | m | |
| Moment about centre | 656.95 | kNm | |

| | | | | | |
|---|---|---|---|---|---|
| Base width B | 4.30 | m | Effective Base width B' = | 1.74 | m |
| (Assume base of stone bed as structure base) | | | Base Stress = | 295.17 | kPa |

Eccentricity Check 0.298
B/6 0.72 m

Stress under base
σmax (toe) 332.37 kPa
σmin (heel) -93.99 kPa

**BEARING CAPACITY**

Bearing Capacity Spreadsheet : acc. to "*A Revised and Extended Formula for Bearing Capacity*"
by J. Brinch Hansen (Reprint of a Lecture in Japan, October 1968)

| | | | |
|---|---|---|---|
| $Q/A=1/2\gamma BN_\gamma s_\gamma d_\gamma i_\gamma b_\gamma g_\gamma+qN_q s_q d_q i_q b_q g_q+cN_c s_c d_c i_c b_c g_c=$ | 316 | kPa | Bearing Capacity |
| V/A= | 295 | kPa | Applied Pressure |
| **Design Utilization Ratio=** | 0.94 | | |

| | | | | |
|---|---|---|---|---|
| $\phi=$ | 32 | frictional angle [deg] | arctan((tanØ)/1.25) | |
| c= | 0 | Cohesion of soil/clay [kN/m2] | | |
| $\gamma=$ | 10.00 | eff unit weight of underlying soil [kN/m$^3$] | | |
| v= | 0 | Slope of foundation from horizontal [deg] | | |
| $\beta=$ | 0 | Slope of ground from horizontal [deg] | 32.00655748 | 38 |
| D= | 2.1 | Depth to foundation [m] | | |
| B= | 1.7 | Short side of foundation [m] | | |
| L= | 200.0 | Long side of foundation [m] | | |
| Q= | 0.00 | Applied surcharge at surface [kN/m$^2$] | | |
| H= | 34674 | Horizontal Component of Force Base [kN] | | |
| V= | 102502 | Component of Force Normal to Base [kN] | | |
| q= | 21.00 | unit surcharge at level of base [kN/m$^2$] | | |

| q | | c | | $\gamma$ | |
|---|---|---|---|---|---|
| $N_q=$ | 23.18 | $N_c=$ | 35.49 | $N_\gamma=$ | 27.72 |
| $s_q=$ | 1.00 | $s_c=$ | 1.01 | $s_\gamma=$ | 1.00 |
| $d_q=$ | 1.24 | $d_c=$ | 1.35 | $d_\gamma=$ | 1.00 |
| $i_q=$ | 0.42 | $i_c=$ | 0.39 | $i_\gamma=$ | 0.26 |
| $b_q=$ | 1.00 | $b_c=$ | 1.00 | $b_\gamma=$ | 1.00 |
| $g_q=$ | 1.00 | $g_c=$ | 1.00 | $g_\gamma=$ | 1.00 |
| $P_q=$ | 12.07 | $P_c=$ | 18.86 | $P_\gamma=$ | 7.15 |
| $q * P_q =$ | 253.51 | $c * P_c =$ | 0.00 | $.5*B*\gamma*P_\chi=$ | 62.09 |

s= shape factors
d= depth factors
i= load inclination factors
b= base inclination factors
g= ground inclination factors
Product= N*s*d*i*b*g

# GLOBAL STABILITY - BEARING STABILITY VERIFICATION

According BS EN 1997-1:2004_Design Approach 1

PRDW
Consulting Port and Coastal Engineers

| S2001_109 | Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment | | | Thursday, January 24, 2019 | | 04 of 04 |
|---|---|---|---|---|---|---|
| APPROVALS | INITIAL | | SECTION | Counterfort Wall | | |
| DESIGN | YH | | REFERENCE ITEMS | NA | | |
| CHECKED | PES | | MODEL REF. | Geo 5 Model: S2001-109-CS-GT-102 | | |
| APPROVED | PES | | CALCULATION No. | S2001-109-CS-GT-103 | REVISION | R 0 |

**Calc**

**Bearing on Stone Bed**
**Shallow Berth- Mooring and Traffic Loads at LAT: Combo 2**
Bearing Capacity Spreadsheet : acc. to "*A Revised and Extended Formula for Bearing Capacity*"
by J. Brinch Hansen (Reprint of a Lecture in Japan, October 1968)
and BS EN 1997-1:2004 - Design Approach 1

**Cell Notation**

Input | Calculation | Note

**Design Assumptions**

**Geo 5 Output**
**Design load acting at the center of footing bottom**

| No. | Moment [kNm/m] | Norm. force [kN/m] | Shear Force [kN/m] | Eccentricity [–] | Stress [kPa] | | DUR |
|---|---|---|---|---|---|---|---|
| 1 | 629.42 | 607.51 | 183.23 | 0.241 | 272.69 | | |
| 2 | 648.43 | 574.07 | 183.23 | 0.263 | 281.28 | PL = Mooring \| SL = Traffic Combo 2 | 0.82 |
| 3 | 633.63 | 566.62 | 170.42 | 0.26 | 274.59 | | |
| 4 | 490.49 | 801.92 | 127.96 | 0.142 | 260.64 | | |
| 5 | 621.61 | 627.04 | 191.7 | 0.231 | 270.59 | | |
| 6 | 648.76 | 579.28 | 191.7 | 0.26 | 281.19 | PL = Traffic \| SL = Mooring Combo 2 | 0.85 |
| 7 | 617.11 | 572.58 | 175.93 | 0.251 | 267.01 | | |
| 8 | 464.57 | 824.42 | 133.47 | 0.131 | 259.82 | | |

**Output**

**TOTAL REACTION ON BASE**

| | | | |
|---|---|---|---|
| Total Horizontal Force | 183.23 | kN | |
| Total Vertical Force | 574.07 | kN | |
| Resultant Force | 602.60 | kN | @ 72 ° to horizontal |
| Eccentricity | 1.13 | m | |
| Moment about centre | 648.43 | kNm | |

| | | | | | |
|---|---|---|---|---|---|
| Base width B | 4.30 | m | Effective Base width B' = | 2.04 | m |
| (Assume base of stone bed as structure base) | | | Base Stress = | 281.28 | kPa |

Eccentricity Check 0.263
B/6 0.72 m

Stress under base
σmax (toe) 343.92 kPa
σmin (heel) -76.91 kPa

**BEARING CAPACITY**

Bearing Capacity Spreadsheet : acc. to "*A Revised and Extended Formula for Bearing Capacity*"
by J. Brinch Hansen (Reprint of a Lecture in Japan, October 1968)

| | | | |
|---|---|---|---|
| $Q/A=1/2\gamma BN_\gamma s_\gamma d_\gamma i_\gamma b_\gamma g_\gamma+qN_qs_qd_qi_qb_qg_q+cN_cs_cd_ci_cb_cg_c=$ | 343 | kPa | Bearing Capacity |
| V/A= | 281 | kPa | Applied Pressure |
| **Design Utilization Ratio=** | 0.82 | | |

| | | | |
|---|---|---|---|
| $\phi=$ | 32 | frictional angle [deg] | arctan((tanØ)/1.25) |
| c= | 0 | Cohesion of soil/clay [kN/m$_2$] | |
| $\gamma=$ | 10.00 | eff unit weight of underlying soil [kN/m$^3$] | |
| v= | 0 | Slope of foundation from horizontal [deg] | |
| $\beta=$ | 0 | Slope of ground from horizontal [deg] | 32.00655748 38 |
| D= | 2.1 | Depth to foundation [m] | |
| B= | 2.0 | Short side of foundation [m] | |
| L= | 200.0 | Long side of foundation [m] | |
| Q= | 0.00 | Applied surcharge at surface [kN/m$^2$] | |
| H= | 36646 | Horizontal Component of Force Base [kN] | |
| V= | 114814 | Component of Force Normal to Base [kN] | |
| q= | 21.00 | unit surcharge at level of base [kN/m$^2$] | |

| q | | c | | $\gamma$ | |
|---|---|---|---|---|---|
| $N_q=$ | 23.18 | $N_c=$ | 35.49 | $N_\gamma=$ | 27.72 |
| $s_q=$ | 1.01 | $s_c=$ | 1.01 | $s_\gamma=$ | 1.00 |
| $d_q=$ | 1.22 | $d_c=$ | 1.32 | $d_\gamma=$ | 1.00 |
| $i_q=$ | 0.44 | $i_c=$ | 0.42 | $i_\gamma=$ | 0.28 |
| $b_q=$ | 1.00 | $b_c=$ | 1.00 | $b_\gamma=$ | 1.00 |
| $g_q=$ | 1.00 | $g_c=$ | 1.00 | $g_\gamma=$ | 1.00 |
| $P_q=$ | 12.55 | $P_c=$ | 19.61 | $P_\gamma=$ | 7.80 |
| $q * P_q=$ | 263.52 | $c * P_c=$ | 0.00 | $.5*B*\gamma*P_\chi=$ | 79.55 |

s= shape factors
d= depth factors
i= load inclination factors
b= base inclination factors
g= ground inclination factors
Product= N*s*d*i*b*g

# Slope stability analysis

## Input data

### Project

| | |
|---|---|
| Task : | Global Stability - Slip Verification |
| Part : | Counterfort Wall |
| Description : | Phase 2 Operational Load - Mooring and Traffic Surcharge |
| Customer : | TNPA |
| Author : | YH |
| Date : | 1/23/2019 |
| Project ID : | Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment |
| Project number : | S2001-109 |

### Settings

(input for current task)

### Stability analysis

| | |
|---|---|
| Earthquake analysis : | Standard |
| Verification methodology : | according to EN 1997 |
| Design approach : | 1 - reduction of actions and soil parameters |

**Partial factors on actions (A)**

**Permanent design situation**

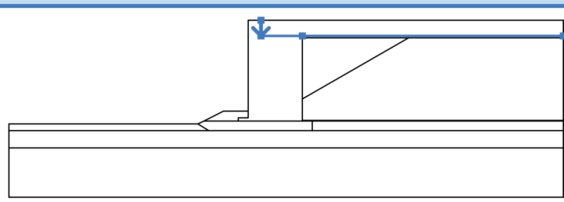
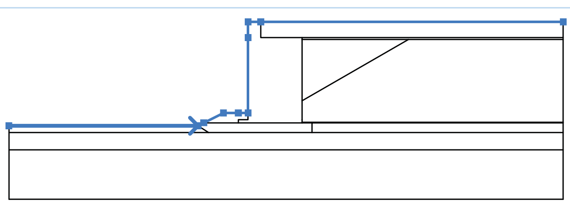
| | | Combination 1 | | | | Combination 2 | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Unfavourable | | Favourable | | Unfavourable | | Favourable | |
| Permanent actions : | $\gamma_G$ = | 1.35 | [–] | 1.00 | [–] | 1.00 | [–] | 1.00 | [–] |
| Variable actions : | $\gamma_Q$ = | 1.50 | [–] | 0.00 | [–] | 1.30 | [–] | 0.00 | [–] |
| Water load : | $\gamma_w$ = | 1.35 | [–] | | | 1.00 | [–] | | |

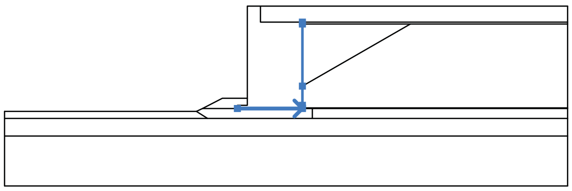
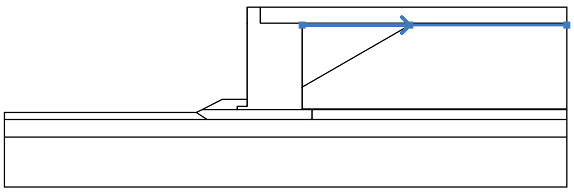
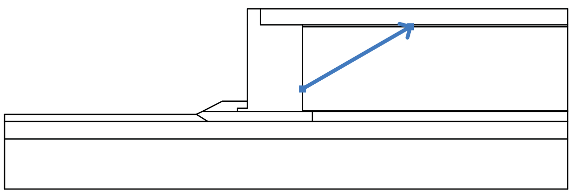
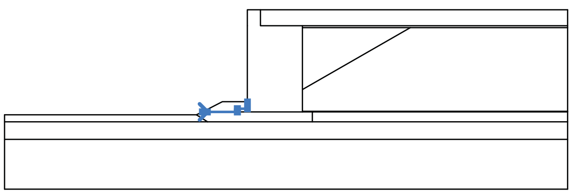
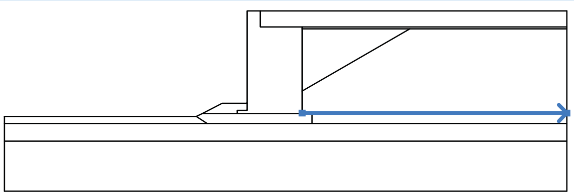
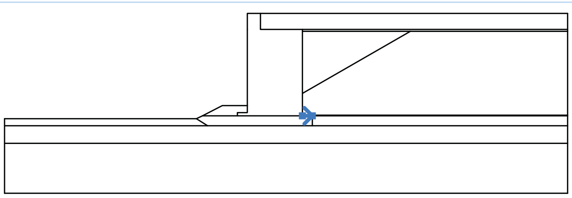
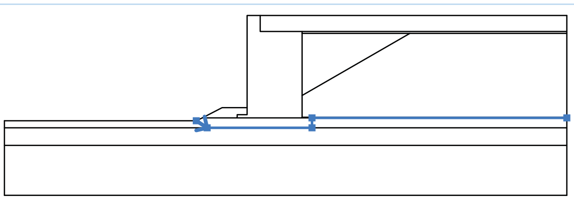
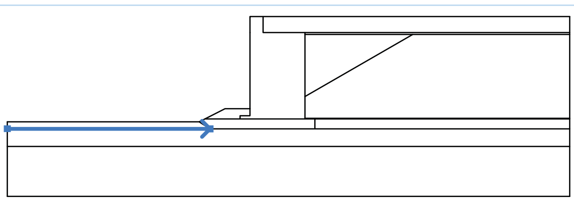
**Partial factors for soil parameters (M)**

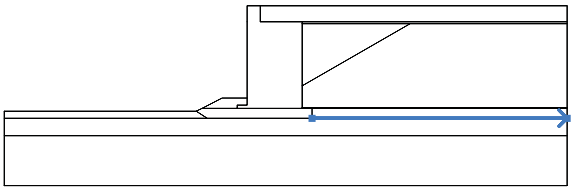
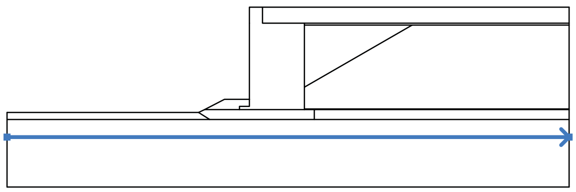
**Permanent design situation**

| | | Combination 1 | | Combination 2 | |
|---|---|---|---|---|---|
| Partial factor on internal friction : | $\gamma_\phi$ = | 1.00 | [–] | 1.25 | [–] |
| Partial factor on effective cohesion : | $\gamma_c$ = | 1.00 | [–] | 1.25 | [–] |
| Partial factor on undrained shear strength : | $\gamma_{cu}$ = | 1.00 | [–] | 1.40 | [–] |

### Interface

| No. | Interface location | Coordinates of interface points [m] | | | | | |
|---|---|---|---|---|---|---|---|
| | | x | z | x | z | x | z |
| 1 |  | 0.00 | 0.00 | 0.00 | -1.60 | 4.20 | -1.60 |
| | | 30.72 | -1.60 | | | | |
| 2 |  | -25.60 | -10.54 | -6.40 | -10.54 | -5.80 | -10.24 |
| | | -3.80 | -9.24 | -2.30 | -9.24 | -1.30 | -9.24 |
| | | -1.30 | -1.60 | -1.30 | 0.00 | 0.00 | 0.00 |
| | | 30.72 | 0.00 | | | | |

| No. | Interface location | Coordinates of interface points [m] | | | | | |
|---|---|---|---|---|---|---|---|
| | | x | z | x | z | x | z |
| 3 |  | -2.30 | -10.24 | 4.20 | -10.24 | 4.20 | -10.20 |
| | | 4.20 | -9.94 | 4.20 | -8.01 | 4.20 | -1.80 |
| | | 4.20 | -1.60 | | | | |
| 4 |  | 4.20 | -1.80 | 15.00 | -1.80 | 30.72 | -1.80 |
| 5 |  | 4.20 | -8.01 | 15.00 | -1.80 | | |
| 6 |  | -5.80 | -10.24 | -5.30 | -10.24 | -2.30 | -10.24 |
| | | -2.30 | -9.94 | -1.30 | -9.94 | -1.30 | -9.24 |
| 7 |  | 4.20 | -10.20 | 30.72 | -10.20 | | |
| 8 |  | 4.20 | -10.24 | 5.20 | -10.24 | | |
| 9 |  | -6.40 | -10.54 | -5.30 | -11.24 | 5.20 | -11.24 |
| | | 5.20 | -10.24 | 30.72 | -10.24 | | |
| 10 |  | -25.60 | -11.23 | -5.30 | -11.24 | | |

| No. | Interface location | Coordinates of interface points [m] | | | | | |
|---|---|---|---|---|---|---|---|
| | | x | z | x | z | x | z |
| 11 |  | 5.20 | -11.24 | 30.72 | -11.24 | | |
| 12 |  | -25.60 | -13.00 | 30.72 | -13.00 | | |

## Soil parameters - effective stress state

| No. | Name | Pattern | $\varphi_{ef}$ [°] | $c_{ef}$ [kPa] | $\gamma$ [kN/m$^3$] |
|---|---|---|---|---|---|
| 1 | Backfill quarry run | | 40.00 | 0.00 | 18.50 |
| 2 | Existing scour rock (Quarry Run) | | 40.00 | 0.00 | 18.50 |
| 3 | Scour rock | | 45.00 | 0.00 | 19.50 |
| 4 | Pavement Layers | | 45.00 | 0.00 | 20.00 |
| 5 | Marine sediment | | 30.00 | 0.00 | 17.50 |
| 6 | Alluvial gravel and cobbles | | 35.00 | 0.00 | 19.00 |

## Soil parameters - uplift

| No. | Name | Pattern | $\gamma_{sat}$ [kN/m$^3$] | $\gamma_s$ [kN/m$^3$] | n [–] |
|---|---|---|---|---|---|
| 1 | Backfill quarry run | | 19.50 | | |
| 2 | Existing scour rock (Quarry Run) | | 19.50 | | |

| No. | Name | Pattern | $\gamma_{sat}$ [kN/m$^3$] | $\gamma_s$ [kN/m$^3$] | n [–] |
|---|---|---|---|---|---|
| 3 | Scour rock | | 20.50 | | |
| 4 | Pavement Layers | | 21.00 | | |
| 5 | Marine sediment | | 18.50 | | |
| 6 | Alluvial gravel and cobbles | | 20.00 | | |

## Soil parameters

**Backfill quarry run**

| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 18.50 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 40.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |
| Saturated unit weight : | $\gamma_{sat}$ = | 19.50 kN/m$^3$ |

**Existing scour rock (Quarry Run)**

| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 18.50 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 40.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |
| Saturated unit weight : | $\gamma_{sat}$ = | 19.50 kN/m$^3$ |

**Scour rock**

| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 19.50 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 45.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |
| Saturated unit weight : | $\gamma_{sat}$ = | 20.50 kN/m$^3$ |

**Pavement Layers**

| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 20.00 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 45.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |
| Saturated unit weight : | $\gamma_{sat}$ = | 21.00 kN/m$^3$ |

**Marine sediment**

| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 17.50 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 30.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |

Saturated unit weight : $\gamma_{sat}$ = 18.50 kN/m$^3$

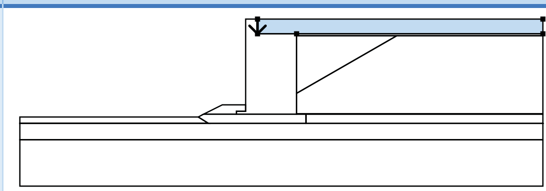
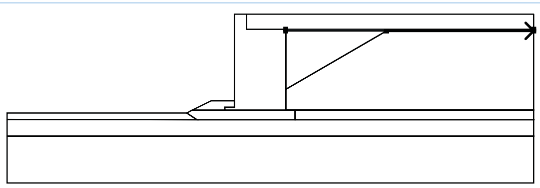
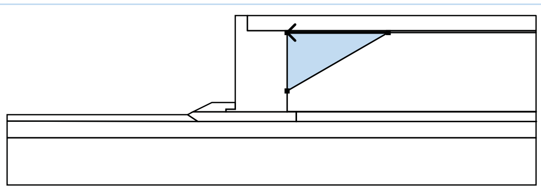
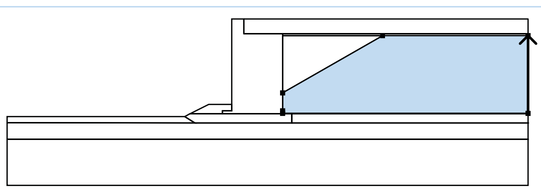
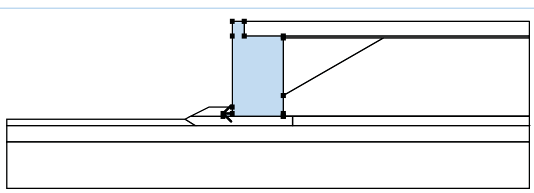
**Alluvial gravel and cobbles**

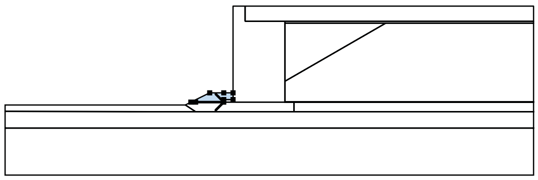
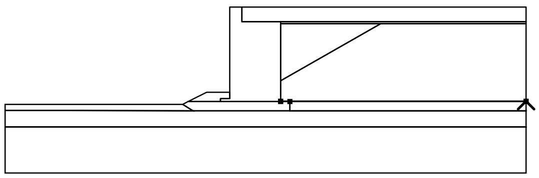
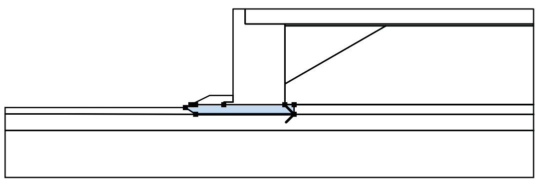
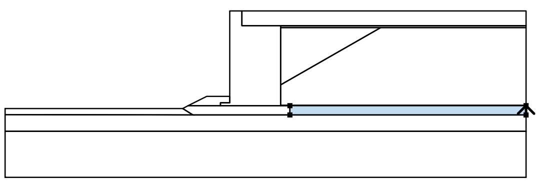
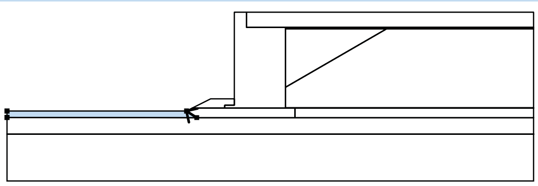
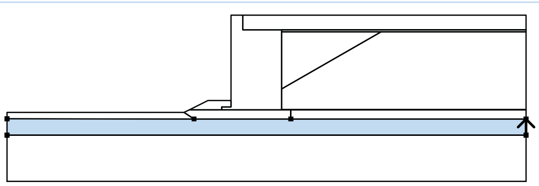
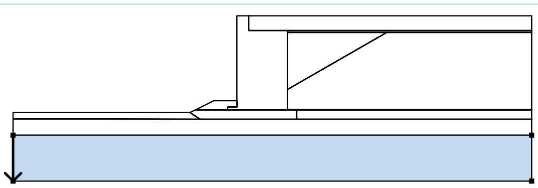
| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 19.00 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 35.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |
| Saturated unit weight : | $\gamma_{sat}$ = | 20.00 kN/m$^3$ |

## Rigid bodies

| No. | Name | Sample | $\gamma$ [kN/m$^3$] |
|---|---|---|---|
| 1 | Wall material | | 23.00 |

## Assigning and surfaces

| No. | Surface position | Coordinates of surface points [m] x | z | x | z | Assigned soil |
|---|---|---|---|---|---|---|
| 1 |  | 0.00 | 0.00 | 0.00 | -1.60 | Pavement Layers |
| | | 4.20 | -1.60 | 30.72 | -1.60 | |
| | | 30.72 | 0.00 | | | |
| 2 |  | 15.00 | -1.80 | 30.72 | -1.80 | Pavement Layers |
| | | 30.72 | -1.60 | 4.20 | -1.60 | |
| | | 4.20 | -1.80 | | | |
| 3 |  | 15.00 | -1.80 | 4.20 | -1.80 | Backfill quarry run |
| | | 4.20 | -8.01 | | | |
| 4 |  | 30.72 | -10.20 | 30.72 | -1.80 | Marine sediment |
| | | 15.00 | -1.80 | 4.20 | -8.01 | |
| | | 4.20 | -9.94 | 4.20 | -10.20 | |
| 5 |  | -1.30 | -9.94 | -2.30 | -9.94 | Wall material |
| | | -2.30 | -10.24 | 4.20 | -10.24 | |
| | | 4.20 | -10.20 | 4.20 | -9.94 | |
| | | 4.20 | -8.01 | 4.20 | -1.80 | |
| | | 4.20 | -1.60 | 0.00 | -1.60 | |
| | | 0.00 | 0.00 | -1.30 | 0.00 | |
| | | -1.30 | -1.60 | -1.30 | -9.24 | |

| No. | Surface position | Coordinates of surface points [m] | | | | Assigned soil |
|---|---|---|---|---|---|---|
| | | x | z | x | z | |
| 6 |  | -5.30 | -10.24 | -2.30 | -10.24 | Scour rock |
| | | -2.30 | -9.94 | -1.30 | -9.94 | |
| | | -1.30 | -9.24 | -2.30 | -9.24 | |
| | | -3.80 | -9.24 | -5.80 | -10.24 | |
| 7 |  | 30.72 | -10.24 | 30.72 | -10.20 | Marine sediment |
| | | 4.20 | -10.20 | 4.20 | -10.24 | |
| | | 5.20 | -10.24 | | | |
| 8 |  | -5.30 | -11.24 | 5.20 | -11.24 | Existing scour rock (Quarry Run) |
| | | 5.20 | -10.24 | 4.20 | -10.24 | |
| | | -2.30 | -10.24 | -5.30 | -10.24 | |
| | | -5.80 | -10.24 | -6.40 | -10.54 | |
| 9 |  | 30.72 | -11.24 | 30.72 | -10.24 | Marine sediment |
| | | 5.20 | -10.24 | 5.20 | -11.24 | |
| 10 |  | -5.30 | -11.24 | -6.40 | -10.54 | Marine sediment |
| | | -25.60 | -10.54 | -25.60 | -11.23 | |
| 11 |  | 30.72 | -13.00 | 30.72 | -11.24 | Marine sediment |
| | | 5.20 | -11.24 | -5.30 | -11.24 | |
| | | -25.60 | -11.23 | -25.60 | -13.00 | |
| 12 |  | -25.60 | -13.00 | -25.60 | -18.00 | Alluvial gravel and cobbles |
| | | 30.72 | -18.00 | 30.72 | -13.00 | |

## Surcharge

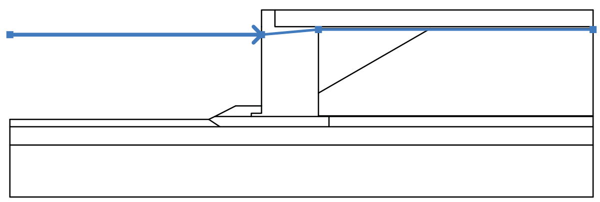
| No. | Type | Type of action | Location | Origin | Length | Width | Slope | Magnitude | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | z [m] | x [m] | l [m] | b [m] | α [°] | q, $q_1$, f, F | $q_2$ | unit |
| 1 | strip | variable | on terrain | x = 0.00 | l = 30.72 | | 0.00 | 20.00 | | kN/m2 |
| 2 | strip | permanent | on terrain | x = 0.00 | l = 30.72 | | 0.00 | 7.50 | | kN/m2 |
| 3 | line | variable | z = 0.00 | x = -1.30 | | | 90.00 | 15.30 | | kN/m |
| 4 | line | permanent | z = 0.00 | x = -0.50 | | | 0.00 | 80.20 | | kN/m |

## Surcharges

| No. | Name |
|---|---|
| 1 | Traffic Surcharge |
| 2 | Pavement |
| 3 | Mooring Load |
| 4 | Deck on Pile Dead Load |

## Water

Water type : GWT

| No. | GWT location | Coordinates of GWT points [m] | | | | | |
|---|---|---|---|---|---|---|---|
| | | x | z | x | z | x | z |
| 1 |  | -25.60 | -2.38 | -1.30 | -2.38 | 4.20 | -1.88 |
| | | 30.72 | -1.88 | | | | |

## Tensile crack

Tensile crack not input.

## Earthquake

Earthquake not included.

## Settings of the stage of construction

Design situation : permanent

# Results (Stage of construction 1)

## Analysis 1 (stage 1)

**Circular slip surface**

| Slip surface parameters | | | | | | | |
|---|---|---|---|---|---|---|---|
| Center : | x = | -5.19 | [m] | Angles : | $\alpha_1$ = | -31.53 | [°] |
| | z = | 3.89 | [m] | | $\alpha_2$ = | 76.72 | [°] |
| Radius : | R = | 16.93 | [m] | | | | |
| The slip surface after optimization. | | | | | | | |

**Slope stability verification (Morgenstern-Price)**
**Combination 1**
Utilization : 67.6 %

**Slope stability ACCEPTABLE**
**Combination 2**
Utilization : 69.2 %

**Slope stability ACCEPTABLE**
Optimized slip surface for : Combination 2
**Optimization of circular slip surface (Morgenstern-Price)**

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 2 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 3 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 4 | 4.89 | 0.83 | 15.62 | 14.9 % | ACCEPTABLE |
| 5 | -13.76 | -7.76 | 11.97 | 2.8 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 6 | -8.38 | 20.53 | 35.43 | 45.1 % | ACCEPTABLE |
| 7 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 8 | -9.31 | 15.79 | 30.48 | 52.6 % | ACCEPTABLE |
| 9 | -7.50 | 8.68 | 25.77 | 50.9 % | ACCEPTABLE |
| 10 | 1.04 | 0.94 | 15.75 | 32.3 % | ACCEPTABLE |
| 11 | -8.98 | 14.49 | 29.53 | 52.7 % | ACCEPTABLE |
| 12 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 13 | -8.48 | 10.40 | 25.02 | 55.2 % | ACCEPTABLE |
| 14 | -7.27 | 6.22 | 22.43 | 53.7 % | ACCEPTABLE |
| 15 | -1.45 | 0.94 | 15.75 | 46.2 % | ACCEPTABLE |
| 16 | -5.52 | 0.14 | 19.79 | 45.7 % | ACCEPTABLE |
| 17 | -8.17 | 9.31 | 24.29 | 55.4 % | ACCEPTABLE |
| 18 | -1.45 | 0.93 | 15.75 | 46.6 % | ACCEPTABLE |
| 19 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 20 | -2.77 | 0.11 | 15.39 | 49.0 % | ACCEPTABLE |
| 21 | -6.14 | 8.58 | 20.63 | 3.1 % | ACCEPTABLE |
| 22 | -7.86 | 7.03 | 21.65 | 50.0 % | ACCEPTABLE |
| 23 | -7.07 | 4.53 | 20.20 | 51.9 % | ACCEPTABLE |
| 24 | -3.11 | 0.94 | 15.75 | 44.5 % | ACCEPTABLE |
| 25 | -5.73 | 0.34 | 18.35 | 44.7 % | ACCEPTABLE |
| 26 | -9.73 | 0.94 | 15.75 | 1.1 % | ACCEPTABLE |
| 27 | -7.61 | 6.23 | 21.16 | 52.3 % | ACCEPTABLE |
| 28 | -3.24 | 1.28 | 15.91 | 52.7 % | ACCEPTABLE |
| 29 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 30 | -4.27 | 1.09 | 15.82 | 55.9 % | ACCEPTABLE |
| 31 | -6.69 | 0.46 | 13.79 | 1.2 % | ACCEPTABLE |
| 32 | -9.11 | 9.86 | 22.85 | 1.5 % | ACCEPTABLE |
| 33 | -5.99 | 5.41 | 18.32 | 8.9 % | ACCEPTABLE |
| 34 | -7.41 | 4.89 | 19.55 | 52.0 % | ACCEPTABLE |
| 35 | -6.90 | 3.38 | 18.72 | 52.0 % | ACCEPTABLE |
| 36 | -4.21 | 0.94 | 15.75 | 55.4 % | ACCEPTABLE |
| 37 | -5.92 | 0.50 | 17.44 | 46.4 % | ACCEPTABLE |
| 38 | -8.63 | 0.94 | 15.75 | 1.7 % | ACCEPTABLE |
| 39 | -8.32 | 0.17 | 15.42 | 2.6 % | ACCEPTABLE |
| 40 | -7.22 | 4.33 | 19.23 | 52.0 % | ACCEPTABLE |
| 41 | -4.35 | 1.30 | 15.92 | 56.0 % | ACCEPTABLE |
| 42 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 43 | -5.09 | 1.30 | 15.92 | 48.9 % | ACCEPTABLE |
| 44 | -6.64 | 0.73 | 14.48 | 2.2 % | ACCEPTABLE |
| 45 | -8.10 | 6.33 | 19.91 | 4.2 % | ACCEPTABLE |
| 46 | -6.05 | 3.71 | 17.23 | 23.3 % | ACCEPTABLE |
| 47 | -7.10 | 3.52 | 18.22 | 49.6 % | ACCEPTABLE |
| 48 | -6.76 | 2.59 | 17.73 | 51.5 % | ACCEPTABLE |
| 49 | -4.95 | 0.94 | 15.75 | 48.7 % | ACCEPTABLE |
| 50 | -6.06 | 0.63 | 16.85 | 47.6 % | ACCEPTABLE |
| 51 | -8.70 | 2.96 | 16.79 | 1.1 % | ACCEPTABLE |
| 52 | -6.92 | 1.37 | 14.81 | 1.7 % | ACCEPTABLE |
| 53 | -7.89 | 0.94 | 15.75 | 5.2 % | ACCEPTABLE |
| 54 | -7.70 | 0.46 | 15.54 | 7.8 % | ACCEPTABLE |
| 55 | -6.96 | 3.14 | 18.01 | 51.5 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 56 | -5.06 | 1.23 | 15.89 | 48.9 % | ACCEPTABLE |
| 57 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 58 | -5.57 | 1.28 | 15.91 | 58.7 % | ACCEPTABLE |
| 59 | -6.58 | 0.84 | 14.92 | 4.5 % | ACCEPTABLE |
| 60 | -7.50 | 4.32 | 18.30 | 7.2 % | ACCEPTABLE |
| 61 | -6.14 | 2.71 | 16.65 | 58.5 % | ACCEPTABLE |
| 62 | -6.88 | 2.64 | 17.36 | 51.3 % | ACCEPTABLE |
| 63 | -6.66 | 2.05 | 17.07 | 51.0 % | ACCEPTABLE |
| 64 | -5.44 | 0.94 | 15.75 | 58.4 % | ACCEPTABLE |
| 65 | -6.17 | 0.72 | 16.47 | 48.3 % | ACCEPTABLE |
| 66 | -7.94 | 2.30 | 16.42 | 1.9 % | ACCEPTABLE |
| 67 | -6.73 | 1.21 | 15.10 | 3.3 % | ACCEPTABLE |
| 68 | -7.40 | 0.94 | 15.75 | 5.9 % | ACCEPTABLE |
| 69 | -7.14 | 0.27 | 15.46 | 50.9 % | ACCEPTABLE |
| 70 | -7.28 | 0.64 | 15.62 | 11.7 % | ACCEPTABLE |
| 71 | -6.78 | 2.38 | 17.23 | 51.3 % | ACCEPTABLE |
| 72 | -5.52 | 1.16 | 15.85 | 58.6 % | ACCEPTABLE |
| 73 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 74 | -5.87 | 1.21 | 15.88 | 50.2 % | ACCEPTABLE |
| 75 | -6.53 | 0.89 | 15.20 | 9.7 % | ACCEPTABLE |
| 76 | -7.13 | 3.11 | 17.36 | 14.2 % | ACCEPTABLE |
| 77 | -6.22 | 2.09 | 16.31 | 50.8 % | ACCEPTABLE |
| 78 | -6.73 | 2.06 | 16.81 | 51.1 % | ACCEPTABLE |
| 79 | -5.40 | 0.02 | 15.35 | 47.2 % | ACCEPTABLE |
| 80 | -6.59 | 1.68 | 16.63 | 50.9 % | ACCEPTABLE |
| 81 | -5.77 | 0.94 | 15.75 | 50.0 % | ACCEPTABLE |
| 82 | -6.25 | 0.79 | 16.22 | 48.4 % | ACCEPTABLE |
| 83 | -6.23 | 0.17 | 14.88 | 60.8 % | ACCEPTABLE |
| 84 | -7.44 | 1.85 | 16.19 | 4.5 % | ACCEPTABLE |
| 85 | -6.62 | 1.11 | 15.31 | 6.2 % | ACCEPTABLE |
| 86 | -7.07 | 0.94 | 15.75 | 14.5 % | ACCEPTABLE |
| 87 | -6.91 | 0.53 | 15.57 | 60.9 % | ACCEPTABLE |
| 88 | -7.00 | 0.75 | 15.66 | 61.5 % | ACCEPTABLE |
| 89 | -6.17 | 0.03 | 14.82 | 60.8 % | ACCEPTABLE |
| 90 | -6.66 | 1.89 | 16.73 | 50.9 % | ACCEPTABLE |
| 91 | -5.83 | 1.09 | 15.82 | 50.1 % | ACCEPTABLE |
| 92 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 93 | -6.06 | 1.14 | 15.84 | 50.3 % | ACCEPTABLE |
| 94 | -6.49 | 0.92 | 15.39 | 28.0 % | ACCEPTABLE |
| 95 | -6.88 | 2.35 | 16.79 | 48.9 % | ACCEPTABLE |
| 96 | -6.28 | 1.69 | 16.11 | 48.4 % | ACCEPTABLE |
| 97 | -6.63 | 1.68 | 16.45 | 51.0 % | ACCEPTABLE |
| 98 | -5.74 | 0.33 | 15.48 | 49.7 % | ACCEPTABLE |
| 99 | -6.53 | 1.44 | 16.33 | 50.7 % | ACCEPTABLE |
| 100 | -5.98 | 0.94 | 15.75 | 50.1 % | ACCEPTABLE |
| 101 | -6.30 | 0.84 | 16.06 | 50.3 % | ACCEPTABLE |
| 102 | -6.29 | 0.43 | 15.17 | 60.9 % | ACCEPTABLE |
| 103 | -7.10 | 1.55 | 16.04 | 7.6 % | ACCEPTABLE |
| 104 | -6.55 | 1.05 | 15.45 | 17.9 % | ACCEPTABLE |
| 105 | -6.86 | 0.94 | 15.75 | 60.9 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 106 | -6.75 | 0.68 | 15.63 | 60.6 % | ACCEPTABLE |
| 107 | -6.21 | 0.22 | 15.07 | 60.7 % | ACCEPTABLE |
| 108 | -6.53 | 0.13 | 15.40 | 57.8 % | ACCEPTABLE |
| 109 | -6.81 | 0.82 | 15.69 | 60.9 % | ACCEPTABLE |
| 110 | -6.25 | 0.33 | 15.12 | 60.9 % | ACCEPTABLE |
| 111 | -6.58 | 1.57 | 16.40 | 50.7 % | ACCEPTABLE |
| 112 | -6.03 | 1.05 | 15.80 | 50.2 % | ACCEPTABLE |
| 113 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 114 | -6.18 | 1.08 | 15.81 | 50.2 % | ACCEPTABLE |
| 115 | -6.47 | 0.93 | 15.51 | 61.2 % | ACCEPTABLE |
| 116 | -6.73 | 1.87 | 16.43 | 50.8 % | ACCEPTABLE |
| 117 | -6.33 | 1.44 | 15.98 | 50.4 % | ACCEPTABLE |
| 118 | -6.56 | 1.43 | 16.22 | 50.7 % | ACCEPTABLE |
| 119 | -5.97 | 0.53 | 15.57 | 49.8 % | ACCEPTABLE |
| 120 | -6.50 | 1.27 | 16.14 | 50.6 % | ACCEPTABLE |
| 121 | -6.13 | 0.94 | 15.75 | 50.2 % | ACCEPTABLE |
| 122 | -6.34 | 0.87 | 15.96 | 50.4 % | ACCEPTABLE |
| 123 | -6.34 | 0.60 | 15.36 | 60.9 % | ACCEPTABLE |
| 124 | -6.87 | 1.35 | 15.94 | 17.9 % | ACCEPTABLE |
| 125 | -6.51 | 1.01 | 15.55 | 61.3 % | ACCEPTABLE |
| 126 | -6.71 | 0.94 | 15.75 | 60.8 % | ACCEPTABLE |
| 127 | -6.31 | 0.23 | 15.32 | 60.2 % | ACCEPTABLE |
| 128 | -6.12 | 0.07 | 15.13 | 59.9 % | ACCEPTABLE |
| 129 | -6.64 | 0.77 | 15.67 | 60.6 % | ACCEPTABLE |
| 130 | -6.28 | 0.45 | 15.30 | 60.7 % | ACCEPTABLE |
| 131 | -6.49 | 0.39 | 15.51 | 60.0 % | ACCEPTABLE |
| 132 | -6.68 | 0.86 | 15.71 | 60.8 % | ACCEPTABLE |
| 133 | -6.31 | 0.53 | 15.33 | 60.6 % | ACCEPTABLE |
| 134 | -6.53 | 1.36 | 16.18 | 50.7 % | ACCEPTABLE |
| 135 | -6.16 | 1.01 | 15.78 | 50.3 % | ACCEPTABLE |
| 136 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 137 | -6.26 | 1.04 | 15.79 | 50.2 % | ACCEPTABLE |
| 138 | -6.45 | 0.93 | 15.59 | 61.1 % | ACCEPTABLE |
| 139 | -6.62 | 1.55 | 16.19 | 50.9 % | ACCEPTABLE |
| 140 | -6.36 | 1.27 | 15.90 | 50.5 % | ACCEPTABLE |
| 141 | -6.51 | 1.27 | 16.06 | 50.8 % | ACCEPTABLE |
| 142 | -6.12 | 0.67 | 15.63 | 50.1 % | ACCEPTABLE |
| 143 | -6.47 | 1.16 | 16.01 | 50.5 % | ACCEPTABLE |
| 144 | -6.23 | 0.94 | 15.75 | 50.2 % | ACCEPTABLE |
| 145 | -6.37 | 0.89 | 15.89 | 50.5 % | ACCEPTABLE |
| 146 | -6.37 | 0.72 | 15.49 | 60.8 % | ACCEPTABLE |
| 147 | -6.72 | 1.21 | 15.88 | 61.2 % | ACCEPTABLE |
| 148 | -6.48 | 0.99 | 15.62 | 61.1 % | ACCEPTABLE |
| 149 | -6.61 | 0.94 | 15.75 | 60.8 % | ACCEPTABLE |
| 150 | -6.34 | 0.46 | 15.46 | 60.3 % | ACCEPTABLE |
| 151 | -6.22 | 0.35 | 15.33 | 60.2 % | ACCEPTABLE |
| 152 | -6.57 | 0.83 | 15.70 | 60.7 % | ACCEPTABLE |
| 153 | -6.33 | 0.62 | 15.45 | 60.7 % | ACCEPTABLE |
| 154 | -6.47 | 0.57 | 15.59 | 60.4 % | ACCEPTABLE |
| 155 | -6.59 | 0.89 | 15.73 | 60.8 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 156 | -6.35 | 0.67 | 15.47 | 60.8 % | ACCEPTABLE |
| 157 | -6.49 | 1.22 | 16.04 | 50.6 % | ACCEPTABLE |
| 158 | -6.25 | 0.99 | 15.77 | 50.4 % | ACCEPTABLE |
| 159 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 160 | -6.32 | 1.01 | 15.78 | 50.4 % | ACCEPTABLE |
| 161 | -6.44 | 0.94 | 15.64 | 60.7 % | ACCEPTABLE |
| 162 | -6.56 | 1.34 | 16.04 | 50.8 % | ACCEPTABLE |
| 163 | -6.38 | 1.16 | 15.85 | 50.6 % | ACCEPTABLE |
| 164 | -6.48 | 1.16 | 15.96 | 50.6 % | ACCEPTABLE |
| 165 | -6.22 | 0.76 | 15.67 | 50.2 % | ACCEPTABLE |
| 166 | -6.45 | 1.09 | 15.92 | 50.6 % | ACCEPTABLE |
| 167 | -6.29 | 0.94 | 15.75 | 50.4 % | ACCEPTABLE |
| 168 | -6.38 | 0.91 | 15.84 | 50.5 % | ACCEPTABLE |
| 169 | -6.38 | 0.79 | 15.58 | 60.8 % | ACCEPTABLE |
| 170 | -6.62 | 1.12 | 15.83 | 61.1 % | ACCEPTABLE |
| 171 | -6.46 | 0.97 | 15.66 | 60.9 % | ACCEPTABLE |
| 172 | -6.55 | 0.94 | 15.75 | 60.7 % | ACCEPTABLE |
| 173 | -6.37 | 0.62 | 15.55 | 60.4 % | ACCEPTABLE |
| 174 | -6.29 | 0.55 | 15.47 | 60.5 % | ACCEPTABLE |
| 175 | -6.52 | 0.87 | 15.72 | 60.6 % | ACCEPTABLE |
| 176 | -6.36 | 0.72 | 15.55 | 60.7 % | ACCEPTABLE |
| 177 | -6.45 | 0.69 | 15.64 | 60.4 % | ACCEPTABLE |
| 178 | -6.54 | 0.91 | 15.73 | 60.8 % | ACCEPTABLE |
| 179 | -6.37 | 0.76 | 15.56 | 60.7 % | ACCEPTABLE |
| 180 | -6.47 | 1.12 | 15.94 | 50.6 % | ACCEPTABLE |
| 181 | -6.30 | 0.97 | 15.77 | 50.2 % | ACCEPTABLE |
| 182 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 183 | -6.35 | 0.98 | 15.77 | 50.2 % | ACCEPTABLE |
| 184 | -6.44 | 0.94 | 15.68 | 61.0 % | ACCEPTABLE |
| 185 | -6.51 | 1.21 | 15.94 | 50.6 % | ACCEPTABLE |
| 186 | -6.39 | 1.08 | 15.82 | 50.5 % | ACCEPTABLE |
| 187 | -6.46 | 1.09 | 15.89 | 50.6 % | ACCEPTABLE |
| 188 | -6.29 | 0.82 | 15.70 | 50.1 % | ACCEPTABLE |
| 189 | -6.44 | 1.04 | 15.87 | 50.6 % | ACCEPTABLE |
| 190 | -6.33 | 0.94 | 15.75 | 50.4 % | ACCEPTABLE |
| 191 | -6.40 | 0.92 | 15.81 | 50.5 % | ACCEPTABLE |
| 192 | -6.40 | 0.84 | 15.63 | 60.8 % | ACCEPTABLE |
| 193 | -6.55 | 1.06 | 15.81 | 60.8 % | ACCEPTABLE |
| 194 | -6.44 | 0.96 | 15.69 | 61.0 % | ACCEPTABLE |
| 195 | -6.51 | 0.94 | 15.75 | 60.7 % | ACCEPTABLE |
| 196 | -6.39 | 0.73 | 15.62 | 60.6 % | ACCEPTABLE |
| 197 | -6.33 | 0.68 | 15.56 | 60.5 % | ACCEPTABLE |
| 198 | -6.49 | 0.89 | 15.73 | 60.5 % | ACCEPTABLE |
| 199 | -6.38 | 0.80 | 15.61 | 60.8 % | ACCEPTABLE |
| 200 | -6.44 | 0.78 | 15.68 | 60.7 % | ACCEPTABLE |
| 201 | -6.50 | 0.92 | 15.74 | 60.7 % | ACCEPTABLE |
| 202 | -6.39 | 0.82 | 15.62 | 60.9 % | ACCEPTABLE |
| 203 | -6.45 | 1.06 | 15.88 | 50.4 % | ACCEPTABLE |
| 204 | -6.34 | 0.96 | 15.76 | 50.3 % | ACCEPTABLE |
| 205 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 206 | -6.37 | 0.97 | 15.76 | 50.4 % | ACCEPTABLE |
| 207 | -6.43 | 0.94 | 15.70 | 60.7 % | ACCEPTABLE |
| 208 | -6.48 | 1.12 | 15.88 | 50.6 % | ACCEPTABLE |
| 209 | -6.40 | 1.04 | 15.79 | 50.3 % | ACCEPTABLE |
| 210 | -6.45 | 1.04 | 15.84 | 50.6 % | ACCEPTABLE |
| 211 | -6.33 | 0.86 | 15.71 | 50.4 % | ACCEPTABLE |
| 212 | -6.44 | 1.01 | 15.83 | 50.4 % | ACCEPTABLE |
| 213 | -6.36 | 0.94 | 15.75 | 50.5 % | ACCEPTABLE |
| 214 | -6.40 | 0.93 | 15.79 | 50.5 % | ACCEPTABLE |
| 215 | -6.40 | 0.87 | 15.67 | 60.6 % | ACCEPTABLE |
| 216 | -6.51 | 1.02 | 15.79 | 60.9 % | ACCEPTABLE |
| 217 | -6.44 | 0.95 | 15.71 | 60.9 % | ACCEPTABLE |
| 218 | -6.48 | 0.94 | 15.75 | 60.6 % | ACCEPTABLE |
| 219 | -6.40 | 0.80 | 15.66 | 60.7 % | ACCEPTABLE |
| 220 | -6.36 | 0.76 | 15.62 | 60.6 % | ACCEPTABLE |
| 221 | -6.47 | 0.91 | 15.74 | 60.7 % | ACCEPTABLE |
| 222 | -6.39 | 0.84 | 15.66 | 60.8 % | ACCEPTABLE |
| 223 | -6.43 | 0.83 | 15.70 | 60.7 % | ACCEPTABLE |
| 224 | -6.47 | 0.92 | 15.74 | 60.6 % | ACCEPTABLE |
| 225 | -6.40 | 0.86 | 15.67 | 60.8 % | ACCEPTABLE |
| 226 | -6.44 | 1.02 | 15.83 | 50.5 % | ACCEPTABLE |
| 227 | -6.37 | 0.96 | 15.76 | 50.3 % | ACCEPTABLE |
| 228 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 229 | -6.39 | 0.96 | 15.76 | 50.4 % | ACCEPTABLE |
| 230 | -6.43 | 0.94 | 15.72 | 60.8 % | ACCEPTABLE |
| 231 | -6.46 | 1.06 | 15.84 | 50.6 % | ACCEPTABLE |
| 232 | -6.41 | 1.00 | 15.78 | 50.5 % | ACCEPTABLE |
| 233 | -6.44 | 1.00 | 15.81 | 50.4 % | ACCEPTABLE |
| 234 | -6.36 | 0.89 | 15.73 | 50.2 % | ACCEPTABLE |
| 235 | -6.43 | 0.98 | 15.80 | 50.4 % | ACCEPTABLE |
| 236 | -6.38 | 0.94 | 15.75 | 50.4 % | ACCEPTABLE |
| 237 | -6.41 | 0.93 | 15.78 | 50.6 % | ACCEPTABLE |
| 238 | -6.41 | 0.90 | 15.70 | 60.8 % | ACCEPTABLE |
| 239 | -6.48 | 0.99 | 15.77 | 60.8 % | ACCEPTABLE |
| 240 | -6.43 | 0.95 | 15.72 | 60.8 % | ACCEPTABLE |
| 241 | -6.46 | 0.94 | 15.75 | 60.6 % | ACCEPTABLE |
| 242 | -6.40 | 0.84 | 15.69 | 60.7 % | ACCEPTABLE |
| 243 | -6.38 | 0.82 | 15.67 | 60.7 % | ACCEPTABLE |
| 244 | -6.45 | 0.92 | 15.74 | 60.8 % | ACCEPTABLE |
| 245 | -6.40 | 0.88 | 15.69 | 61.2 % | ACCEPTABLE |
| 246 | -6.43 | 0.87 | 15.72 | 60.7 % | ACCEPTABLE |
| 247 | -6.45 | 0.93 | 15.75 | 60.7 % | ACCEPTABLE |
| 248 | -6.41 | 0.89 | 15.69 | 60.7 % | ACCEPTABLE |
| 249 | -6.43 | 0.99 | 15.81 | 50.5 % | ACCEPTABLE |
| 250 | -6.39 | 0.95 | 15.75 | 50.3 % | ACCEPTABLE |
| 251 | 4.89 | 0.83 | 15.62 | 14.9 % | ACCEPTABLE |
| 252 | 0.39 | 23.11 | 37.97 | 26.8 % | ACCEPTABLE |
| 253 | -5.69 | 38.51 | 52.86 | 26.6 % | ACCEPTABLE |
| 254 | -1.33 | 15.39 | 35.38 | 29.5 % | ACCEPTABLE |
| 255 | -1.42 | 7.40 | 22.04 | 40.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 256 | -5.68 | 38.45 | 52.81 | 26.6 % | ACCEPTABLE |
| 257 | 10.75 | 6.23 | 20.73 | 3.5 % | ACCEPTABLE |
| 258 | 0.68 | 4.68 | 30.20 | 26.9 % | ACCEPTABLE |
| 259 | -5.06 | 35.16 | 50.02 | 27.4 % | ACCEPTABLE |
| 260 | 11.97 | 1.81 | 18.64 | 3.9 % | ACCEPTABLE |
| 261 | -1.42 | 7.40 | 22.04 | 40.7 % | ACCEPTABLE |
| 262 | -4.48 | 27.12 | 41.40 | 30.4 % | ACCEPTABLE |
| 263 | -2.34 | 17.24 | 33.85 | 34.4 % | ACCEPTABLE |
| 264 | 6.04 | 7.40 | 22.04 | 20.7 % | ACCEPTABLE |
| 265 | 0.29 | 5.18 | 27.01 | 32.4 % | ACCEPTABLE |
| 266 | -8.88 | 7.40 | 22.04 | 57.5 % | ACCEPTABLE |
| 267 | -9.26 | 21.16 | 35.57 | 46.5 % | ACCEPTABLE |
| 268 | -7.78 | 14.87 | 30.92 | 46.5 % | ACCEPTABLE |
| 269 | -1.42 | 7.40 | 22.04 | 40.7 % | ACCEPTABLE |
| 270 | -4.90 | 2.64 | 24.38 | 40.0 % | ACCEPTABLE |
| 271 | -1.51 | 7.68 | 22.22 | 40.7 % | ACCEPTABLE |
| 272 | -8.88 | 7.40 | 22.04 | 57.5 % | ACCEPTABLE |
| 273 | -3.38 | 5.72 | 21.03 | 50.2 % | ACCEPTABLE |
| 274 | -10.20 | 18.48 | 32.76 | 51.9 % | ACCEPTABLE |
| 275 | -8.90 | 13.26 | 28.96 | 52.1 % | ACCEPTABLE |
| 276 | -3.91 | 7.40 | 22.04 | 51.1 % | ACCEPTABLE |
| 277 | -6.79 | 4.80 | 24.12 | 47.1 % | ACCEPTABLE |
| 278 | -12.20 | 3.78 | 19.48 | 1.0 % | ACCEPTABLE |
| 279 | -9.81 | 16.90 | 31.56 | 52.2 % | ACCEPTABLE |
| 280 | -4.22 | 8.40 | 22.68 | 51.6 % | ACCEPTABLE |
| 281 | -8.88 | 7.40 | 22.04 | 57.5 % | ACCEPTABLE |
| 282 | -5.77 | 8.04 | 22.45 | 55.4 % | ACCEPTABLE |
| 283 | -9.23 | 19.05 | 30.97 | 1.3 % | ACCEPTABLE |
| 284 | -10.37 | 15.59 | 29.94 | 49.4 % | ACCEPTABLE |
| 285 | -3.63 | 1.23 | 18.86 | 47.1 % | ACCEPTABLE |
| 286 | -9.41 | 11.92 | 27.34 | 50.2 % | ACCEPTABLE |
| 287 | -5.57 | 7.40 | 22.04 | 55.1 % | ACCEPTABLE |
| 288 | -7.88 | 6.08 | 23.86 | 47.5 % | ACCEPTABLE |
| 289 | -7.87 | 2.32 | 16.60 | 2.4 % | ACCEPTABLE |
| 290 | -10.83 | 3.04 | 19.63 | 6.3 % | ACCEPTABLE |
| 291 | -7.12 | 0.41 | 15.70 | 48.9 % | ACCEPTABLE |
| 292 | -9.94 | 0.22 | 18.51 | 52.0 % | ACCEPTABLE |
| 293 | -11.61 | 5.54 | 20.92 | 2.1 % | ACCEPTABLE |
| 294 | -7.68 | 1.84 | 16.35 | 4.2 % | ACCEPTABLE |
| 295 | -10.00 | 14.18 | 28.91 | 49.6 % | ACCEPTABLE |
| 296 | -5.87 | 8.37 | 22.66 | 55.6 % | ACCEPTABLE |
| 297 | -8.88 | 7.40 | 22.04 | 57.5 % | ACCEPTABLE |
| 298 | -6.99 | 8.43 | 22.70 | 49.3 % | ACCEPTABLE |
| 299 | -9.40 | 7.17 | 20.37 | 1.0 % | ACCEPTABLE |
| 300 | -11.89 | 19.90 | 32.72 | 1.2 % | ACCEPTABLE |
| 301 | -8.77 | 14.09 | 26.85 | 3.2 % | ACCEPTABLE |
| 302 | -9.90 | 12.74 | 27.16 | 49.8 % | ACCEPTABLE |
| 303 | -5.36 | 3.22 | 19.71 | 46.7 % | ACCEPTABLE |
| 304 | -9.26 | 10.45 | 25.58 | 50.1 % | ACCEPTABLE |
| 305 | -6.67 | 7.40 | 22.04 | 51.1 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 306 | -8.15 | 6.44 | 23.15 | 49.2 % | ACCEPTABLE |
| 307 | -8.30 | 4.12 | 18.43 | 6.3 % | ACCEPTABLE |
| 308 | -11.09 | 7.40 | 22.04 | 2.6 % | ACCEPTABLE |
| 309 | -8.13 | 1.05 | 17.83 | 55.5 % | ACCEPTABLE |
| 310 | -10.26 | 4.77 | 20.50 | 11.7 % | ACCEPTABLE |
| 311 | -7.74 | 2.59 | 17.61 | 60.9 % | ACCEPTABLE |
| 312 | -5.66 | 2.94 | 17.79 | 50.6 % | ACCEPTABLE |
| 313 | -10.40 | 12.25 | 25.43 | 1.8 % | ACCEPTABLE |
| 314 | -7.31 | 7.51 | 20.61 | 5.1 % | ACCEPTABLE |
| 315 | -8.71 | 6.86 | 21.70 | 55.1 % | ACCEPTABLE |
| 316 | -8.19 | 5.21 | 20.74 | 58.6 % | ACCEPTABLE |
| 317 | -5.53 | 2.59 | 17.61 | 50.4 % | ACCEPTABLE |
| 318 | -7.20 | 2.06 | 19.20 | 53.5 % | ACCEPTABLE |
| 319 | -9.95 | 2.59 | 17.61 | 1.6 % | ACCEPTABLE |
| 320 | -9.22 | 0.58 | 16.70 | 5.0 % | ACCEPTABLE |
| 321 | -9.64 | 1.75 | 17.20 | 2.1 % | ACCEPTABLE |
| 322 | -8.51 | 6.23 | 21.33 | 57.0 % | ACCEPTABLE |
| 323 | -5.69 | 3.03 | 17.84 | 50.7 % | ACCEPTABLE |
| 324 | -7.74 | 2.59 | 17.61 | 60.9 % | ACCEPTABLE |
| 325 | -6.44 | 3.07 | 17.86 | 59.1 % | ACCEPTABLE |
| 326 | -7.98 | 2.40 | 16.37 | 1.5 % | ACCEPTABLE |
| 327 | -9.40 | 8.44 | 22.22 | 3.7 % | ACCEPTABLE |
| 328 | -7.37 | 5.64 | 19.36 | 11.5 % | ACCEPTABLE |
| 329 | -8.40 | 5.39 | 20.28 | 57.7 % | ACCEPTABLE |
| 330 | -5.45 | 0.34 | 16.61 | 53.7 % | ACCEPTABLE |
| 331 | -8.06 | 4.36 | 19.70 | 59.1 % | ACCEPTABLE |
| 332 | -6.27 | 2.59 | 17.61 | 59.0 % | ACCEPTABLE |
| 333 | -7.36 | 2.21 | 18.64 | 55.7 % | ACCEPTABLE |
| 334 | -7.30 | 0.71 | 15.52 | 6.6 % | ACCEPTABLE |
| 335 | -10.02 | 4.83 | 18.86 | 1.5 % | ACCEPTABLE |
| 336 | -8.27 | 3.10 | 16.76 | 1.1 % | ACCEPTABLE |
| 337 | -9.21 | 2.59 | 17.61 | 4.1 % | ACCEPTABLE |
| 338 | -8.78 | 1.39 | 17.04 | 9.8 % | ACCEPTABLE |
| 339 | -7.02 | 0.01 | 15.23 | 48.5 % | ACCEPTABLE |
| 340 | -9.02 | 2.07 | 17.35 | 5.8 % | ACCEPTABLE |
| 341 | -7.20 | 0.45 | 15.41 | 12.5 % | ACCEPTABLE |
| 342 | -8.26 | 4.96 | 20.03 | 57.4 % | ACCEPTABLE |
| 343 | -6.39 | 2.94 | 17.79 | 59.2 % | ACCEPTABLE |
| 344 | -7.74 | 2.59 | 17.61 | 60.9 % | ACCEPTABLE |
| 345 | -6.91 | 3.00 | 17.82 | 51.5 % | ACCEPTABLE |
| 346 | -7.91 | 2.51 | 16.80 | 2.6 % | ACCEPTABLE |
| 347 | -8.81 | 6.27 | 20.45 | 5.9 % | ACCEPTABLE |
| 348 | -7.46 | 4.53 | 18.68 | 14.0 % | ACCEPTABLE |
| 349 | -8.18 | 4.43 | 19.36 | 57.9 % | ACCEPTABLE |
| 350 | -6.22 | 1.09 | 16.91 | 48.6 % | ACCEPTABLE |
| 351 | -7.96 | 3.78 | 19.00 | 59.2 % | ACCEPTABLE |
| 352 | -6.76 | 2.59 | 17.61 | 51.3 % | ACCEPTABLE |
| 353 | -7.47 | 2.33 | 18.28 | 56.8 % | ACCEPTABLE |
| 354 | -7.47 | 1.35 | 16.22 | 8.3 % | ACCEPTABLE |
| 355 | -9.26 | 4.09 | 18.42 | 2.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 356 | -8.07 | 2.91 | 17.02 | 1.8 % | ACCEPTABLE |
| 357 | -8.72 | 2.59 | 17.61 | 6.8 % | ACCEPTABLE |
| 358 | -7.41 | 0.14 | 16.11 | 48.4 % | ACCEPTABLE |
| 359 | -8.46 | 1.86 | 17.25 | 12.4 % | ACCEPTABLE |
| 360 | -7.27 | 0.84 | 15.99 | 51.7 % | ACCEPTABLE |
| 361 | -8.03 | 0.67 | 16.74 | 58.0 % | ACCEPTABLE |
| 362 | -8.60 | 2.26 | 17.45 | 9.7 % | ACCEPTABLE |
| 363 | -7.38 | 1.14 | 16.12 | 12.5 % | ACCEPTABLE |
| 364 | -8.09 | 4.14 | 19.20 | 59.4 % | ACCEPTABLE |
| 365 | -6.85 | 2.84 | 17.74 | 51.3 % | ACCEPTABLE |
| 366 | -7.74 | 2.59 | 17.61 | 60.9 % | ACCEPTABLE |
| 367 | -7.20 | 2.91 | 17.77 | 60.0 % | ACCEPTABLE |
| 368 | -7.86 | 2.55 | 17.08 | 4.2 % | ACCEPTABLE |
| 369 | -8.43 | 4.95 | 19.41 | 8.2 % | ACCEPTABLE |
| 370 | -7.54 | 3.85 | 18.28 | 27.1 % | ACCEPTABLE |
| 371 | -8.04 | 3.81 | 18.76 | 60.0 % | ACCEPTABLE |
| 372 | -6.72 | 1.59 | 17.13 | 57.6 % | ACCEPTABLE |
| 373 | -7.89 | 3.39 | 18.54 | 59.7 % | ACCEPTABLE |
| 374 | -7.09 | 2.59 | 17.61 | 59.9 % | ACCEPTABLE |
| 375 | -7.56 | 2.41 | 18.05 | 57.2 % | ACCEPTABLE |
| 376 | -7.56 | 1.77 | 16.68 | 25.1 % | ACCEPTABLE |
| 377 | -8.76 | 3.59 | 18.14 | 2.5 % | ACCEPTABLE |
| 378 | -7.95 | 2.80 | 17.20 | 3.4 % | ACCEPTABLE |
| 379 | -8.39 | 2.59 | 17.61 | 6.5 % | ACCEPTABLE |
| 380 | -7.51 | 0.91 | 16.56 | 49.3 % | ACCEPTABLE |
| 381 | -7.10 | 0.53 | 16.13 | 49.1 % | ACCEPTABLE |
| 382 | -8.23 | 2.13 | 17.38 | 11.6 % | ACCEPTABLE |
| 383 | -7.43 | 1.41 | 16.51 | 51.9 % | ACCEPTABLE |
| 384 | -7.92 | 1.28 | 16.99 | 49.6 % | ACCEPTABLE |
| 385 | -8.32 | 2.38 | 17.50 | 8.4 % | ACCEPTABLE |
| 386 | -7.50 | 1.61 | 16.60 | 25.2 % | ACCEPTABLE |
| 387 | -7.97 | 3.61 | 18.66 | 59.8 % | ACCEPTABLE |
| 388 | -7.15 | 2.77 | 17.70 | 60.1 % | ACCEPTABLE |
| 389 | -7.74 | 2.59 | 17.61 | 60.9 % | ACCEPTABLE |
| 390 | -7.39 | 2.82 | 17.73 | 60.2 % | ACCEPTABLE |
| 391 | -7.82 | 2.57 | 17.26 | 8.2 % | ACCEPTABLE |
| 392 | -8.20 | 4.13 | 18.77 | 12.5 % | ACCEPTABLE |
| 393 | -7.60 | 3.41 | 18.04 | 60.6 % | ACCEPTABLE |
| 394 | -7.94 | 3.40 | 18.37 | 59.8 % | ACCEPTABLE |
| 395 | -7.06 | 1.92 | 17.28 | 59.5 % | ACCEPTABLE |
| 396 | -7.84 | 3.12 | 18.23 | 59.8 % | ACCEPTABLE |
| 397 | -7.30 | 2.59 | 17.61 | 60.0 % | ACCEPTABLE |
| 398 | -7.61 | 2.47 | 17.90 | 59.4 % | ACCEPTABLE |
| 399 | -7.63 | 2.05 | 16.99 | 25.1 % | ACCEPTABLE |
| 400 | -8.42 | 3.26 | 17.96 | 4.5 % | ACCEPTABLE |
| 401 | -7.88 | 2.72 | 17.34 | 5.6 % | ACCEPTABLE |
| 402 | -8.18 | 2.59 | 17.61 | 11.4 % | ACCEPTABLE |
| 403 | -7.58 | 1.45 | 16.89 | 51.7 % | ACCEPTABLE |
| 404 | -7.31 | 1.19 | 16.59 | 51.8 % | ACCEPTABLE |
| 405 | -8.07 | 2.30 | 17.47 | 25.1 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 406 | -7.53 | 1.80 | 16.87 | 52.2 % | ACCEPTABLE |
| 407 | -7.85 | 1.70 | 17.18 | 52.0 % | ACCEPTABLE |
| 408 | -8.13 | 2.45 | 17.54 | 24.9 % | ACCEPTABLE |
| 409 | -7.58 | 1.93 | 16.94 | 52.4 % | ACCEPTABLE |
| 410 | -7.90 | 3.27 | 18.30 | 60.0 % | ACCEPTABLE |
| 411 | -7.35 | 2.71 | 17.67 | 60.2 % | ACCEPTABLE |
| 412 | -7.74 | 2.59 | 17.61 | 60.9 % | ACCEPTABLE |
| 413 | -7.51 | 2.75 | 17.69 | 60.2 % | ACCEPTABLE |
| 414 | -7.80 | 2.58 | 17.38 | 16.1 % | ACCEPTABLE |
| 415 | -8.04 | 3.60 | 18.37 | 26.8 % | ACCEPTABLE |
| 416 | -7.65 | 3.13 | 17.89 | 60.2 % | ACCEPTABLE |
| 417 | -7.87 | 3.13 | 18.12 | 60.1 % | ACCEPTABLE |
| 418 | -7.29 | 2.15 | 17.39 | 59.7 % | ACCEPTABLE |
| 419 | -7.81 | 2.95 | 18.02 | 59.9 % | ACCEPTABLE |
| 420 | -7.45 | 2.59 | 17.61 | 60.1 % | ACCEPTABLE |
| 421 | -7.65 | 2.51 | 17.80 | 59.6 % | ACCEPTABLE |
| 422 | -7.66 | 2.23 | 17.20 | 25.2 % | ACCEPTABLE |
| 423 | -8.19 | 3.03 | 17.84 | 8.1 % | ACCEPTABLE |
| 424 | -7.83 | 2.68 | 17.43 | 8.2 % | ACCEPTABLE |
| 425 | -8.03 | 2.59 | 17.61 | 24.9 % | ACCEPTABLE |
| 426 | -7.63 | 1.82 | 17.12 | 52.1 % | ACCEPTABLE |
| 427 | -7.45 | 1.64 | 16.92 | 52.3 % | ACCEPTABLE |
| 428 | -7.96 | 2.40 | 17.52 | 26.4 % | ACCEPTABLE |
| 429 | -7.60 | 2.06 | 17.12 | 52.4 % | ACCEPTABLE |
| 430 | -7.81 | 1.99 | 17.32 | 52.1 % | ACCEPTABLE |
| 431 | -8.00 | 2.50 | 17.56 | 25.0 % | ACCEPTABLE |
| 432 | -7.64 | 2.15 | 17.16 | 52.6 % | ACCEPTABLE |
| 433 | -7.84 | 3.04 | 18.07 | 59.8 % | ACCEPTABLE |
| 434 | -7.48 | 2.67 | 17.65 | 60.1 % | ACCEPTABLE |
| 435 | -7.74 | 2.59 | 17.61 | 60.9 % | ACCEPTABLE |
| 436 | -7.59 | 2.70 | 17.67 | 60.1 % | ACCEPTABLE |
| 437 | -7.78 | 2.59 | 17.45 | 17.2 % | ACCEPTABLE |
| 438 | -7.94 | 3.25 | 18.11 | 27.2 % | ACCEPTABLE |
| 439 | -7.68 | 2.95 | 17.79 | 60.3 % | ACCEPTABLE |
| 440 | -7.83 | 2.95 | 17.95 | 60.0 % | ACCEPTABLE |
| 441 | -7.44 | 2.29 | 17.46 | 60.0 % | ACCEPTABLE |
| 442 | -7.79 | 2.83 | 17.89 | 60.1 % | ACCEPTABLE |
| 443 | -7.55 | 2.59 | 17.61 | 60.1 % | ACCEPTABLE |
| 444 | -7.68 | 2.53 | 17.74 | 60.0 % | ACCEPTABLE |
| 445 | -7.69 | 2.35 | 17.33 | 52.5 % | ACCEPTABLE |
| 446 | -8.04 | 2.89 | 17.76 | 16.0 % | ACCEPTABLE |
| 447 | -7.80 | 2.65 | 17.49 | 17.2 % | ACCEPTABLE |
| 448 | -7.93 | 2.59 | 17.61 | 25.0 % | ACCEPTABLE |
| 449 | -7.67 | 2.07 | 17.28 | 52.2 % | ACCEPTABLE |
| 450 | -7.54 | 1.95 | 17.14 | 60.4 % | ACCEPTABLE |
| 451 | -7.89 | 2.47 | 17.55 | 52.6 % | ACCEPTABLE |
| 452 | -7.65 | 2.24 | 17.28 | 52.5 % | ACCEPTABLE |
| 453 | -7.79 | 2.19 | 17.41 | 52.3 % | ACCEPTABLE |
| 454 | -7.91 | 2.53 | 17.58 | 52.5 % | ACCEPTABLE |
| 455 | -7.67 | 2.29 | 17.31 | 52.5 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 456 | -7.81 | 2.89 | 17.92 | 60.2 % | ACCEPTABLE |
| 457 | -7.57 | 2.65 | 17.64 | 60.2 % | ACCEPTABLE |
| 458 | -7.74 | 2.59 | 17.61 | 60.9 % | ACCEPTABLE |
| 459 | -7.64 | 2.66 | 17.65 | 60.3 % | ACCEPTABLE |
| 460 | -7.76 | 2.59 | 17.51 | 61.1 % | ACCEPTABLE |
| 461 | -7.66 | 2.67 | 17.55 | 60.5 % | ACCEPTABLE |
| 462 | -7.79 | 2.59 | 17.41 | 24.9 % | ACCEPTABLE |
| 463 | -7.89 | 3.03 | 17.84 | 27.2 % | ACCEPTABLE |
| 464 | -7.72 | 2.83 | 17.63 | 28.7 % | ACCEPTABLE |
| 465 | -7.82 | 2.83 | 17.73 | 61.0 % | ACCEPTABLE |
| 466 | -7.56 | 2.39 | 17.41 | 60.0 % | ACCEPTABLE |
| 467 | -7.79 | 2.75 | 17.69 | 29.0 % | ACCEPTABLE |
| 468 | -7.63 | 2.59 | 17.51 | 60.4 % | ACCEPTABLE |
| 469 | -7.72 | 2.55 | 17.59 | 61.1 % | ACCEPTABLE |
| 470 | -7.73 | 2.43 | 17.33 | 25.0 % | ACCEPTABLE |
| 471 | -7.96 | 2.79 | 17.61 | 8.2 % | ACCEPTABLE |
| 472 | -7.80 | 2.63 | 17.43 | 24.9 % | ACCEPTABLE |
| 473 | -7.89 | 2.59 | 17.51 | 26.2 % | ACCEPTABLE |
| 474 | -7.71 | 2.24 | 17.28 | 52.6 % | ACCEPTABLE |
| 475 | -7.63 | 2.16 | 17.19 | 52.5 % | ACCEPTABLE |
| 476 | -7.86 | 2.51 | 17.47 | 26.3 % | ACCEPTABLE |
| 477 | -7.70 | 2.35 | 17.29 | 26.5 % | ACCEPTABLE |
| 478 | -7.79 | 2.32 | 17.37 | 52.5 % | ACCEPTABLE |
| 479 | -7.87 | 2.55 | 17.49 | 24.9 % | ACCEPTABLE |
| 480 | -7.71 | 2.39 | 17.31 | 52.3 % | ACCEPTABLE |
| 481 | -7.81 | 2.79 | 17.71 | 61.0 % | ACCEPTABLE |
| 482 | -7.64 | 2.63 | 17.53 | 60.5 % | ACCEPTABLE |
| 483 | -7.76 | 2.59 | 17.51 | 61.1 % | ACCEPTABLE |
| 484 | -7.69 | 2.64 | 17.54 | 28.8 % | ACCEPTABLE |
| 485 | -7.78 | 2.59 | 17.44 | 17.2 % | ACCEPTABLE |
| 486 | -7.85 | 2.88 | 17.73 | 27.4 % | ACCEPTABLE |
| 487 | -7.73 | 2.75 | 17.59 | 60.2 % | ACCEPTABLE |
| 488 | -7.80 | 2.75 | 17.66 | 29.0 % | ACCEPTABLE |
| 489 | -7.63 | 2.46 | 17.44 | 60.3 % | ACCEPTABLE |
| 490 | -7.78 | 2.70 | 17.63 | 27.6 % | ACCEPTABLE |
| 491 | -7.67 | 2.59 | 17.51 | 60.4 % | ACCEPTABLE |
| 492 | -7.73 | 2.56 | 17.57 | 60.9 % | ACCEPTABLE |
| 493 | -7.74 | 2.48 | 17.39 | 26.3 % | ACCEPTABLE |
| 494 | -7.89 | 2.72 | 17.58 | 17.3 % | ACCEPTABLE |
| 495 | -7.79 | 2.62 | 17.46 | 24.9 % | ACCEPTABLE |
| 496 | -7.85 | 2.59 | 17.51 | 26.4 % | ACCEPTABLE |
| 497 | -7.73 | 2.35 | 17.36 | 52.4 % | ACCEPTABLE |
| 498 | -7.67 | 2.30 | 17.30 | 52.5 % | ACCEPTABLE |
| 499 | -7.83 | 2.54 | 17.48 | 26.4 % | ACCEPTABLE |
| 500 | -7.72 | 2.43 | 17.36 | 26.3 % | ACCEPTABLE |
| 501 | -7.78 | 2.41 | 17.42 | 52.6 % | ACCEPTABLE |
| 502 | -7.84 | 2.56 | 17.50 | 26.4 % | ACCEPTABLE |
| 503 | -7.73 | 2.46 | 17.37 | 52.5 % | ACCEPTABLE |
| 504 | -7.79 | 2.72 | 17.65 | 27.4 % | ACCEPTABLE |
| 505 | -7.68 | 2.62 | 17.52 | 28.9 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 506 | -7.76 | 2.59 | 17.51 | 61.1 % | ACCEPTABLE |
| 507 | -7.72 | 2.62 | 17.53 | 27.6 % | ACCEPTABLE |
| 508 | -7.77 | 2.59 | 17.46 | 27.5 % | ACCEPTABLE |
| 509 | -7.82 | 2.78 | 17.66 | 27.5 % | ACCEPTABLE |
| 510 | -7.74 | 2.70 | 17.56 | 61.3 % | ACCEPTABLE |
| 511 | -7.70 | 2.74 | 17.58 | 60.4 % | ACCEPTABLE |
| 512 | -7.75 | 2.70 | 17.51 | 27.4 % | ACCEPTABLE |
| 513 | -7.80 | 2.90 | 17.71 | 27.2 % | ACCEPTABLE |
| 514 | -7.72 | 2.81 | 17.62 | 27.2 % | ACCEPTABLE |
| 515 | -7.77 | 2.81 | 17.66 | 60.2 % | ACCEPTABLE |
| 516 | -7.65 | 2.61 | 17.51 | 60.4 % | ACCEPTABLE |
| 517 | -7.75 | 2.77 | 17.64 | 60.3 % | ACCEPTABLE |
| 518 | -7.68 | 2.70 | 17.56 | 60.5 % | ACCEPTABLE |
| 519 | -7.72 | 2.68 | 17.60 | 60.4 % | ACCEPTABLE |
| 520 | -7.73 | 2.63 | 17.48 | 27.5 % | ACCEPTABLE |
| 521 | -7.83 | 2.79 | 17.61 | 17.5 % | ACCEPTABLE |
| 522 | -7.76 | 2.72 | 17.52 | 28.9 % | ACCEPTABLE |
| 523 | -7.80 | 2.70 | 17.56 | 27.5 % | ACCEPTABLE |
| 524 | -7.72 | 2.54 | 17.46 | 61.1 % | ACCEPTABLE |
| 525 | -7.68 | 2.51 | 17.42 | 27.5 % | ACCEPTABLE |
| 526 | -7.78 | 2.66 | 17.54 | 29.0 % | ACCEPTABLE |
| 527 | -7.71 | 2.59 | 17.46 | 27.5 % | ACCEPTABLE |
| 528 | -7.75 | 2.58 | 17.50 | 27.6 % | ACCEPTABLE |
| 529 | -7.79 | 2.68 | 17.55 | 27.5 % | ACCEPTABLE |
| 530 | -7.72 | 2.61 | 17.47 | 27.5 % | ACCEPTABLE |
| 531 | -7.76 | 2.79 | 17.65 | 60.2 % | ACCEPTABLE |
| 532 | -7.69 | 2.72 | 17.57 | 60.2 % | ACCEPTABLE |
| 533 | -7.74 | 2.70 | 17.56 | 61.3 % | ACCEPTABLE |
| 534 | -7.71 | 2.72 | 17.57 | 60.2 % | ACCEPTABLE |
| 535 | -7.75 | 2.70 | 17.53 | 27.4 % | ACCEPTABLE |
| 536 | -7.78 | 2.83 | 17.66 | 28.8 % | ACCEPTABLE |
| 537 | -7.73 | 2.77 | 17.60 | 60.3 % | ACCEPTABLE |
| 538 | -7.76 | 2.77 | 17.63 | 60.1 % | ACCEPTABLE |
| 539 | -7.68 | 2.64 | 17.53 | 28.9 % | ACCEPTABLE |
| 540 | -7.75 | 2.75 | 17.61 | 28.9 % | ACCEPTABLE |
| 541 | -7.70 | 2.70 | 17.56 | 60.5 % | ACCEPTABLE |
| 542 | -7.73 | 2.69 | 17.58 | 60.5 % | ACCEPTABLE |
| 543 | -7.73 | 2.65 | 17.51 | 27.5 % | ACCEPTABLE |
| 544 | -7.80 | 2.76 | 17.59 | 27.4 % | ACCEPTABLE |
| 545 | -7.75 | 2.71 | 17.54 | 27.4 % | ACCEPTABLE |
| 546 | -7.78 | 2.70 | 17.56 | 27.5 % | ACCEPTABLE |
| 547 | -7.72 | 2.59 | 17.49 | 29.0 % | ACCEPTABLE |
| 548 | -7.70 | 2.57 | 17.46 | 29.0 % | ACCEPTABLE |
| 549 | -7.77 | 2.68 | 17.55 | 27.5 % | ACCEPTABLE |
| 550 | -7.72 | 2.63 | 17.49 | 27.5 % | ACCEPTABLE |
| 551 | -7.75 | 2.62 | 17.52 | 29.0 % | ACCEPTABLE |
| 552 | -7.77 | 2.69 | 17.55 | 27.5 % | ACCEPTABLE |
| 553 | -7.73 | 2.64 | 17.50 | 27.5 % | ACCEPTABLE |
| 554 | -7.75 | 2.76 | 17.62 | 28.9 % | ACCEPTABLE |
| 555 | -7.71 | 2.71 | 17.57 | 60.3 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 556 | -6.42 | 0.94 | 15.75 | 67.6 % | ACCEPTABLE |
| 557 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 558 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 559 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 560 | 4.89 | 0.83 | 15.62 | 12.7 % | ACCEPTABLE |
| 561 | -8.38 | 20.53 | 35.43 | 50.7 % | ACCEPTABLE |
| 562 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 563 | -9.31 | 15.79 | 30.48 | 58.2 % | ACCEPTABLE |
| 564 | -7.50 | 8.68 | 25.77 | 51.1 % | ACCEPTABLE |
| 565 | 1.04 | 0.94 | 15.75 | 32.2 % | ACCEPTABLE |
| 566 | -8.98 | 14.49 | 29.53 | 57.4 % | ACCEPTABLE |
| 567 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 568 | -8.48 | 10.40 | 25.02 | 61.0 % | ACCEPTABLE |
| 569 | -7.27 | 6.22 | 22.43 | 55.2 % | ACCEPTABLE |
| 570 | -1.45 | 0.94 | 15.75 | 48.1 % | ACCEPTABLE |
| 571 | -5.52 | 0.14 | 19.79 | 42.0 % | ACCEPTABLE |
| 572 | -8.17 | 9.31 | 24.29 | 60.1 % | ACCEPTABLE |
| 573 | -1.45 | 0.93 | 15.75 | 48.5 % | ACCEPTABLE |
| 574 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 575 | -2.77 | 0.11 | 15.39 | 51.8 % | ACCEPTABLE |
| 576 | -6.14 | 8.58 | 20.63 | 3.0 % | ACCEPTABLE |
| 577 | -7.86 | 7.03 | 21.65 | 57.1 % | ACCEPTABLE |
| 578 | -7.07 | 4.53 | 20.20 | 53.8 % | ACCEPTABLE |
| 579 | -3.11 | 0.94 | 15.75 | 48.4 % | ACCEPTABLE |
| 580 | -5.73 | 0.34 | 18.35 | 43.8 % | ACCEPTABLE |
| 581 | -9.73 | 0.94 | 15.75 | 1.1 % | ACCEPTABLE |
| 582 | -7.61 | 6.23 | 21.16 | 56.4 % | ACCEPTABLE |
| 583 | -3.24 | 1.28 | 15.91 | 55.9 % | ACCEPTABLE |
| 584 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 585 | -4.27 | 1.09 | 15.82 | 58.7 % | ACCEPTABLE |
| 586 | -6.69 | 0.46 | 13.79 | 1.6 % | ACCEPTABLE |
| 587 | -9.11 | 9.86 | 22.85 | 1.6 % | ACCEPTABLE |
| 588 | -5.99 | 5.41 | 18.32 | 9.1 % | ACCEPTABLE |
| 589 | -7.41 | 4.89 | 19.55 | 57.1 % | ACCEPTABLE |
| 590 | -6.90 | 3.38 | 18.72 | 54.6 % | ACCEPTABLE |
| 591 | -4.21 | 0.94 | 15.75 | 58.0 % | ACCEPTABLE |
| 592 | -5.92 | 0.50 | 17.44 | 47.2 % | ACCEPTABLE |
| 593 | -8.63 | 0.94 | 15.75 | 1.7 % | ACCEPTABLE |
| 594 | -8.32 | 0.17 | 15.42 | 2.6 % | ACCEPTABLE |
| 595 | -7.22 | 4.33 | 19.23 | 56.1 % | ACCEPTABLE |
| 596 | -4.35 | 1.30 | 15.92 | 59.3 % | ACCEPTABLE |
| 597 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 598 | -5.09 | 1.30 | 15.92 | 53.7 % | ACCEPTABLE |
| 599 | -6.64 | 0.73 | 14.48 | 2.7 % | ACCEPTABLE |
| 600 | -8.10 | 6.33 | 19.91 | 4.5 % | ACCEPTABLE |
| 601 | -6.05 | 3.71 | 17.23 | 25.5 % | ACCEPTABLE |
| 602 | -7.10 | 3.52 | 18.22 | 56.2 % | ACCEPTABLE |
| 603 | -6.76 | 2.59 | 17.73 | 54.6 % | ACCEPTABLE |
| 604 | -4.95 | 0.94 | 15.75 | 52.8 % | ACCEPTABLE |
| 605 | -6.06 | 0.63 | 16.85 | 49.6 % | ACCEPTABLE |

| No. | Center x [m] | Center z [m] | Radius R [m] | Utilization | Verification |
|---|---|---|---|---|---|
| 606 | -8.70 | 2.96 | 16.79 | 1.8 % | ACCEPTABLE |
| 607 | -6.92 | 1.37 | 14.81 | 2.0 % | ACCEPTABLE |
| 608 | -7.89 | 0.94 | 15.75 | 4.6 % | ACCEPTABLE |
| 609 | -7.70 | 0.46 | 15.54 | 6.9 % | ACCEPTABLE |
| 610 | -6.96 | 3.14 | 18.01 | 55.6 % | ACCEPTABLE |
| 611 | -5.06 | 1.23 | 15.89 | 53.5 % | ACCEPTABLE |
| 612 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 613 | -5.57 | 1.28 | 15.91 | 62.0 % | ACCEPTABLE |
| 614 | -6.58 | 0.84 | 14.92 | 4.9 % | ACCEPTABLE |
| 615 | -7.50 | 4.32 | 18.30 | 7.8 % | ACCEPTABLE |
| 616 | -6.14 | 2.71 | 16.65 | 66.4 % | ACCEPTABLE |
| 617 | -6.88 | 2.64 | 17.36 | 55.9 % | ACCEPTABLE |
| 618 | -6.66 | 2.05 | 17.07 | 54.5 % | ACCEPTABLE |
| 619 | -5.44 | 0.94 | 15.75 | 61.0 % | ACCEPTABLE |
| 620 | -6.17 | 0.72 | 16.47 | 51.4 % | ACCEPTABLE |
| 621 | -7.94 | 2.30 | 16.42 | 2.2 % | ACCEPTABLE |
| 622 | -6.73 | 1.21 | 15.10 | 3.5 % | ACCEPTABLE |
| 623 | -7.40 | 0.94 | 15.75 | 5.8 % | ACCEPTABLE |
| 624 | -7.14 | 0.27 | 15.46 | 53.0 % | ACCEPTABLE |
| 625 | -7.28 | 0.64 | 15.62 | 14.5 % | ACCEPTABLE |
| 626 | -6.78 | 2.38 | 17.23 | 55.3 % | ACCEPTABLE |
| 627 | -5.52 | 1.16 | 15.85 | 61.7 % | ACCEPTABLE |
| 628 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 629 | -5.87 | 1.21 | 15.88 | 54.8 % | ACCEPTABLE |
| 630 | -6.53 | 0.89 | 15.20 | 9.6 % | ACCEPTABLE |
| 631 | -7.13 | 3.11 | 17.36 | 15.5 % | ACCEPTABLE |
| 632 | -6.22 | 2.09 | 16.31 | 57.2 % | ACCEPTABLE |
| 633 | -6.73 | 2.06 | 16.81 | 55.5 % | ACCEPTABLE |
| 634 | -5.40 | 0.02 | 15.35 | 51.5 % | ACCEPTABLE |
| 635 | -6.59 | 1.68 | 16.63 | 54.5 % | ACCEPTABLE |
| 636 | -5.77 | 0.94 | 15.75 | 54.0 % | ACCEPTABLE |
| 637 | -6.25 | 0.79 | 16.22 | 52.5 % | ACCEPTABLE |
| 638 | -6.23 | 0.17 | 14.88 | 63.1 % | ACCEPTABLE |
| 639 | -7.44 | 1.85 | 16.19 | 4.7 % | ACCEPTABLE |
| 640 | -6.62 | 1.11 | 15.31 | 6.6 % | ACCEPTABLE |
| 641 | -7.07 | 0.94 | 15.75 | 17.2 % | ACCEPTABLE |
| 642 | -6.91 | 0.53 | 15.57 | 62.0 % | ACCEPTABLE |
| 643 | -7.00 | 0.75 | 15.66 | 63.1 % | ACCEPTABLE |
| 644 | -6.17 | 0.03 | 14.82 | 62.8 % | ACCEPTABLE |
| 645 | -6.66 | 1.89 | 16.73 | 54.9 % | ACCEPTABLE |
| 646 | -5.83 | 1.09 | 15.82 | 54.5 % | ACCEPTABLE |
| 647 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 648 | -6.06 | 1.14 | 15.84 | 54.7 % | ACCEPTABLE |
| 649 | -6.49 | 0.92 | 15.39 | 26.0 % | ACCEPTABLE |
| 650 | -6.88 | 2.35 | 16.79 | 56.4 % | ACCEPTABLE |
| 651 | -6.28 | 1.69 | 16.11 | 55.9 % | ACCEPTABLE |
| 652 | -6.63 | 1.68 | 16.45 | 55.2 % | ACCEPTABLE |
| 653 | -5.74 | 0.33 | 15.48 | 52.5 % | ACCEPTABLE |
| 654 | -6.53 | 1.44 | 16.33 | 54.5 % | ACCEPTABLE |
| 655 | -5.98 | 0.94 | 15.75 | 54.0 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 656 | -6.30 | 0.84 | 16.06 | 52.9 % | ACCEPTABLE |
| 657 | -6.29 | 0.43 | 15.17 | 63.2 % | ACCEPTABLE |
| 658 | -7.10 | 1.55 | 16.04 | 7.3 % | ACCEPTABLE |
| 659 | -6.55 | 1.05 | 15.45 | 16.2 % | ACCEPTABLE |
| 660 | -6.86 | 0.94 | 15.75 | 63.0 % | ACCEPTABLE |
| 661 | -6.75 | 0.68 | 15.63 | 62.1 % | ACCEPTABLE |
| 662 | -6.21 | 0.22 | 15.07 | 62.5 % | ACCEPTABLE |
| 663 | -6.53 | 0.13 | 15.40 | 60.1 % | ACCEPTABLE |
| 664 | -6.81 | 0.82 | 15.69 | 62.7 % | ACCEPTABLE |
| 665 | -6.25 | 0.33 | 15.12 | 62.9 % | ACCEPTABLE |
| 666 | -6.58 | 1.57 | 16.40 | 54.7 % | ACCEPTABLE |
| 667 | -6.03 | 1.05 | 15.80 | 54.4 % | ACCEPTABLE |
| 668 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 669 | -6.18 | 1.08 | 15.81 | 54.4 % | ACCEPTABLE |
| 670 | -6.47 | 0.93 | 15.51 | 64.4 % | ACCEPTABLE |
| 671 | -6.73 | 1.87 | 16.43 | 55.8 % | ACCEPTABLE |
| 672 | -6.33 | 1.44 | 15.98 | 55.4 % | ACCEPTABLE |
| 673 | -6.56 | 1.43 | 16.22 | 54.7 % | ACCEPTABLE |
| 674 | -5.97 | 0.53 | 15.57 | 52.9 % | ACCEPTABLE |
| 675 | -6.50 | 1.27 | 16.14 | 54.3 % | ACCEPTABLE |
| 676 | -6.13 | 0.94 | 15.75 | 54.1 % | ACCEPTABLE |
| 677 | -6.34 | 0.87 | 15.96 | 53.3 % | ACCEPTABLE |
| 678 | -6.34 | 0.60 | 15.36 | 63.3 % | ACCEPTABLE |
| 679 | -6.87 | 1.35 | 15.94 | 16.1 % | ACCEPTABLE |
| 680 | -6.51 | 1.01 | 15.55 | 64.7 % | ACCEPTABLE |
| 681 | -6.71 | 0.94 | 15.75 | 63.0 % | ACCEPTABLE |
| 682 | -6.31 | 0.23 | 15.32 | 61.3 % | ACCEPTABLE |
| 683 | -6.12 | 0.07 | 15.13 | 61.2 % | ACCEPTABLE |
| 684 | -6.64 | 0.77 | 15.67 | 62.4 % | ACCEPTABLE |
| 685 | -6.28 | 0.45 | 15.30 | 62.7 % | ACCEPTABLE |
| 686 | -6.49 | 0.39 | 15.51 | 61.1 % | ACCEPTABLE |
| 687 | -6.68 | 0.86 | 15.71 | 62.8 % | ACCEPTABLE |
| 688 | -6.31 | 0.53 | 15.33 | 62.9 % | ACCEPTABLE |
| 689 | -6.53 | 1.36 | 16.18 | 54.5 % | ACCEPTABLE |
| 690 | -6.16 | 1.01 | 15.78 | 54.3 % | ACCEPTABLE |
| 691 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 692 | -6.26 | 1.04 | 15.79 | 54.4 % | ACCEPTABLE |
| 693 | -6.45 | 0.93 | 15.59 | 64.0 % | ACCEPTABLE |
| 694 | -6.62 | 1.55 | 16.19 | 55.5 % | ACCEPTABLE |
| 695 | -6.36 | 1.27 | 15.90 | 55.1 % | ACCEPTABLE |
| 696 | -6.51 | 1.27 | 16.06 | 54.8 % | ACCEPTABLE |
| 697 | -6.12 | 0.67 | 15.63 | 53.5 % | ACCEPTABLE |
| 698 | -6.47 | 1.16 | 16.01 | 54.3 % | ACCEPTABLE |
| 699 | -6.23 | 0.94 | 15.75 | 54.1 % | ACCEPTABLE |
| 700 | -6.37 | 0.89 | 15.89 | 53.8 % | ACCEPTABLE |
| 701 | -6.37 | 0.72 | 15.49 | 63.2 % | ACCEPTABLE |
| 702 | -6.72 | 1.21 | 15.88 | 64.0 % | ACCEPTABLE |
| 703 | -6.48 | 0.99 | 15.62 | 64.1 % | ACCEPTABLE |
| 704 | -6.61 | 0.94 | 15.75 | 63.1 % | ACCEPTABLE |
| 705 | -6.34 | 0.46 | 15.46 | 61.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 706 | -6.22 | 0.35 | 15.33 | 61.8 % | ACCEPTABLE |
| 707 | -6.57 | 0.83 | 15.70 | 62.7 % | ACCEPTABLE |
| 708 | -6.33 | 0.62 | 15.45 | 62.9 % | ACCEPTABLE |
| 709 | -6.47 | 0.57 | 15.59 | 61.8 % | ACCEPTABLE |
| 710 | -6.59 | 0.89 | 15.73 | 62.9 % | ACCEPTABLE |
| 711 | -6.35 | 0.67 | 15.47 | 63.0 % | ACCEPTABLE |
| 712 | -6.49 | 1.22 | 16.04 | 54.4 % | ACCEPTABLE |
| 713 | -6.25 | 0.99 | 15.77 | 54.4 % | ACCEPTABLE |
| 714 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 715 | -6.32 | 1.01 | 15.78 | 54.4 % | ACCEPTABLE |
| 716 | -6.44 | 0.94 | 15.64 | 63.4 % | ACCEPTABLE |
| 717 | -6.56 | 1.34 | 16.04 | 55.1 % | ACCEPTABLE |
| 718 | -6.38 | 1.16 | 15.85 | 54.9 % | ACCEPTABLE |
| 719 | -6.48 | 1.16 | 15.96 | 54.6 % | ACCEPTABLE |
| 720 | -6.22 | 0.76 | 15.67 | 53.8 % | ACCEPTABLE |
| 721 | -6.45 | 1.09 | 15.92 | 54.4 % | ACCEPTABLE |
| 722 | -6.29 | 0.94 | 15.75 | 54.3 % | ACCEPTABLE |
| 723 | -6.38 | 0.91 | 15.84 | 53.9 % | ACCEPTABLE |
| 724 | -6.38 | 0.79 | 15.58 | 63.1 % | ACCEPTABLE |
| 725 | -6.62 | 1.12 | 15.83 | 63.7 % | ACCEPTABLE |
| 726 | -6.46 | 0.97 | 15.66 | 63.7 % | ACCEPTABLE |
| 727 | -6.55 | 0.94 | 15.75 | 63.0 % | ACCEPTABLE |
| 728 | -6.37 | 0.62 | 15.55 | 62.1 % | ACCEPTABLE |
| 729 | -6.29 | 0.55 | 15.47 | 62.3 % | ACCEPTABLE |
| 730 | -6.52 | 0.87 | 15.72 | 62.7 % | ACCEPTABLE |
| 731 | -6.36 | 0.72 | 15.55 | 62.9 % | ACCEPTABLE |
| 732 | -6.45 | 0.69 | 15.64 | 62.1 % | ACCEPTABLE |
| 733 | -6.54 | 0.91 | 15.73 | 62.9 % | ACCEPTABLE |
| 734 | -6.37 | 0.76 | 15.56 | 63.0 % | ACCEPTABLE |
| 735 | -6.47 | 1.12 | 15.94 | 54.5 % | ACCEPTABLE |
| 736 | -6.30 | 0.97 | 15.77 | 54.2 % | ACCEPTABLE |
| 737 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 738 | -6.35 | 0.98 | 15.77 | 54.2 % | ACCEPTABLE |
| 739 | -6.44 | 0.94 | 15.68 | 63.5 % | ACCEPTABLE |
| 740 | -6.51 | 1.21 | 15.94 | 54.8 % | ACCEPTABLE |
| 741 | -6.39 | 1.08 | 15.82 | 54.6 % | ACCEPTABLE |
| 742 | -6.46 | 1.09 | 15.89 | 54.5 % | ACCEPTABLE |
| 743 | -6.29 | 0.82 | 15.70 | 53.8 % | ACCEPTABLE |
| 744 | -6.44 | 1.04 | 15.87 | 54.4 % | ACCEPTABLE |
| 745 | -6.33 | 0.94 | 15.75 | 54.3 % | ACCEPTABLE |
| 746 | -6.40 | 0.92 | 15.81 | 54.0 % | ACCEPTABLE |
| 747 | -6.40 | 0.84 | 15.63 | 63.1 % | ACCEPTABLE |
| 748 | -6.55 | 1.06 | 15.81 | 63.3 % | ACCEPTABLE |
| 749 | -6.44 | 0.96 | 15.69 | 63.6 % | ACCEPTABLE |
| 750 | -6.51 | 0.94 | 15.75 | 63.0 % | ACCEPTABLE |
| 751 | -6.39 | 0.73 | 15.62 | 62.5 % | ACCEPTABLE |
| 752 | -6.33 | 0.68 | 15.56 | 62.5 % | ACCEPTABLE |
| 753 | -6.49 | 0.89 | 15.73 | 62.6 % | ACCEPTABLE |
| 754 | -6.38 | 0.80 | 15.61 | 63.0 % | ACCEPTABLE |
| 755 | -6.44 | 0.78 | 15.68 | 62.5 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 756 | -6.50 | 0.92 | 15.74 | 62.9 % | ACCEPTABLE |
| 757 | -6.39 | 0.82 | 15.62 | 63.2 % | ACCEPTABLE |
| 758 | -6.45 | 1.06 | 15.88 | 54.3 % | ACCEPTABLE |
| 759 | -6.34 | 0.96 | 15.76 | 54.2 % | ACCEPTABLE |
| 760 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 761 | -6.37 | 0.97 | 15.76 | 54.4 % | ACCEPTABLE |
| 762 | -6.43 | 0.94 | 15.70 | 63.2 % | ACCEPTABLE |
| 763 | -6.48 | 1.12 | 15.88 | 54.7 % | ACCEPTABLE |
| 764 | -6.40 | 1.04 | 15.79 | 54.4 % | ACCEPTABLE |
| 765 | -6.45 | 1.04 | 15.84 | 54.5 % | ACCEPTABLE |
| 766 | -6.33 | 0.86 | 15.71 | 54.1 % | ACCEPTABLE |
| 767 | -6.44 | 1.01 | 15.83 | 54.3 % | ACCEPTABLE |
| 768 | -6.36 | 0.94 | 15.75 | 54.3 % | ACCEPTABLE |
| 769 | -6.40 | 0.93 | 15.79 | 54.2 % | ACCEPTABLE |
| 770 | -6.40 | 0.87 | 15.67 | 63.0 % | ACCEPTABLE |
| 771 | -6.51 | 1.02 | 15.79 | 63.4 % | ACCEPTABLE |
| 772 | -6.44 | 0.95 | 15.71 | 63.4 % | ACCEPTABLE |
| 773 | -6.48 | 0.94 | 15.75 | 62.9 % | ACCEPTABLE |
| 774 | -6.40 | 0.80 | 15.66 | 62.8 % | ACCEPTABLE |
| 775 | -6.36 | 0.76 | 15.62 | 62.7 % | ACCEPTABLE |
| 776 | -6.47 | 0.91 | 15.74 | 62.9 % | ACCEPTABLE |
| 777 | -6.39 | 0.84 | 15.66 | 63.0 % | ACCEPTABLE |
| 778 | -6.43 | 0.83 | 15.70 | 62.8 % | ACCEPTABLE |
| 779 | -6.47 | 0.92 | 15.74 | 62.9 % | ACCEPTABLE |
| 780 | -6.40 | 0.86 | 15.67 | 63.0 % | ACCEPTABLE |
| 781 | -6.44 | 1.02 | 15.83 | 54.4 % | ACCEPTABLE |
| 782 | -6.37 | 0.96 | 15.76 | 54.2 % | ACCEPTABLE |
| 783 | -6.42 | 0.94 | 15.75 | 68.6 % | ACCEPTABLE |
| 784 | -6.39 | 0.96 | 15.76 | 54.2 % | ACCEPTABLE |
| 785 | -6.43 | 0.94 | 15.72 | 63.2 % | ACCEPTABLE |
| 786 | -6.46 | 1.06 | 15.84 | 54.5 % | ACCEPTABLE |
| 787 | -6.41 | 1.00 | 15.78 | 54.4 % | ACCEPTABLE |
| 788 | -6.44 | 1.00 | 15.81 | 54.3 % | ACCEPTABLE |
| 789 | -6.36 | 0.89 | 15.73 | 54.0 % | ACCEPTABLE |
| 790 | -6.43 | 0.98 | 15.80 | 54.2 % | ACCEPTABLE |
| 791 | -6.38 | 0.94 | 15.75 | 54.3 % | ACCEPTABLE |
| 792 | -6.41 | 0.93 | 15.78 | 54.3 % | ACCEPTABLE |
| 793 | -6.41 | 0.90 | 15.70 | 63.2 % | ACCEPTABLE |
| 794 | -6.48 | 0.99 | 15.77 | 63.3 % | ACCEPTABLE |
| 795 | -6.43 | 0.95 | 15.72 | 63.3 % | ACCEPTABLE |
| 796 | -6.46 | 0.94 | 15.75 | 62.9 % | ACCEPTABLE |
| 797 | -6.40 | 0.84 | 15.69 | 62.9 % | ACCEPTABLE |
| 798 | -6.38 | 0.82 | 15.67 | 62.9 % | ACCEPTABLE |
| 799 | -6.45 | 0.92 | 15.74 | 63.1 % | ACCEPTABLE |
| 800 | -6.40 | 0.88 | 15.69 | 62.7 % | ACCEPTABLE |
| 801 | -6.43 | 0.87 | 15.72 | 62.9 % | ACCEPTABLE |
| 802 | -6.45 | 0.93 | 15.75 | 63.0 % | ACCEPTABLE |
| 803 | -6.41 | 0.89 | 15.69 | 63.1 % | ACCEPTABLE |
| 804 | -6.43 | 0.99 | 15.81 | 54.3 % | ACCEPTABLE |
| 805 | -6.39 | 0.95 | 15.75 | 54.2 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 806 | 4.89 | 0.83 | 15.62 | 12.7 % | ACCEPTABLE |
| 807 | 0.39 | 23.11 | 37.97 | 31.0 % | ACCEPTABLE |
| 808 | -5.69 | 38.51 | 52.86 | 34.5 % | ACCEPTABLE |
| 809 | 3.54 | 14.32 | 30.54 | 26.1 % | ACCEPTABLE |
| 810 | 3.01 | 16.56 | 32.11 | 27.4 % | ACCEPTABLE |
| 811 | -1.05 | 6.21 | 21.31 | 42.8 % | ACCEPTABLE |
| 812 | -2.25 | 20.26 | 38.53 | 31.8 % | ACCEPTABLE |
| 813 | -4.55 | 32.48 | 47.80 | 34.0 % | ACCEPTABLE |
| 814 | -1.05 | 6.21 | 21.31 | 42.8 % | ACCEPTABLE |
| 815 | -3.90 | 24.40 | 39.20 | 44.8 % | ACCEPTABLE |
| 816 | 2.64 | 18.11 | 33.24 | 27.9 % | ACCEPTABLE |
| 817 | 6.39 | 2.20 | 24.23 | 18.4 % | ACCEPTABLE |
| 818 | 2.61 | 18.25 | 33.35 | 27.9 % | ACCEPTABLE |
| 819 | -0.53 | 11.11 | 32.98 | 27.8 % | ACCEPTABLE |
| 820 | -1.52 | 7.70 | 22.22 | 44.8 % | ACCEPTABLE |
| 821 | -5.74 | 6.19 | 25.82 | 41.0 % | ACCEPTABLE |
| 822 | 0.16 | 2.34 | 19.30 | 36.7 % | ACCEPTABLE |
| 823 | -4.54 | 1.09 | 23.89 | 33.3 % | ACCEPTABLE |
| 824 | -7.79 | 14.88 | 30.93 | 49.6 % | ACCEPTABLE |
| 825 | 1.05 | 9.03 | 27.27 | 36.3 % | ACCEPTABLE |
| 826 | -8.91 | 11.34 | 23.68 | 1.3 % | ACCEPTABLE |
| 827 | -0.33 | 14.88 | 30.93 | 40.4 % | ACCEPTABLE |
| 828 | -1.52 | 5.69 | 28.87 | 28.0 % | ACCEPTABLE |
| 829 | -5.00 | 0.27 | 16.87 | 52.0 % | ACCEPTABLE |
| 830 | -6.19 | 8.09 | 26.76 | 43.3 % | ACCEPTABLE |
| 831 | 2.46 | 0.27 | 16.87 | 26.8 % | ACCEPTABLE |
| 832 | -5.00 | 0.27 | 16.87 | 52.0 % | ACCEPTABLE |
| 833 | -11.19 | 25.47 | 37.88 | 2.1 % | ACCEPTABLE |
| 834 | -4.04 | 11.63 | 23.90 | 53.5 % | ACCEPTABLE |
| 835 | -0.37 | 15.30 | 26.94 | 35.7 % | ACCEPTABLE |
| 836 | -7.74 | 31.20 | 42.97 | 7.9 % | ACCEPTABLE |
| 837 | -4.36 | 18.48 | 32.04 | 52.4 % | ACCEPTABLE |
| 838 | 0.93 | 11.63 | 23.90 | 34.9 % | ACCEPTABLE |
| 839 | -1.58 | 7.98 | 24.71 | 43.8 % | ACCEPTABLE |
| 840 | -2.69 | 3.44 | 14.96 | 4.8 % | ACCEPTABLE |
| 841 | -9.01 | 11.63 | 23.90 | 1.3 % | ACCEPTABLE |
| 842 | -5.07 | 0.48 | 16.94 | 52.8 % | ACCEPTABLE |
| 843 | -7.15 | 6.37 | 20.06 | 27.8 % | ACCEPTABLE |
| 844 | -1.78 | 1.74 | 13.76 | 46.4 % | ACCEPTABLE |
| 845 | -6.22 | 25.48 | 37.88 | 52.3 % | ACCEPTABLE |
| 846 | -0.44 | 15.50 | 27.12 | 31.7 % | ACCEPTABLE |
| 847 | -4.04 | 11.63 | 23.90 | 53.5 % | ACCEPTABLE |
| 848 | -2.33 | 16.16 | 27.68 | 42.8 % | ACCEPTABLE |
| 849 | -6.54 | 24.05 | 35.93 | 50.3 % | ACCEPTABLE |
| 850 | 2.14 | 3.53 | 18.36 | 32.5 % | ACCEPTABLE |
| 851 | -4.29 | 16.24 | 29.34 | 57.0 % | ACCEPTABLE |
| 852 | -2.04 | 19.92 | 32.36 | 49.0 % | ACCEPTABLE |
| 853 | -5.95 | 17.03 | 28.45 | 2.4 % | ACCEPTABLE |
| 854 | -6.33 | 28.49 | 41.22 | 52.1 % | ACCEPTABLE |
| 855 | 1.62 | 7.27 | 23.02 | 31.5 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 856 | -4.65 | 21.62 | 35.46 | 49.8 % | ACCEPTABLE |
| 857 | -0.98 | 16.24 | 29.34 | 46.7 % | ACCEPTABLE |
| 858 | -2.52 | 12.93 | 29.02 | 45.0 % | ACCEPTABLE |
| 859 | -3.60 | 10.37 | 22.91 | 54.8 % | ACCEPTABLE |
| 860 | -7.60 | 16.24 | 29.34 | 61.4 % | ACCEPTABLE |
| 861 | -5.35 | 19.92 | 32.36 | 55.0 % | ACCEPTABLE |
| 862 | -9.64 | 28.49 | 41.22 | 53.8 % | ACCEPTABLE |
| 863 | -1.69 | 7.27 | 23.02 | 46.1 % | ACCEPTABLE |
| 864 | -7.96 | 21.62 | 35.46 | 56.8 % | ACCEPTABLE |
| 865 | -4.29 | 16.24 | 29.34 | 57.0 % | ACCEPTABLE |
| 866 | -5.83 | 12.93 | 29.02 | 50.4 % | ACCEPTABLE |
| 867 | -6.91 | 10.37 | 22.91 | 5.8 % | ACCEPTABLE |
| 868 | -10.91 | 16.24 | 29.34 | 2.3 % | ACCEPTABLE |
| 869 | -5.77 | 3.33 | 19.58 | 54.6 % | ACCEPTABLE |
| 870 | -3.74 | 1.41 | 17.32 | 52.4 % | ACCEPTABLE |
| 871 | -8.90 | 9.28 | 24.26 | 56.1 % | ACCEPTABLE |
| 872 | -5.35 | 5.97 | 19.80 | 63.6 % | ACCEPTABLE |
| 873 | -2.30 | 6.72 | 20.29 | 48.9 % | ACCEPTABLE |
| 874 | -5.95 | 4.78 | 16.85 | 1.7 % | ACCEPTABLE |
| 875 | -6.33 | 18.11 | 29.41 | 1.3 % | ACCEPTABLE |
| 876 | -7.04 | 14.33 | 27.85 | 62.2 % | ACCEPTABLE |
| 877 | -5.85 | 10.21 | 24.88 | 57.6 % | ACCEPTABLE |
| 878 | -2.04 | 5.97 | 19.80 | 47.5 % | ACCEPTABLE |
| 879 | -4.25 | 4.67 | 21.61 | 49.1 % | ACCEPTABLE |
| 880 | -4.27 | 1.09 | 14.52 | 65.8 % | ACCEPTABLE |
| 881 | -0.69 | 0.52 | 14.23 | 47.2 % | ACCEPTABLE |
| 882 | -5.12 | 10.24 | 21.26 | 1.0 % | ACCEPTABLE |
| 883 | -6.05 | 7.94 | 21.12 | 66.4 % | ACCEPTABLE |
| 884 | -3.37 | 9.73 | 22.42 | 55.1 % | ACCEPTABLE |
| 885 | -7.99 | 17.59 | 30.43 | 60.9 % | ACCEPTABLE |
| 886 | -0.37 | 1.25 | 17.25 | 38.3 % | ACCEPTABLE |
| 887 | -6.47 | 12.34 | 26.37 | 60.2 % | ACCEPTABLE |
| 888 | -2.74 | 7.94 | 21.12 | 52.2 % | ACCEPTABLE |
| 889 | -4.69 | 6.18 | 22.39 | 51.8 % | ACCEPTABLE |
| 890 | -5.11 | 2.93 | 15.59 | 5.7 % | ACCEPTABLE |
| 891 | -9.36 | 7.94 | 21.12 | 1.7 % | ACCEPTABLE |
| 892 | -7.44 | 2.50 | 17.82 | 60.4 % | ACCEPTABLE |
| 893 | -3.84 | 0.15 | 14.05 | 61.5 % | ACCEPTABLE |
| 894 | -8.50 | 5.49 | 19.49 | 4.9 % | ACCEPTABLE |
| 895 | -4.68 | 2.00 | 15.02 | 18.9 % | ACCEPTABLE |
| 896 | -7.35 | 15.37 | 28.65 | 61.7 % | ACCEPTABLE |
| 897 | -3.31 | 9.55 | 22.29 | 55.3 % | ACCEPTABLE |
| 898 | -6.05 | 7.94 | 21.12 | 66.4 % | ACCEPTABLE |
| 899 | -4.50 | 9.81 | 22.48 | 57.6 % | ACCEPTABLE |
| 900 | -6.73 | 7.62 | 19.58 | 1.5 % | ACCEPTABLE |
| 901 | -6.78 | 16.26 | 27.77 | 1.3 % | ACCEPTABLE |
| 902 | -7.37 | 14.19 | 27.11 | 63.7 % | ACCEPTABLE |
| 903 | -2.23 | 3.40 | 18.28 | 46.6 % | ACCEPTABLE |
| 904 | -6.36 | 10.91 | 24.64 | 62.9 % | ACCEPTABLE |
| 905 | -3.84 | 7.94 | 21.12 | 56.8 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 906 | -5.04 | 6.63 | 21.80 | 56.1 % | ACCEPTABLE |
| 907 | -5.53 | 4.73 | 17.49 | 7.3 % | ACCEPTABLE |
| 908 | -8.26 | 7.94 | 21.12 | 3.2 % | ACCEPTABLE |
| 909 | -4.86 | 0.96 | 16.20 | 51.4 % | ACCEPTABLE |
| 910 | -7.06 | 4.54 | 18.92 | 57.8 % | ACCEPTABLE |
| 911 | -4.61 | 2.52 | 16.12 | 64.9 % | ACCEPTABLE |
| 912 | -6.19 | 2.09 | 17.63 | 53.2 % | ACCEPTABLE |
| 913 | -7.71 | 6.38 | 20.06 | 8.8 % | ACCEPTABLE |
| 914 | -5.15 | 3.81 | 16.90 | 69.0 % | ACCEPTABLE |
| 915 | -3.46 | 5.05 | 17.71 | 62.8 % | ACCEPTABLE |
| 916 | -5.61 | 3.15 | 15.05 | 1.0 % | ACCEPTABLE |
| 917 | -5.66 | 10.36 | 21.80 | 1.5 % | ACCEPTABLE |
| 918 | -6.47 | 9.12 | 21.98 | 17.3 % | ACCEPTABLE |
| 919 | -1.37 | 0.02 | 14.89 | 47.3 % | ACCEPTABLE |
| 920 | -5.50 | 6.37 | 20.06 | 64.4 % | ACCEPTABLE |
| 921 | -2.94 | 3.81 | 16.90 | 62.1 % | ACCEPTABLE |
| 922 | -4.28 | 2.94 | 18.05 | 56.6 % | ACCEPTABLE |
| 923 | -4.51 | 0.95 | 13.65 | 4.1 % | ACCEPTABLE |
| 924 | -7.36 | 3.81 | 16.90 | 1.8 % | ACCEPTABLE |
| 925 | -6.17 | 0.95 | 15.31 | 55.4 % | ACCEPTABLE |
| 926 | -6.82 | 2.51 | 16.12 | 4.0 % | ACCEPTABLE |
| 927 | -4.20 | 0.35 | 13.31 | 10.5 % | ACCEPTABLE |
| 928 | -6.05 | 7.93 | 21.12 | 66.4 % | ACCEPTABLE |
| 929 | -3.32 | 4.72 | 17.49 | 63.1 % | ACCEPTABLE |
| 930 | -5.15 | 3.81 | 16.90 | 69.0 % | ACCEPTABLE |
| 931 | -4.13 | 4.91 | 17.62 | 58.0 % | ACCEPTABLE |
| 932 | -5.52 | 3.54 | 15.76 | 2.1 % | ACCEPTABLE |
| 933 | -7.46 | 11.07 | 23.07 | 1.5 % | ACCEPTABLE |
| 934 | -5.30 | 7.72 | 19.67 | 3.3 % | ACCEPTABLE |
| 935 | -6.04 | 7.27 | 20.19 | 28.3 % | ACCEPTABLE |
| 936 | -2.63 | 1.28 | 15.47 | 48.0 % | ACCEPTABLE |
| 937 | -5.40 | 5.54 | 19.01 | 66.2 % | ACCEPTABLE |
| 938 | -3.68 | 3.81 | 16.90 | 56.9 % | ACCEPTABLE |
| 939 | -4.52 | 3.18 | 17.60 | 60.6 % | ACCEPTABLE |
| 940 | -4.77 | 1.96 | 14.75 | 7.3 % | ACCEPTABLE |
| 941 | -7.67 | 6.34 | 18.63 | 1.2 % | ACCEPTABLE |
| 942 | -6.09 | 4.75 | 16.62 | 1.3 % | ACCEPTABLE |
| 943 | -6.62 | 3.81 | 16.90 | 4.0 % | ACCEPTABLE |
| 944 | -5.88 | 2.02 | 15.85 | 28.3 % | ACCEPTABLE |
| 945 | -4.19 | 0.72 | 14.05 | 67.3 % | ACCEPTABLE |
| 946 | -5.22 | 0.44 | 15.07 | 61.5 % | ACCEPTABLE |
| 947 | -6.28 | 2.98 | 16.39 | 6.1 % | ACCEPTABLE |
| 948 | -4.53 | 1.43 | 14.44 | 13.9 % | ACCEPTABLE |
| 949 | -5.75 | 6.49 | 19.64 | 67.3 % | ACCEPTABLE |
| 950 | -3.95 | 4.47 | 17.32 | 57.9 % | ACCEPTABLE |
| 951 | -5.15 | 3.81 | 16.90 | 69.0 % | ACCEPTABLE |
| 952 | -4.51 | 4.64 | 17.44 | 66.2 % | ACCEPTABLE |
| 953 | -5.41 | 3.70 | 16.18 | 3.6 % | ACCEPTABLE |
| 954 | -6.60 | 8.28 | 20.63 | 2.3 % | ACCEPTABLE |
| 955 | -5.18 | 6.26 | 18.57 | 6.4 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 956 | -5.75 | 6.08 | 19.04 | 28.2 % | ACCEPTABLE |
| 957 | -3.47 | 2.12 | 15.91 | 60.3 % | ACCEPTABLE |
| 958 | -5.33 | 4.97 | 18.31 | 67.2 % | ACCEPTABLE |
| 959 | -4.17 | 3.81 | 16.90 | 65.8 % | ACCEPTABLE |
| 960 | -4.71 | 3.37 | 17.34 | 63.1 % | ACCEPTABLE |
| 961 | -4.92 | 2.59 | 15.47 | 8.9 % | ACCEPTABLE |
| 962 | -6.83 | 5.50 | 18.02 | 1.6 % | ACCEPTABLE |
| 963 | -5.73 | 4.39 | 16.65 | 2.7 % | ACCEPTABLE |
| 964 | -6.13 | 3.81 | 16.90 | 4.9 % | ACCEPTABLE |
| 965 | -4.54 | 0.92 | 14.91 | 62.9 % | ACCEPTABLE |
| 966 | -3.93 | 0.39 | 14.27 | 62.0 % | ACCEPTABLE |
| 967 | -5.66 | 2.67 | 16.22 | 25.2 % | ACCEPTABLE |
| 968 | -4.52 | 1.71 | 14.95 | 68.1 % | ACCEPTABLE |
| 969 | -5.15 | 1.44 | 15.55 | 55.0 % | ACCEPTABLE |
| 970 | -5.91 | 3.27 | 16.57 | 7.9 % | ACCEPTABLE |
| 971 | -4.74 | 2.19 | 15.23 | 18.9 % | ACCEPTABLE |
| 972 | -5.55 | 5.56 | 18.70 | 67.8 % | ACCEPTABLE |
| 973 | -4.36 | 4.27 | 17.19 | 66.6 % | ACCEPTABLE |
| 974 | -5.15 | 3.81 | 16.90 | 69.0 % | ACCEPTABLE |
| 975 | -4.74 | 4.41 | 17.28 | 60.2 % | ACCEPTABLE |
| 976 | -5.33 | 3.76 | 16.43 | 5.7 % | ACCEPTABLE |
| 977 | -6.08 | 6.64 | 19.24 | 5.6 % | ACCEPTABLE |
| 978 | -5.15 | 5.38 | 17.94 | 7.8 % | ACCEPTABLE |
| 979 | -5.55 | 5.30 | 18.31 | 30.2 % | ACCEPTABLE |
| 980 | -4.03 | 2.69 | 16.22 | 55.3 % | ACCEPTABLE |
| 981 | -5.27 | 4.59 | 17.84 | 67.7 % | ACCEPTABLE |
| 982 | -4.50 | 3.81 | 16.90 | 59.5 % | ACCEPTABLE |
| 983 | -4.84 | 3.50 | 17.17 | 64.7 % | ACCEPTABLE |
| 984 | -5.00 | 3.01 | 15.95 | 13.6 % | ACCEPTABLE |
| 985 | -6.27 | 4.94 | 17.64 | 3.2 % | ACCEPTABLE |
| 986 | -5.52 | 4.18 | 16.71 | 4.1 % | ACCEPTABLE |
| 987 | -5.80 | 3.81 | 16.90 | 7.6 % | ACCEPTABLE |
| 988 | -4.72 | 1.80 | 15.49 | 64.1 % | ACCEPTABLE |
| 989 | -4.32 | 1.44 | 15.05 | 64.1 % | ACCEPTABLE |
| 990 | -5.50 | 3.08 | 16.45 | 27.5 % | ACCEPTABLE |
| 991 | -4.73 | 2.39 | 15.58 | 68.3 % | ACCEPTABLE |
| 992 | -5.12 | 2.17 | 15.93 | 56.6 % | ACCEPTABLE |
| 993 | -5.66 | 3.46 | 16.68 | 11.9 % | ACCEPTABLE |
| 994 | -4.88 | 2.72 | 15.77 | 29.5 % | ACCEPTABLE |
| 995 | -5.42 | 4.96 | 18.08 | 68.3 % | ACCEPTABLE |
| 996 | -4.63 | 4.13 | 17.10 | 60.3 % | ACCEPTABLE |
| 997 | -5.15 | 3.81 | 16.90 | 69.0 % | ACCEPTABLE |
| 998 | -4.89 | 4.22 | 17.16 | 60.5 % | ACCEPTABLE |
| 999 | -5.28 | 3.79 | 16.59 | 7.4 % | ACCEPTABLE |
| 1000 | -5.76 | 5.64 | 18.40 | 7.6 % | ACCEPTABLE |
| 1001 | -5.14 | 4.83 | 17.57 | 12.7 % | ACCEPTABLE |
| 1002 | -5.42 | 4.80 | 17.83 | 68.9 % | ACCEPTABLE |
| 1003 | -4.40 | 3.06 | 16.44 | 56.3 % | ACCEPTABLE |
| 1004 | -5.23 | 4.33 | 17.53 | 68.1 % | ACCEPTABLE |
| 1005 | -4.71 | 3.81 | 16.90 | 59.6 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1006 | -4.94 | 3.60 | 17.08 | 66.3 % | ACCEPTABLE |
| 1007 | -5.06 | 3.28 | 16.27 | 18.6 % | ACCEPTABLE |
| 1008 | -5.90 | 4.56 | 17.38 | 5.5 % | ACCEPTABLE |
| 1009 | -5.39 | 4.05 | 16.76 | 6.9 % | ACCEPTABLE |
| 1010 | -5.59 | 3.81 | 16.90 | 13.4 % | ACCEPTABLE |
| 1011 | -4.85 | 2.44 | 15.92 | 66.4 % | ACCEPTABLE |
| 1012 | -4.59 | 2.18 | 15.62 | 66.7 % | ACCEPTABLE |
| 1013 | -5.39 | 3.34 | 16.61 | 69.0 % | ACCEPTABLE |
| 1014 | -4.87 | 2.85 | 16.01 | 68.6 % | ACCEPTABLE |
| 1015 | -5.12 | 2.68 | 16.22 | 66.9 % | ACCEPTABLE |
| 1016 | -5.49 | 3.58 | 16.76 | 18.5 % | ACCEPTABLE |
| 1017 | -4.97 | 3.07 | 16.14 | 29.4 % | ACCEPTABLE |
| 1018 | -5.33 | 4.57 | 17.68 | 68.5 % | ACCEPTABLE |
| 1019 | -4.80 | 4.02 | 17.04 | 60.3 % | ACCEPTABLE |
| 1020 | -5.15 | 3.81 | 16.90 | 69.0 % | ACCEPTABLE |
| 1021 | -4.98 | 4.09 | 17.08 | 60.9 % | ACCEPTABLE |
| 1022 | -5.23 | 3.80 | 16.70 | 13.4 % | ACCEPTABLE |
| 1023 | -5.55 | 5.00 | 17.87 | 14.2 % | ACCEPTABLE |
| 1024 | -5.14 | 4.48 | 17.33 | 16.3 % | ACCEPTABLE |
| 1025 | -5.33 | 4.46 | 17.52 | 68.6 % | ACCEPTABLE |
| 1026 | -4.65 | 3.31 | 16.59 | 58.0 % | ACCEPTABLE |
| 1027 | -5.21 | 4.16 | 17.32 | 68.2 % | ACCEPTABLE |
| 1028 | -4.86 | 3.81 | 16.90 | 59.9 % | ACCEPTABLE |
| 1029 | -5.01 | 3.67 | 17.01 | 67.7 % | ACCEPTABLE |
| 1030 | -5.09 | 3.46 | 16.48 | 30.9 % | ACCEPTABLE |
| 1031 | -5.65 | 4.31 | 17.22 | 7.9 % | ACCEPTABLE |
| 1032 | -5.30 | 3.96 | 16.80 | 11.4 % | ACCEPTABLE |
| 1033 | -5.44 | 3.81 | 16.90 | 18.3 % | ACCEPTABLE |
| 1034 | -4.95 | 2.88 | 16.23 | 67.7 % | ACCEPTABLE |
| 1035 | -4.77 | 2.71 | 16.02 | 68.0 % | ACCEPTABLE |
| 1036 | -5.31 | 3.50 | 16.71 | 68.6 % | ACCEPTABLE |
| 1037 | -4.97 | 3.17 | 16.30 | 68.8 % | ACCEPTABLE |
| 1038 | -5.12 | 3.04 | 16.43 | 67.5 % | ACCEPTABLE |
| 1039 | -5.38 | 3.66 | 16.81 | 29.0 % | ACCEPTABLE |
| 1040 | -5.03 | 3.32 | 16.39 | 69.1 % | ACCEPTABLE |
| 1041 | -4.86 | 3.59 | 16.56 | 60.7 % | ACCEPTABLE |
| 1042 | -5.11 | 3.31 | 16.18 | 10.6 % | ACCEPTABLE |
| 1043 | -5.43 | 4.48 | 17.33 | 10.4 % | ACCEPTABLE |
| 1044 | -5.01 | 3.97 | 16.80 | 11.9 % | ACCEPTABLE |
| 1045 | -5.21 | 3.96 | 16.99 | 29.1 % | ACCEPTABLE |
| 1046 | -4.53 | 2.83 | 16.10 | 57.6 % | ACCEPTABLE |
| 1047 | -5.09 | 3.66 | 16.80 | 68.6 % | ACCEPTABLE |
| 1048 | -4.74 | 3.32 | 16.39 | 59.8 % | ACCEPTABLE |
| 1049 | -4.89 | 3.18 | 16.51 | 67.6 % | ACCEPTABLE |
| 1050 | -4.97 | 2.97 | 15.98 | 20.0 % | ACCEPTABLE |
| 1051 | -5.53 | 3.80 | 16.70 | 8.6 % | ACCEPTABLE |
| 1052 | -5.18 | 3.47 | 16.28 | 8.1 % | ACCEPTABLE |
| 1053 | -5.32 | 3.32 | 16.39 | 14.5 % | ACCEPTABLE |
| 1054 | -4.83 | 2.41 | 15.74 | 68.0 % | ACCEPTABLE |
| 1055 | -4.65 | 2.24 | 15.54 | 68.1 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1056 | -5.19 | 3.02 | 16.21 | 29.2 % | ACCEPTABLE |
| 1057 | -4.85 | 2.70 | 15.81 | 69.0 % | ACCEPTABLE |
| 1058 | -5.01 | 2.58 | 15.94 | 68.0 % | ACCEPTABLE |
| 1059 | -5.26 | 3.17 | 16.30 | 18.5 % | ACCEPTABLE |
| 1060 | -4.91 | 2.84 | 15.89 | 29.5 % | ACCEPTABLE |
| 1061 | -5.15 | 3.81 | 16.90 | 69.0 % | ACCEPTABLE |
| 1062 | -4.80 | 3.46 | 16.48 | 60.4 % | ACCEPTABLE |
| 1063 | -5.03 | 3.32 | 16.39 | 69.1 % | ACCEPTABLE |
| 1064 | -4.91 | 3.51 | 16.51 | 60.9 % | ACCEPTABLE |
| 1065 | -5.09 | 3.31 | 16.25 | 13.5 % | ACCEPTABLE |
| 1066 | -5.29 | 4.09 | 17.01 | 13.4 % | ACCEPTABLE |
| 1067 | -5.02 | 3.75 | 16.66 | 25.7 % | ACCEPTABLE |
| 1068 | -5.15 | 3.74 | 16.79 | 30.8 % | ACCEPTABLE |
| 1069 | -4.70 | 3.00 | 16.19 | 58.8 % | ACCEPTABLE |
| 1070 | -5.07 | 3.55 | 16.67 | 68.8 % | ACCEPTABLE |
| 1071 | -4.84 | 3.32 | 16.39 | 59.9 % | ACCEPTABLE |
| 1072 | -4.94 | 3.23 | 16.47 | 68.1 % | ACCEPTABLE |
| 1073 | -4.99 | 3.09 | 16.11 | 31.1 % | ACCEPTABLE |
| 1074 | -5.36 | 3.64 | 16.59 | 8.7 % | ACCEPTABLE |
| 1075 | -5.13 | 3.42 | 16.32 | 10.6 % | ACCEPTABLE |
| 1076 | -5.22 | 3.32 | 16.39 | 19.8 % | ACCEPTABLE |
| 1077 | -4.89 | 2.71 | 15.95 | 68.2 % | ACCEPTABLE |
| 1078 | -4.77 | 2.59 | 15.82 | 68.2 % | ACCEPTABLE |
| 1079 | -5.14 | 3.12 | 16.27 | 29.4 % | ACCEPTABLE |
| 1080 | -4.91 | 2.90 | 16.00 | 69.0 % | ACCEPTABLE |
| 1081 | -5.01 | 2.82 | 16.09 | 68.0 % | ACCEPTABLE |
| 1082 | -5.18 | 3.22 | 16.33 | 18.6 % | ACCEPTABLE |
| 1083 | -4.95 | 3.00 | 16.06 | 31.1 % | ACCEPTABLE |
| 1084 | -5.11 | 3.65 | 16.73 | 69.1 % | ACCEPTABLE |
| 1085 | -5.00 | 3.84 | 16.85 | 60.9 % | ACCEPTABLE |
| 1086 | -5.17 | 3.65 | 16.59 | 13.5 % | ACCEPTABLE |
| 1087 | -5.37 | 4.43 | 17.36 | 13.3 % | ACCEPTABLE |
| 1088 | -5.10 | 4.09 | 17.01 | 16.3 % | ACCEPTABLE |
| 1089 | -5.23 | 4.08 | 17.14 | 69.0 % | ACCEPTABLE |
| 1090 | -4.78 | 3.32 | 16.53 | 59.0 % | ACCEPTABLE |
| 1091 | -5.15 | 3.88 | 17.01 | 68.6 % | ACCEPTABLE |
| 1092 | -4.92 | 3.65 | 16.73 | 60.1 % | ACCEPTABLE |
| 1093 | -5.01 | 3.56 | 16.81 | 68.2 % | ACCEPTABLE |
| 1094 | -5.07 | 3.42 | 16.45 | 29.3 % | ACCEPTABLE |
| 1095 | -5.44 | 3.98 | 16.94 | 11.4 % | ACCEPTABLE |
| 1096 | -5.21 | 3.75 | 16.66 | 13.4 % | ACCEPTABLE |
| 1097 | -5.30 | 3.65 | 16.73 | 18.4 % | ACCEPTABLE |
| 1098 | -4.97 | 3.02 | 16.28 | 68.2 % | ACCEPTABLE |
| 1099 | -4.85 | 2.91 | 16.14 | 68.1 % | ACCEPTABLE |
| 1100 | -5.22 | 3.45 | 16.60 | 29.2 % | ACCEPTABLE |
| 1101 | -4.99 | 3.22 | 16.33 | 69.0 % | ACCEPTABLE |
| 1102 | -5.09 | 3.14 | 16.42 | 68.3 % | ACCEPTABLE |
| 1103 | -5.26 | 3.55 | 16.67 | 29.2 % | ACCEPTABLE |
| 1104 | -5.03 | 3.32 | 16.39 | 69.1 % | ACCEPTABLE |
| 1105 | -5.19 | 3.98 | 17.07 | 69.0 % | ACCEPTABLE |

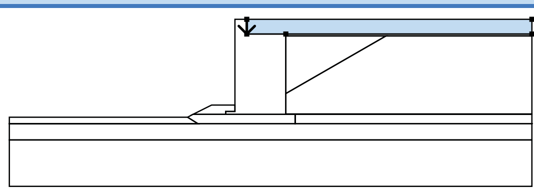
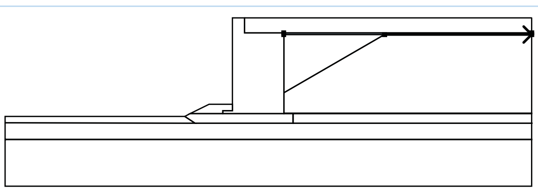
| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1106 | -4.96 | 3.75 | 16.79 | 60.5 % | ACCEPTABLE |
| 1107 | -5.11 | 3.65 | 16.73 | 69.1 % | ACCEPTABLE |
| 1108 | -5.03 | 3.78 | 16.81 | 60.6 % | ACCEPTABLE |
| 1109 | -5.15 | 3.65 | 16.64 | 18.5 % | ACCEPTABLE |
| 1110 | -5.29 | 4.16 | 17.15 | 18.3 % | ACCEPTABLE |
| 1111 | -5.10 | 3.94 | 16.91 | 27.2 % | ACCEPTABLE |
| 1112 | -5.19 | 3.94 | 17.00 | 29.1 % | ACCEPTABLE |
| 1113 | -4.89 | 3.43 | 16.59 | 59.8 % | ACCEPTABLE |
| 1114 | -5.14 | 3.80 | 16.92 | 68.8 % | ACCEPTABLE |
| 1115 | -4.98 | 3.65 | 16.73 | 60.3 % | ACCEPTABLE |
| 1116 | -5.05 | 3.59 | 16.78 | 68.4 % | ACCEPTABLE |
| 1117 | -5.08 | 3.49 | 16.54 | 30.9 % | ACCEPTABLE |
| 1118 | -5.33 | 3.87 | 16.87 | 18.3 % | ACCEPTABLE |
| 1119 | -5.18 | 3.72 | 16.68 | 18.4 % | ACCEPTABLE |
| 1120 | -5.24 | 3.65 | 16.73 | 29.1 % | ACCEPTABLE |
| 1121 | -5.02 | 3.23 | 16.43 | 68.3 % | ACCEPTABLE |
| 1122 | -4.94 | 3.15 | 16.33 | 68.4 % | ACCEPTABLE |
| 1123 | -5.18 | 3.52 | 16.65 | 69.0 % | ACCEPTABLE |
| 1124 | -5.03 | 3.37 | 16.46 | 68.9 % | ACCEPTABLE |
| 1125 | -5.10 | 3.31 | 16.52 | 68.3 % | ACCEPTABLE |
| 1126 | -5.21 | 3.58 | 16.69 | 68.8 % | ACCEPTABLE |
| 1127 | -5.06 | 3.43 | 16.50 | 29.3 % | ACCEPTABLE |
| 1128 | -5.16 | 3.87 | 16.96 | 69.0 % | ACCEPTABLE |
| 1129 | -5.01 | 3.71 | 16.77 | 60.3 % | ACCEPTABLE |
| 1130 | -5.11 | 3.65 | 16.73 | 69.1 % | ACCEPTABLE |
| 1131 | -5.06 | 3.74 | 16.78 | 25.9 % | ACCEPTABLE |
| 1132 | -5.14 | 3.65 | 16.67 | 30.9 % | ACCEPTABLE |
| 1133 | -5.23 | 3.99 | 17.00 | 29.1 % | ACCEPTABLE |
| 1134 | -5.10 | 3.84 | 16.85 | 25.9 % | ACCEPTABLE |
| 1135 | -5.16 | 3.84 | 16.91 | 68.9 % | ACCEPTABLE |
| 1136 | -4.96 | 3.50 | 16.64 | 60.0 % | ACCEPTABLE |
| 1137 | -5.13 | 3.75 | 16.85 | 68.9 % | ACCEPTABLE |
| 1138 | -5.02 | 3.65 | 16.73 | 60.4 % | ACCEPTABLE |
| 1139 | -5.07 | 3.61 | 16.76 | 68.6 % | ACCEPTABLE |
| 1140 | -5.09 | 3.55 | 16.61 | 30.9 % | ACCEPTABLE |
| 1141 | -5.26 | 3.80 | 16.82 | 18.5 % | ACCEPTABLE |
| 1142 | -5.15 | 3.69 | 16.70 | 18.5 % | ACCEPTABLE |
| 1143 | -5.20 | 3.65 | 16.73 | 29.2 % | ACCEPTABLE |
| 1144 | -5.05 | 3.37 | 16.53 | 68.6 % | ACCEPTABLE |
| 1145 | -5.00 | 3.32 | 16.46 | 68.7 % | ACCEPTABLE |
| 1146 | -5.16 | 3.56 | 16.67 | 68.7 % | ACCEPTABLE |
| 1147 | -5.06 | 3.46 | 16.55 | 68.9 % | ACCEPTABLE |
| 1148 | -5.10 | 3.42 | 16.59 | 68.5 % | ACCEPTABLE |
| 1149 | -5.18 | 3.61 | 16.70 | 69.0 % | ACCEPTABLE |
| 1150 | -5.07 | 3.50 | 16.58 | 29.3 % | ACCEPTABLE |
| 1151 | -5.15 | 3.80 | 16.88 | 69.1 % | ACCEPTABLE |
| 1152 | -5.10 | 3.89 | 16.93 | 60.8 % | ACCEPTABLE |
| 1153 | -5.18 | 3.80 | 16.82 | 29.2 % | ACCEPTABLE |
| 1154 | -5.27 | 4.14 | 17.16 | 29.1 % | ACCEPTABLE |
| 1155 | -5.14 | 3.99 | 17.00 | 61.2 % | ACCEPTABLE |

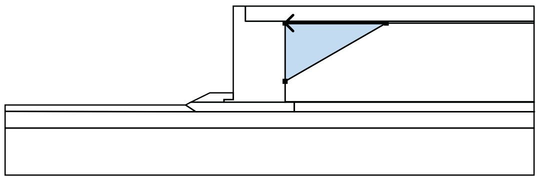
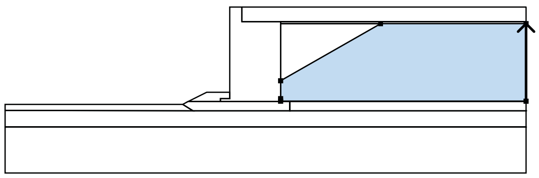
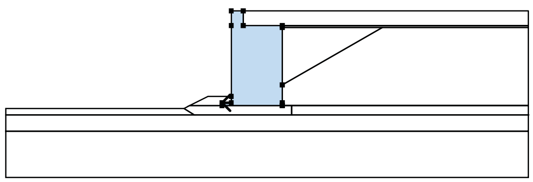
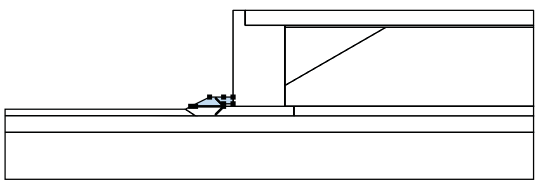
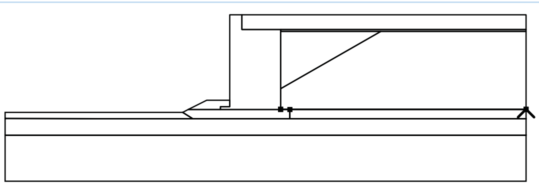
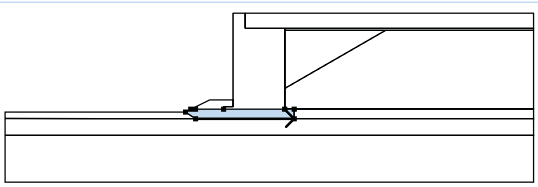
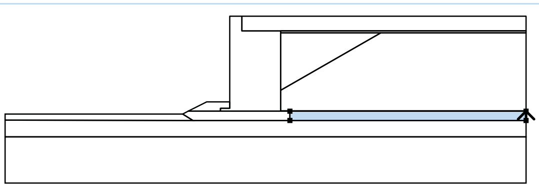
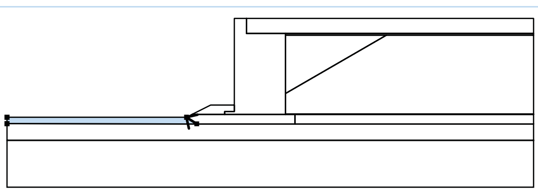
| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1156 | -5.20 | 3.99 | 17.06 | 68.8 % | ACCEPTABLE |
| 1157 | -5.00 | 3.65 | 16.79 | 60.1 % | ACCEPTABLE |
| 1158 | -5.17 | 3.90 | 17.00 | 68.9 % | ACCEPTABLE |
| 1159 | -5.06 | 3.80 | 16.88 | 60.4 % | ACCEPTABLE |
| 1160 | -5.11 | 3.76 | 16.91 | 68.5 % | ACCEPTABLE |
| 1161 | -5.13 | 3.70 | 16.76 | 68.9 % | ACCEPTABLE |
| 1162 | -5.30 | 3.95 | 16.97 | 18.4 % | ACCEPTABLE |
| 1163 | -5.19 | 3.84 | 16.85 | 29.1 % | ACCEPTABLE |
| 1164 | -5.24 | 3.80 | 16.88 | 29.2 % | ACCEPTABLE |
| 1165 | -5.09 | 3.52 | 16.67 | 68.5 % | ACCEPTABLE |
| 1166 | -5.04 | 3.46 | 16.61 | 68.6 % | ACCEPTABLE |
| 1167 | -5.20 | 3.71 | 16.82 | 29.2 % | ACCEPTABLE |
| 1168 | -5.10 | 3.61 | 16.70 | 69.0 % | ACCEPTABLE |
| 1169 | -5.14 | 3.57 | 16.73 | 68.5 % | ACCEPTABLE |
| 1170 | -5.22 | 3.76 | 16.85 | 29.2 % | ACCEPTABLE |
| 1171 | -5.11 | 3.65 | 16.73 | 69.1 % | ACCEPTABLE |
| 1172 | -5.19 | 3.95 | 17.03 | 68.8 % | ACCEPTABLE |
| 1173 | -5.08 | 3.84 | 16.91 | 60.3 % | ACCEPTABLE |
| 1174 | -5.15 | 3.80 | 16.88 | 69.1 % | ACCEPTABLE |
| 1175 | -5.12 | 3.86 | 16.92 | 68.8 % | ACCEPTABLE |
| 1176 | -5.17 | 3.80 | 16.84 | 29.1 % | ACCEPTABLE |
| 1177 | -5.23 | 4.03 | 17.06 | 30.7 % | ACCEPTABLE |
| 1178 | -5.15 | 3.93 | 16.96 | 30.9 % | ACCEPTABLE |
| 1179 | -5.19 | 3.93 | 17.00 | 68.8 % | ACCEPTABLE |
| 1180 | -5.05 | 3.70 | 16.82 | 68.4 % | ACCEPTABLE |
| 1181 | -5.16 | 3.87 | 16.96 | 69.0 % | ACCEPTABLE |
| 1182 | -5.09 | 3.80 | 16.88 | 69.0 % | ACCEPTABLE |
| 1183 | -5.12 | 3.77 | 16.90 | 68.5 % | ACCEPTABLE |
| 1184 | -5.14 | 3.73 | 16.80 | 69.1 % | ACCEPTABLE |
| 1185 | -5.25 | 3.90 | 16.94 | 30.8 % | ACCEPTABLE |
| 1186 | -5.18 | 3.83 | 16.86 | 30.8 % | ACCEPTABLE |
| 1187 | -5.21 | 3.80 | 16.88 | 69.0 % | ACCEPTABLE |
| 1188 | -5.11 | 3.61 | 16.74 | 68.8 % | ACCEPTABLE |
| 1189 | -5.07 | 3.58 | 16.70 | 68.8 % | ACCEPTABLE |
| 1190 | -5.18 | 3.74 | 16.84 | 68.9 % | ACCEPTABLE |
| 1191 | -5.11 | 3.67 | 16.76 | 69.0 % | ACCEPTABLE |
| 1192 | -5.14 | 3.64 | 16.78 | 68.7 % | ACCEPTABLE |
| 1193 | -5.20 | 3.77 | 16.86 | 29.2 % | ACCEPTABLE |
| 1194 | -5.13 | 3.70 | 16.78 | 30.8 % | ACCEPTABLE |
| 1195 | -5.17 | 3.90 | 16.98 | 68.8 % | ACCEPTABLE |
| 1196 | -5.10 | 3.83 | 16.90 | 68.7 % | ACCEPTABLE |
| 1197 | -5.15 | 3.80 | 16.88 | 69.1 % | ACCEPTABLE |
| 1198 | -5.13 | 3.84 | 16.90 | 68.9 % | ACCEPTABLE |
| 1199 | -5.16 | 3.80 | 16.85 | 69.1 % | ACCEPTABLE |
| 1200 | -5.20 | 3.95 | 17.00 | 69.1 % | ACCEPTABLE |
| 1201 | -5.15 | 3.89 | 16.93 | 69.2 % | ACCEPTABLE |
| 1202 | -5.13 | 3.93 | 16.96 | 30.1 % | ACCEPTABLE |
| 1203 | -5.16 | 3.89 | 16.90 | 30.9 % | ACCEPTABLE |
| 1204 | -5.20 | 4.04 | 17.05 | 29.2 % | ACCEPTABLE |
| 1205 | -5.15 | 3.98 | 16.99 | 30.1 % | ACCEPTABLE |

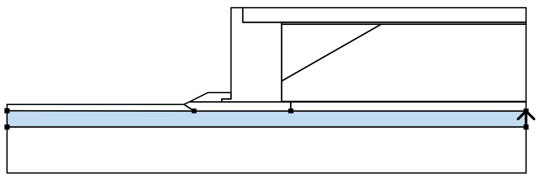
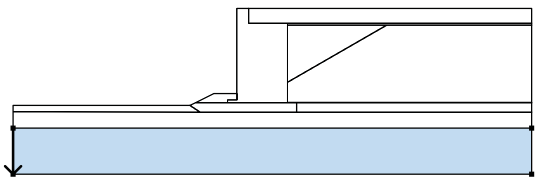
| No. | Center x [m] | Center z [m] | Radius R [m] | Utilization | Verification |
|---|---|---|---|---|---|
| 1206 | -5.17 | 3.98 | 17.01 | 29.2 % | ACCEPTABLE |
| 1207 | -5.08 | 3.82 | 16.89 | 60.4 % | ACCEPTABLE |
| 1208 | -5.16 | 3.94 | 16.99 | 29.2 % | ACCEPTABLE |
| 1209 | -5.11 | 3.89 | 16.93 | 60.8 % | ACCEPTABLE |
| 1210 | -5.13 | 3.87 | 16.94 | 68.8 % | ACCEPTABLE |
| 1211 | -5.14 | 3.84 | 16.87 | 29.3 % | ACCEPTABLE |
| 1212 | -5.22 | 3.96 | 16.97 | 29.1 % | ACCEPTABLE |
| 1213 | -5.17 | 3.91 | 16.92 | 30.9 % | ACCEPTABLE |
| 1214 | -5.19 | 3.89 | 16.93 | 69.2 % | ACCEPTABLE |
| 1215 | -5.17 | 3.93 | 16.96 | 30.9 % | ACCEPTABLE |
| 1216 | -5.20 | 3.89 | 16.90 | 19.7 % | ACCEPTABLE |
| 1217 | -5.24 | 4.04 | 17.05 | 29.1 % | ACCEPTABLE |
| 1218 | -5.19 | 3.98 | 16.99 | 30.9 % | ACCEPTABLE |
| 1219 | -5.21 | 3.98 | 17.01 | 29.1 % | ACCEPTABLE |
| 1220 | -5.12 | 3.82 | 16.89 | 68.8 % | ACCEPTABLE |
| 1221 | -5.20 | 3.94 | 16.99 | 29.1 % | ACCEPTABLE |
| 1222 | -5.15 | 3.89 | 16.93 | 69.2 % | ACCEPTABLE |
| 1223 | -5.17 | 3.87 | 16.94 | 68.9 % | ACCEPTABLE |
| 1224 | -5.18 | 3.84 | 16.87 | 29.1 % | ACCEPTABLE |
| 1225 | -5.26 | 3.96 | 16.97 | 29.1 % | ACCEPTABLE |
| 1226 | -5.21 | 3.91 | 16.92 | 19.7 % | ACCEPTABLE |
| 1227 | -5.23 | 3.89 | 16.93 | 30.8 % | ACCEPTABLE |
| 1228 | -5.16 | 3.76 | 16.84 | 30.8 % | ACCEPTABLE |
| 1229 | -5.14 | 3.74 | 16.81 | 30.8 % | ACCEPTABLE |
| 1230 | -5.21 | 3.85 | 16.90 | 29.1 % | ACCEPTABLE |
| 1231 | -5.17 | 3.80 | 16.85 | 69.0 % | ACCEPTABLE |
| 1232 | -5.18 | 3.78 | 16.86 | 69.0 % | ACCEPTABLE |
| 1233 | -5.22 | 3.87 | 16.92 | 29.1 % | ACCEPTABLE |
| 1234 | -5.17 | 3.82 | 16.86 | 29.1 % | ACCEPTABLE |
| 1235 | -5.21 | 3.96 | 17.00 | 30.7 % | ACCEPTABLE |
| 1236 | -5.16 | 3.91 | 16.94 | 30.9 % | ACCEPTABLE |
| 1237 | -5.19 | 3.89 | 16.93 | 69.2 % | ACCEPTABLE |

# Input data (Stage of construction 2)

## Assigning and surfaces

| No. | Surface position | Coordinates of surface points [m] x | z | x | z | Assigned soil |
|---|---|---|---|---|---|---|
| 1 |  | 0.00 | 0.00 | 0.00 | -1.60 | Pavement Layers |
| | | 4.20 | -1.60 | 30.72 | -1.60 | |
| | | 30.72 | 0.00 | | | |
| 2 |  | 15.00 | -1.80 | 30.72 | -1.80 | Pavement Layers |
| | | 30.72 | -1.60 | 4.20 | -1.60 | |
| | | 4.20 | -1.80 | | | |

| No. | Surface position | Coordinates of surface points [m] x | z | x | z | Assigned soil |
|---|---|---|---|---|---|---|
| 3 |  | 15.00 | -1.80 | 4.20 | -1.80 | Backfill quarry run |
| | | 4.20 | -8.01 | | | |
| 4 |  | 30.72 | -10.20 | 30.72 | -1.80 | Marine sediment |
| | | 15.00 | -1.80 | 4.20 | -8.01 | |
| | | 4.20 | -9.94 | 4.20 | -10.20 | |
| 5 |  | -1.30 | -9.94 | -2.30 | -9.94 | Wall material |
| | | -2.30 | -10.24 | 4.20 | -10.24 | |
| | | 4.20 | -10.20 | 4.20 | -9.94 | |
| | | 4.20 | -8.01 | 4.20 | -1.80 | |
| | | 4.20 | -1.60 | 0.00 | -1.60 | |
| | | 0.00 | 0.00 | -1.30 | 0.00 | |
| | | -1.30 | -1.60 | -1.30 | -9.24 | |
| 6 |  | -5.30 | -10.24 | -2.30 | -10.24 | Scour rock |
| | | -2.30 | -9.94 | -1.30 | -9.94 | |
| | | -1.30 | -9.24 | -2.30 | -9.24 | |
| | | -3.80 | -9.24 | -5.80 | -10.24 | |
| 7 |  | 30.72 | -10.24 | 30.72 | -10.20 | Marine sediment |
| | | 4.20 | -10.20 | 4.20 | -10.24 | |
| | | 5.20 | -10.24 | | | |
| 8 |  | -5.30 | -11.24 | 5.20 | -11.24 | Existing scour rock (Quarry Run) |
| | | 5.20 | -10.24 | 4.20 | -10.24 | |
| | | -2.30 | -10.24 | -5.30 | -10.24 | |
| | | -5.80 | -10.24 | -6.40 | -10.54 | |
| 9 |  | 30.72 | -11.24 | 30.72 | -10.24 | Marine sediment |
| | | 5.20 | -10.24 | 5.20 | -11.24 | |
| 10 |  | -5.30 | -11.24 | -6.40 | -10.54 | Marine sediment |
| | | -25.60 | -10.54 | -25.60 | -11.23 | |

| No. | Surface position | Coordinates of surface points [m] | | | | Assigned soil |
|---|---|---|---|---|---|---|
| | | x | z | x | z | |
| 11 |  | 30.72 | -13.00 | 30.72 | -11.24 | Marine sediment |
| | | 5.20 | -11.24 | -5.30 | -11.24 | |
| | | -25.60 | -11.23 | -25.60 | -13.00 | |
| 12 |  | -25.60 | -13.00 | -25.60 | -18.00 | Alluvial gravel and cobbles |
| | | 30.72 | -18.00 | 30.72 | -13.00 | |

## Surcharge

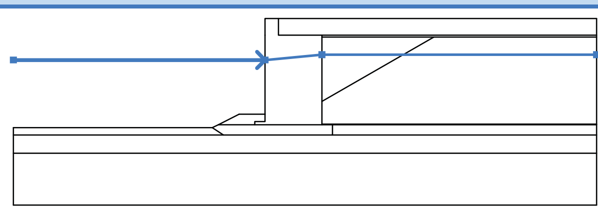
| No. | Surcharge new | Surcharge change | Type | Type of action | Location z [m] | Origin x [m] | Length l [m] | Width b [m] | Slope α [°] | Magnitude q, $q_1$, f, F | Magnitude $q_2$ | Magnitude unit |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | No | No | strip | variable | on terrain | x = 0.00 | l = 30.72 | | 0.00 | 20.00 | | kN/m2 |
| 2 | No | No | strip | permanent | on terrain | x = 0.00 | l = 30.72 | | 0.00 | 7.50 | | kN/m2 |
| 3 | No | No | line | variable | z = 0.00 | x = -1.30 | | | 90.00 | 15.30 | | kN/m |
| 4 | No | No | line | permanent | z = 0.00 | x = -0.50 | | | 0.00 | 80.20 | | kN/m |

## Surcharges

| No. | Name |
|---|---|
| 1 | Traffic Surcharge |
| 2 | Pavement |
| 3 | Mooring Load |
| 4 | Deck on Pile Dead Load |

## Water

Water type : GWT

| No. | GWT location | Coordinates of GWT points [m] | | | | | |
|---|---|---|---|---|---|---|---|
| | | x | z | x | z | x | z |
| 1 |  | -25.60 | -4.00 | -1.30 | -4.00 | 4.20 | -3.50 |
| | | 30.72 | -3.50 | | | | |

## Tensile crack

Tensile crack not input.

## Earthquake

Earthquake not included.

## Settings of the stage of construction

Design situation : permanent

# Results (Stage of construction 2)

## Analysis 1 (stage 2)

### Circular slip surface

| Slip surface parameters | | | | | | | |
|---|---|---|---|---|---|---|---|
| Center : | x = | -5.31 | [m] | Angles : | $\alpha_1$ = | -30.65 | [°] |
| | z = | 4.61 | [m] | | $\alpha_2$ = | 74.82 | [°] |
| Radius : | R = | 17.61 | [m] | | | | |
| The slip surface after optimization. | | | | | | | |

**Slope stability verification (Morgenstern-Price)**
**Combination 1**
Utilization : 65.9 %

**Slope stability ACCEPTABLE**
**Combination 2**
Utilization : 76.4 %

**Slope stability ACCEPTABLE**
Optimized slip surface for : Combination 2
**Optimization of circular slip surface (Morgenstern-Price)**

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 2 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 3 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 4 | -6.14 | 17.05 | 33.65 | 48.0 % | ACCEPTABLE |
| 5 | 7.02 | 3.42 | 16.21 | 3.5 % | ACCEPTABLE |
| 6 | -2.86 | 2.04 | 25.81 | 39.4 % | ACCEPTABLE |
| 7 | -9.65 | 33.12 | 46.42 | 38.9 % | ACCEPTABLE |
| 8 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 9 | -9.43 | 26.28 | 38.82 | 7.4 % | ACCEPTABLE |
| 10 | -6.03 | 13.08 | 28.37 | 51.3 % | ACCEPTABLE |
| 11 | 2.15 | 4.61 | 17.61 | 33.2 % | ACCEPTABLE |
| 12 | -3.30 | 2.50 | 22.59 | 43.8 % | ACCEPTABLE |
| 13 | -8.27 | 21.76 | 35.00 | 54.4 % | ACCEPTABLE |
| 14 | 1.95 | 5.10 | 17.94 | 33.5 % | ACCEPTABLE |
| 15 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 16 | 0.86 | 1.65 | 15.88 | 35.9 % | ACCEPTABLE |
| 17 | -8.19 | 18.20 | 30.80 | 10.0 % | ACCEPTABLE |
| 18 | -5.89 | 10.36 | 24.81 | 59.5 % | ACCEPTABLE |
| 19 | -0.34 | 4.61 | 17.61 | 42.7 % | ACCEPTABLE |
| 20 | -3.70 | 2.92 | 20.57 | 47.8 % | ACCEPTABLE |
| 21 | -7.31 | 15.19 | 28.37 | 57.5 % | ACCEPTABLE |
| 22 | -0.92 | 6.05 | 18.59 | 43.0 % | ACCEPTABLE |
| 23 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 24 | -2.40 | 5.62 | 18.29 | 55.8 % | ACCEPTABLE |
| 25 | -7.29 | 13.26 | 25.94 | 13.7 % | ACCEPTABLE |
| 26 | -5.75 | 8.50 | 22.43 | 56.6 % | ACCEPTABLE |
| 27 | -2.00 | 4.61 | 17.61 | 56.5 % | ACCEPTABLE |
| 28 | -4.07 | 3.31 | 19.36 | 50.7 % | ACCEPTABLE |
| 29 | -7.74 | 2.43 | 16.29 | 2.1 % | ACCEPTABLE |
| 30 | -6.65 | 11.29 | 24.42 | 57.8 % | ACCEPTABLE |
| 31 | -2.53 | 5.93 | 18.50 | 55.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 32 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 33 | -3.69 | 6.06 | 18.60 | 57.7 % | ACCEPTABLE |
| 34 | -5.82 | 3.97 | 15.80 | 1.2 % | ACCEPTABLE |
| 35 | -5.94 | 11.62 | 22.99 | 1.7 % | ACCEPTABLE |
| 36 | -6.66 | 10.19 | 22.94 | 11.9 % | ACCEPTABLE |
| 37 | -1.50 | 0.66 | 15.41 | 49.5 % | ACCEPTABLE |
| 38 | -5.64 | 7.24 | 20.83 | 62.3 % | ACCEPTABLE |
| 39 | -3.10 | 4.61 | 17.61 | 59.6 % | ACCEPTABLE |
| 40 | -4.39 | 3.64 | 18.64 | 54.0 % | ACCEPTABLE |
| 41 | -4.71 | 1.70 | 14.29 | 5.1 % | ACCEPTABLE |
| 42 | -7.52 | 4.61 | 17.61 | 2.5 % | ACCEPTABLE |
| 43 | -6.29 | 1.58 | 15.84 | 56.6 % | ACCEPTABLE |
| 44 | -6.96 | 3.23 | 16.75 | 4.6 % | ACCEPTABLE |
| 45 | -4.37 | 1.00 | 13.88 | 12.2 % | ACCEPTABLE |
| 46 | -6.21 | 8.89 | 21.99 | 63.4 % | ACCEPTABLE |
| 47 | -3.51 | 5.62 | 18.29 | 58.3 % | ACCEPTABLE |
| 48 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 49 | -4.34 | 5.84 | 18.44 | 55.3 % | ACCEPTABLE |
| 50 | -5.71 | 4.36 | 16.51 | 2.0 % | ACCEPTABLE |
| 51 | -7.69 | 12.27 | 24.19 | 1.5 % | ACCEPTABLE |
| 52 | -5.53 | 8.78 | 20.65 | 2.1 % | ACCEPTABLE |
| 53 | -6.22 | 8.24 | 21.06 | 15.2 % | ACCEPTABLE |
| 54 | -2.76 | 1.97 | 16.04 | 50.2 % | ACCEPTABLE |
| 55 | -5.55 | 6.38 | 19.76 | 63.1 % | ACCEPTABLE |
| 56 | -3.84 | 4.61 | 17.61 | 56.5 % | ACCEPTABLE |
| 57 | -4.65 | 3.91 | 18.23 | 61.9 % | ACCEPTABLE |
| 58 | -4.96 | 2.72 | 15.41 | 7.4 % | ACCEPTABLE |
| 59 | -7.87 | 7.30 | 19.50 | 1.2 % | ACCEPTABLE |
| 60 | -6.31 | 5.67 | 17.47 | 1.3 % | ACCEPTABLE |
| 61 | -6.78 | 4.61 | 17.61 | 4.1 % | ACCEPTABLE |
| 62 | -4.43 | 0.30 | 14.65 | 54.3 % | ACCEPTABLE |
| 63 | -6.01 | 2.70 | 16.45 | 31.0 % | ACCEPTABLE |
| 64 | -4.34 | 1.36 | 14.61 | 64.0 % | ACCEPTABLE |
| 65 | -5.33 | 1.04 | 15.58 | 62.4 % | ACCEPTABLE |
| 66 | -6.42 | 3.72 | 17.05 | 7.0 % | ACCEPTABLE |
| 67 | -4.69 | 2.13 | 15.05 | 15.3 % | ACCEPTABLE |
| 68 | -5.92 | 7.39 | 20.46 | 63.1 % | ACCEPTABLE |
| 69 | -4.13 | 5.33 | 18.09 | 55.7 % | ACCEPTABLE |
| 70 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 71 | -4.70 | 5.53 | 18.23 | 61.1 % | ACCEPTABLE |
| 72 | -5.60 | 4.51 | 16.91 | 4.3 % | ACCEPTABLE |
| 73 | -6.80 | 9.32 | 21.59 | 3.7 % | ACCEPTABLE |
| 74 | -5.38 | 7.21 | 19.44 | 6.8 % | ACCEPTABLE |
| 75 | -5.93 | 6.99 | 19.86 | 21.5 % | ACCEPTABLE |
| 76 | -3.61 | 2.84 | 16.53 | 58.2 % | ACCEPTABLE |
| 77 | -5.48 | 5.80 | 19.05 | 64.7 % | ACCEPTABLE |
| 78 | -4.33 | 4.61 | 17.61 | 61.8 % | ACCEPTABLE |
| 79 | -4.84 | 4.11 | 17.99 | 61.9 % | ACCEPTABLE |
| 80 | -5.09 | 3.37 | 16.15 | 9.2 % | ACCEPTABLE |
| 81 | -7.02 | 6.40 | 18.84 | 1.8 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 82 | -5.92 | 5.26 | 17.44 | 1.9 % | ACCEPTABLE |
| 83 | -6.29 | 4.61 | 17.61 | 5.7 % | ACCEPTABLE |
| 84 | -4.67 | 1.57 | 15.46 | 60.3 % | ACCEPTABLE |
| 85 | -4.06 | 1.02 | 14.80 | 52.0 % | ACCEPTABLE |
| 86 | -5.80 | 3.39 | 16.85 | 30.3 % | ACCEPTABLE |
| 87 | -4.67 | 2.40 | 15.56 | 64.4 % | ACCEPTABLE |
| 88 | -5.27 | 2.10 | 16.11 | 54.9 % | ACCEPTABLE |
| 89 | -6.06 | 4.03 | 17.24 | 9.9 % | ACCEPTABLE |
| 90 | -4.90 | 2.92 | 15.87 | 21.7 % | ACCEPTABLE |
| 91 | -5.72 | 6.43 | 19.48 | 63.8 % | ACCEPTABLE |
| 92 | -4.53 | 5.11 | 17.94 | 61.4 % | ACCEPTABLE |
| 93 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 94 | -4.92 | 5.26 | 18.04 | 62.4 % | ACCEPTABLE |
| 95 | -5.51 | 4.57 | 17.16 | 6.0 % | ACCEPTABLE |
| 96 | -6.27 | 7.59 | 20.10 | 5.1 % | ACCEPTABLE |
| 97 | -5.33 | 6.27 | 18.75 | 10.2 % | ACCEPTABLE |
| 98 | -5.72 | 6.18 | 19.09 | 29.2 % | ACCEPTABLE |
| 99 | -4.18 | 3.43 | 16.87 | 59.5 % | ACCEPTABLE |
| 100 | -5.43 | 5.41 | 18.57 | 64.8 % | ACCEPTABLE |
| 101 | -4.66 | 4.61 | 17.61 | 62.9 % | ACCEPTABLE |
| 102 | -4.98 | 4.27 | 17.84 | 55.0 % | ACCEPTABLE |
| 103 | -5.17 | 3.79 | 16.64 | 11.1 % | ACCEPTABLE |
| 104 | -6.45 | 5.80 | 18.41 | 4.0 % | ACCEPTABLE |
| 105 | -5.70 | 5.02 | 17.47 | 4.3 % | ACCEPTABLE |
| 106 | -5.96 | 4.61 | 17.61 | 9.1 % | ACCEPTABLE |
| 107 | -4.86 | 2.50 | 16.09 | 61.2 % | ACCEPTABLE |
| 108 | -4.46 | 2.12 | 15.63 | 62.4 % | ACCEPTABLE |
| 109 | -5.65 | 3.83 | 17.11 | 28.9 % | ACCEPTABLE |
| 110 | -4.88 | 3.12 | 16.22 | 57.0 % | ACCEPTABLE |
| 111 | -5.26 | 2.87 | 16.54 | 55.6 % | ACCEPTABLE |
| 112 | -5.81 | 4.23 | 17.37 | 12.0 % | ACCEPTABLE |
| 113 | -5.04 | 3.47 | 16.44 | 20.7 % | ACCEPTABLE |
| 114 | -5.58 | 5.81 | 18.84 | 58.9 % | ACCEPTABLE |
| 115 | -4.80 | 4.95 | 17.84 | 57.9 % | ACCEPTABLE |
| 116 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 117 | -5.06 | 5.06 | 17.91 | 58.2 % | ACCEPTABLE |
| 118 | -5.44 | 4.60 | 17.31 | 8.5 % | ACCEPTABLE |
| 119 | -5.94 | 6.54 | 19.20 | 7.8 % | ACCEPTABLE |
| 120 | -5.31 | 5.69 | 18.34 | 12.5 % | ACCEPTABLE |
| 121 | -5.59 | 5.65 | 18.59 | 31.3 % | ACCEPTABLE |
| 122 | -4.55 | 3.82 | 17.11 | 55.5 % | ACCEPTABLE |
| 123 | -5.39 | 5.14 | 18.25 | 65.0 % | ACCEPTABLE |
| 124 | -4.87 | 4.61 | 17.61 | 58.5 % | ACCEPTABLE |
| 125 | -5.09 | 4.37 | 17.76 | 62.9 % | ACCEPTABLE |
| 126 | -5.22 | 4.07 | 16.96 | 13.9 % | ACCEPTABLE |
| 127 | -6.07 | 5.40 | 18.14 | 5.8 % | ACCEPTABLE |
| 128 | -5.56 | 4.88 | 17.50 | 6.0 % | ACCEPTABLE |
| 129 | -5.75 | 4.61 | 17.61 | 12.0 % | ACCEPTABLE |
| 130 | -5.00 | 3.16 | 16.55 | 63.3 % | ACCEPTABLE |
| 131 | -4.73 | 2.90 | 16.24 | 55.1 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 132 | -5.54 | 4.10 | 17.28 | 32.4 % | ACCEPTABLE |
| 133 | -5.03 | 3.61 | 16.67 | 58.8 % | ACCEPTABLE |
| 134 | -5.26 | 3.41 | 16.86 | 63.0 % | ACCEPTABLE |
| 135 | -5.65 | 4.36 | 17.45 | 15.1 % | ACCEPTABLE |
| 136 | -5.13 | 3.84 | 16.82 | 32.2 % | ACCEPTABLE |
| 137 | -5.49 | 5.40 | 18.42 | 65.1 % | ACCEPTABLE |
| 138 | -4.97 | 4.84 | 17.76 | 58.2 % | ACCEPTABLE |
| 139 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 140 | -5.14 | 4.92 | 17.81 | 58.5 % | ACCEPTABLE |
| 141 | -5.40 | 4.61 | 17.42 | 9.8 % | ACCEPTABLE |
| 142 | -5.72 | 5.87 | 18.64 | 11.0 % | ACCEPTABLE |
| 143 | -5.31 | 5.32 | 18.08 | 19.4 % | ACCEPTABLE |
| 144 | -5.50 | 5.30 | 18.26 | 64.1 % | ACCEPTABLE |
| 145 | -4.81 | 4.08 | 17.27 | 56.8 % | ACCEPTABLE |
| 146 | -5.36 | 4.97 | 18.04 | 58.8 % | ACCEPTABLE |
| 147 | -5.02 | 4.61 | 17.61 | 58.7 % | ACCEPTABLE |
| 148 | -5.16 | 4.45 | 17.70 | 64.0 % | ACCEPTABLE |
| 149 | -5.25 | 4.25 | 17.18 | 19.9 % | ACCEPTABLE |
| 150 | -5.81 | 5.14 | 17.96 | 9.1 % | ACCEPTABLE |
| 151 | -5.47 | 4.78 | 17.53 | 8.5 % | ACCEPTABLE |
| 152 | -5.60 | 4.61 | 17.61 | 15.1 % | ACCEPTABLE |
| 153 | -5.10 | 3.62 | 16.88 | 63.4 % | ACCEPTABLE |
| 154 | -4.92 | 3.45 | 16.68 | 64.3 % | ACCEPTABLE |
| 155 | -5.47 | 4.28 | 17.39 | 30.9 % | ACCEPTABLE |
| 156 | -5.12 | 3.94 | 16.98 | 58.8 % | ACCEPTABLE |
| 157 | -5.27 | 3.80 | 17.09 | 63.4 % | ACCEPTABLE |
| 158 | -5.53 | 4.45 | 17.50 | 20.3 % | ACCEPTABLE |
| 159 | -5.19 | 4.10 | 17.08 | 20.0 % | ACCEPTABLE |
| 160 | -5.43 | 5.14 | 18.15 | 29.6 % | ACCEPTABLE |
| 161 | -5.08 | 4.77 | 17.71 | 58.6 % | ACCEPTABLE |
| 162 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 163 | -5.20 | 4.82 | 17.75 | 58.7 % | ACCEPTABLE |
| 164 | -5.37 | 4.61 | 17.48 | 14.9 % | ACCEPTABLE |
| 165 | -5.58 | 5.44 | 18.29 | 13.8 % | ACCEPTABLE |
| 166 | -5.31 | 5.08 | 17.92 | 19.9 % | ACCEPTABLE |
| 167 | -5.43 | 5.07 | 18.04 | 28.1 % | ACCEPTABLE |
| 168 | -4.97 | 4.26 | 17.38 | 58.3 % | ACCEPTABLE |
| 169 | -5.35 | 4.85 | 17.90 | 64.3 % | ACCEPTABLE |
| 170 | -5.12 | 4.61 | 17.61 | 58.9 % | ACCEPTABLE |
| 171 | -5.21 | 4.50 | 17.67 | 65.3 % | ACCEPTABLE |
| 172 | -5.27 | 4.37 | 17.32 | 18.7 % | ACCEPTABLE |
| 173 | -5.65 | 4.96 | 17.84 | 11.9 % | ACCEPTABLE |
| 174 | -5.42 | 4.72 | 17.56 | 15.0 % | ACCEPTABLE |
| 175 | -5.50 | 4.61 | 17.61 | 20.3 % | ACCEPTABLE |
| 176 | -5.16 | 3.94 | 17.12 | 63.4 % | ACCEPTABLE |
| 177 | -5.05 | 3.83 | 16.98 | 64.4 % | ACCEPTABLE |
| 178 | -5.41 | 4.39 | 17.47 | 32.4 % | ACCEPTABLE |
| 179 | -5.19 | 4.16 | 17.19 | 64.6 % | ACCEPTABLE |
| 180 | -5.28 | 4.06 | 17.26 | 63.4 % | ACCEPTABLE |
| 181 | -5.46 | 4.50 | 17.54 | 32.2 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 182 | -5.23 | 4.27 | 17.26 | 32.8 % | ACCEPTABLE |
| 183 | -5.39 | 4.96 | 17.97 | 65.5 % | ACCEPTABLE |
| 184 | -5.16 | 4.72 | 17.68 | 58.6 % | ACCEPTABLE |
| 185 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 186 | -5.24 | 4.75 | 17.70 | 58.7 % | ACCEPTABLE |
| 187 | -5.35 | 4.61 | 17.52 | 18.6 % | ACCEPTABLE |
| 188 | -5.49 | 5.16 | 18.06 | 19.7 % | ACCEPTABLE |
| 189 | -5.31 | 4.92 | 17.81 | 27.9 % | ACCEPTABLE |
| 190 | -5.39 | 4.91 | 17.90 | 30.2 % | ACCEPTABLE |
| 191 | -5.09 | 4.38 | 17.46 | 58.5 % | ACCEPTABLE |
| 192 | -5.33 | 4.77 | 17.80 | 59.0 % | ACCEPTABLE |
| 193 | -5.18 | 4.61 | 17.61 | 58.8 % | ACCEPTABLE |
| 194 | -5.24 | 4.54 | 17.65 | 58.8 % | ACCEPTABLE |
| 195 | -5.28 | 4.45 | 17.42 | 29.6 % | ACCEPTABLE |
| 196 | -5.53 | 4.84 | 17.76 | 20.1 % | ACCEPTABLE |
| 197 | -5.38 | 4.69 | 17.57 | 14.9 % | ACCEPTABLE |
| 198 | -5.44 | 4.61 | 17.61 | 30.8 % | ACCEPTABLE |
| 199 | -5.21 | 4.16 | 17.28 | 64.6 % | ACCEPTABLE |
| 200 | -5.13 | 4.08 | 17.18 | 58.7 % | ACCEPTABLE |
| 201 | -5.38 | 4.46 | 17.52 | 64.4 % | ACCEPTABLE |
| 202 | -5.23 | 4.31 | 17.33 | 65.9 % | ACCEPTABLE |
| 203 | -5.16 | 4.45 | 17.42 | 58.8 % | ACCEPTABLE |
| 204 | -5.27 | 4.31 | 17.24 | 19.9 % | ACCEPTABLE |
| 205 | -5.41 | 4.85 | 17.77 | 21.1 % | ACCEPTABLE |
| 206 | -5.22 | 4.61 | 17.53 | 28.1 % | ACCEPTABLE |
| 207 | -5.31 | 4.61 | 17.61 | 65.6 % | ACCEPTABLE |
| 208 | -5.01 | 4.08 | 17.18 | 58.5 % | ACCEPTABLE |
| 209 | -5.25 | 4.47 | 17.52 | 58.8 % | ACCEPTABLE |
| 210 | -5.10 | 4.31 | 17.33 | 58.8 % | ACCEPTABLE |
| 211 | -5.16 | 4.24 | 17.37 | 64.0 % | ACCEPTABLE |
| 212 | -5.20 | 4.15 | 17.14 | 31.3 % | ACCEPTABLE |
| 213 | -5.45 | 4.54 | 17.48 | 15.1 % | ACCEPTABLE |
| 214 | -5.30 | 4.38 | 17.29 | 16.3 % | ACCEPTABLE |
| 215 | -5.36 | 4.31 | 17.33 | 32.4 % | ACCEPTABLE |
| 216 | -5.13 | 3.87 | 17.01 | 63.2 % | ACCEPTABLE |
| 217 | -5.06 | 3.79 | 16.91 | 64.6 % | ACCEPTABLE |
| 218 | -5.30 | 4.17 | 17.24 | 30.9 % | ACCEPTABLE |
| 219 | -5.15 | 4.01 | 17.05 | 64.8 % | ACCEPTABLE |
| 220 | -5.21 | 3.95 | 17.10 | 63.2 % | ACCEPTABLE |
| 221 | -5.33 | 4.24 | 17.28 | 30.9 % | ACCEPTABLE |
| 222 | -5.18 | 4.08 | 17.10 | 64.7 % | ACCEPTABLE |
| 223 | -5.28 | 4.54 | 17.57 | 65.9 % | ACCEPTABLE |
| 224 | -5.21 | 4.68 | 17.66 | 58.8 % | ACCEPTABLE |
| 225 | -5.32 | 4.54 | 17.48 | 19.9 % | ACCEPTABLE |
| 226 | -5.46 | 5.08 | 18.01 | 19.7 % | ACCEPTABLE |
| 227 | -5.28 | 4.85 | 17.77 | 58.7 % | ACCEPTABLE |
| 228 | -5.36 | 4.84 | 17.85 | 59.1 % | ACCEPTABLE |
| 229 | -5.06 | 4.31 | 17.42 | 58.4 % | ACCEPTABLE |
| 230 | -5.30 | 4.70 | 17.76 | 58.9 % | ACCEPTABLE |
| 231 | -5.15 | 4.54 | 17.57 | 58.9 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 232 | -5.21 | 4.47 | 17.61 | 57.4 % | ACCEPTABLE |
| 233 | -5.25 | 4.38 | 17.38 | 28.2 % | ACCEPTABLE |
| 234 | -5.50 | 4.77 | 17.72 | 16.2 % | ACCEPTABLE |
| 235 | -5.35 | 4.61 | 17.53 | 21.1 % | ACCEPTABLE |
| 236 | -5.41 | 4.54 | 17.57 | 30.8 % | ACCEPTABLE |
| 237 | -5.18 | 4.09 | 17.24 | 64.5 % | ACCEPTABLE |
| 238 | -5.11 | 4.02 | 17.15 | 64.4 % | ACCEPTABLE |
| 239 | -5.35 | 4.40 | 17.48 | 64.6 % | ACCEPTABLE |
| 240 | -5.20 | 4.24 | 17.29 | 65.5 % | ACCEPTABLE |
| 241 | -5.26 | 4.17 | 17.33 | 63.2 % | ACCEPTABLE |
| 242 | -5.38 | 4.47 | 17.52 | 64.5 % | ACCEPTABLE |
| 243 | -5.23 | 4.31 | 17.33 | 65.9 % | ACCEPTABLE |
| 244 | -5.33 | 4.77 | 17.81 | 65.5 % | ACCEPTABLE |
| 245 | -5.18 | 4.61 | 17.62 | 58.8 % | ACCEPTABLE |
| 246 | -5.28 | 4.54 | 17.57 | 65.9 % | ACCEPTABLE |
| 247 | -5.23 | 4.63 | 17.63 | 59.0 % | ACCEPTABLE |
| 248 | -5.31 | 4.54 | 17.51 | 30.3 % | ACCEPTABLE |
| 249 | -5.40 | 4.90 | 17.86 | 30.2 % | ACCEPTABLE |
| 250 | -5.28 | 4.74 | 17.70 | 28.2 % | ACCEPTABLE |
| 251 | -5.33 | 4.74 | 17.76 | 59.1 % | ACCEPTABLE |
| 252 | -5.13 | 4.39 | 17.47 | 58.5 % | ACCEPTABLE |
| 253 | -5.30 | 4.65 | 17.70 | 65.4 % | ACCEPTABLE |
| 254 | -5.19 | 4.54 | 17.57 | 58.9 % | ACCEPTABLE |
| 255 | -5.23 | 4.49 | 17.60 | 58.7 % | ACCEPTABLE |
| 256 | -5.26 | 4.43 | 17.44 | 29.7 % | ACCEPTABLE |
| 257 | -5.43 | 4.70 | 17.67 | 21.6 % | ACCEPTABLE |
| 258 | -5.33 | 4.59 | 17.54 | 19.9 % | ACCEPTABLE |
| 259 | -5.37 | 4.54 | 17.57 | 30.8 % | ACCEPTABLE |
| 260 | -5.21 | 4.24 | 17.35 | 64.5 % | ACCEPTABLE |
| 261 | -5.16 | 4.19 | 17.29 | 58.6 % | ACCEPTABLE |
| 262 | -5.33 | 4.44 | 17.51 | 64.7 % | ACCEPTABLE |
| 263 | -5.23 | 4.34 | 17.38 | 64.7 % | ACCEPTABLE |
| 264 | -5.27 | 4.29 | 17.41 | 63.3 % | ACCEPTABLE |
| 265 | -5.35 | 4.49 | 17.54 | 64.5 % | ACCEPTABLE |
| 266 | -5.24 | 4.39 | 17.41 | 28.3 % | ACCEPTABLE |
| 267 | -5.32 | 4.69 | 17.73 | 64.7 % | ACCEPTABLE |
| 268 | -5.21 | 4.59 | 17.60 | 58.9 % | ACCEPTABLE |
| 269 | -5.28 | 4.54 | 17.57 | 65.9 % | ACCEPTABLE |
| 270 | -5.25 | 4.60 | 17.61 | 59.2 % | ACCEPTABLE |
| 271 | -5.30 | 4.54 | 17.53 | 30.4 % | ACCEPTABLE |
| 272 | -5.36 | 4.78 | 17.76 | 28.2 % | ACCEPTABLE |
| 273 | -5.28 | 4.68 | 17.66 | 59.1 % | ACCEPTABLE |
| 274 | -5.32 | 4.67 | 17.70 | 64.6 % | ACCEPTABLE |
| 275 | -5.18 | 4.44 | 17.50 | 58.7 % | ACCEPTABLE |
| 276 | -5.29 | 4.61 | 17.65 | 58.9 % | ACCEPTABLE |
| 277 | -5.22 | 4.54 | 17.57 | 59.2 % | ACCEPTABLE |
| 278 | -5.25 | 4.51 | 17.59 | 65.4 % | ACCEPTABLE |
| 279 | -5.27 | 4.47 | 17.49 | 30.4 % | ACCEPTABLE |
| 280 | -5.38 | 4.64 | 17.64 | 32.2 % | ACCEPTABLE |
| 281 | -5.31 | 4.57 | 17.55 | 31.9 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 282 | -5.34 | 4.54 | 17.57 | 30.8 % | ACCEPTABLE |
| 283 | -5.24 | 4.34 | 17.42 | 64.6 % | ACCEPTABLE |
| 284 | -5.20 | 4.30 | 17.38 | 65.4 % | ACCEPTABLE |
| 285 | -5.31 | 4.48 | 17.53 | 64.4 % | ACCEPTABLE |
| 286 | -5.24 | 4.41 | 17.44 | 59.0 % | ACCEPTABLE |
| 287 | -5.27 | 4.38 | 17.46 | 64.5 % | ACCEPTABLE |
| 288 | -5.32 | 4.51 | 17.55 | 30.9 % | ACCEPTABLE |
| 289 | -5.26 | 4.44 | 17.47 | 30.9 % | ACCEPTABLE |
| 290 | -5.30 | 4.64 | 17.68 | 65.7 % | ACCEPTABLE |
| 291 | -5.24 | 4.57 | 17.59 | 59.1 % | ACCEPTABLE |
| 292 | -5.28 | 4.54 | 17.57 | 65.9 % | ACCEPTABLE |
| 293 | -5.26 | 4.58 | 17.60 | 59.1 % | ACCEPTABLE |
| 294 | -5.29 | 4.54 | 17.54 | 59.1 % | ACCEPTABLE |
| 295 | -5.33 | 4.70 | 17.70 | 59.2 % | ACCEPTABLE |
| 296 | -5.28 | 4.63 | 17.63 | 59.2 % | ACCEPTABLE |
| 297 | -5.30 | 4.63 | 17.65 | 59.1 % | ACCEPTABLE |
| 298 | -5.21 | 4.47 | 17.53 | 58.7 % | ACCEPTABLE |
| 299 | -5.29 | 4.59 | 17.63 | 65.8 % | ACCEPTABLE |
| 300 | -5.24 | 4.54 | 17.57 | 59.2 % | ACCEPTABLE |
| 301 | -5.26 | 4.52 | 17.58 | 65.2 % | ACCEPTABLE |
| 302 | -5.27 | 4.49 | 17.51 | 59.0 % | ACCEPTABLE |
| 303 | -5.35 | 4.61 | 17.61 | 30.8 % | ACCEPTABLE |
| 304 | -5.30 | 4.56 | 17.56 | 65.7 % | ACCEPTABLE |
| 305 | -5.32 | 4.54 | 17.57 | 30.9 % | ACCEPTABLE |
| 306 | -5.25 | 4.41 | 17.47 | 64.5 % | ACCEPTABLE |
| 307 | -5.23 | 4.38 | 17.44 | 65.4 % | ACCEPTABLE |
| 308 | -5.30 | 4.50 | 17.54 | 64.6 % | ACCEPTABLE |
| 309 | -5.26 | 4.45 | 17.49 | 64.6 % | ACCEPTABLE |
| 310 | -5.27 | 4.43 | 17.50 | 64.5 % | ACCEPTABLE |
| 311 | -5.31 | 4.52 | 17.56 | 30.9 % | ACCEPTABLE |
| 312 | -5.26 | 4.47 | 17.50 | 59.1 % | ACCEPTABLE |
| 313 | -5.30 | 4.61 | 17.64 | 65.6 % | ACCEPTABLE |
| 314 | -5.25 | 4.56 | 17.58 | 59.0 % | ACCEPTABLE |
| 315 | 7.05 | 3.36 | 16.19 | 3.7 % | ACCEPTABLE |
| 316 | -2.85 | 2.00 | 25.80 | 39.4 % | ACCEPTABLE |
| 317 | 0.95 | 25.30 | 38.92 | 29.5 % | ACCEPTABLE |
| 318 | 1.10 | 2.49 | 29.53 | 28.7 % | ACCEPTABLE |
| 319 | 0.60 | 5.14 | 30.36 | 30.3 % | ACCEPTABLE |
| 320 | -5.23 | 4.48 | 17.50 | 59.2 % | ACCEPTABLE |
| 321 | 7.09 | 3.30 | 16.12 | 3.6 % | ACCEPTABLE |
| 322 | -2.85 | 2.00 | 25.80 | 39.4 % | ACCEPTABLE |
| 323 | -9.60 | 32.91 | 46.23 | 38.9 % | ACCEPTABLE |
| 324 | -5.23 | 4.48 | 17.50 | 59.2 % | ACCEPTABLE |
| 325 | -9.33 | 25.96 | 38.53 | 14.9 % | ACCEPTABLE |
| 326 | -5.96 | 12.92 | 28.23 | 51.3 % | ACCEPTABLE |
| 327 | 2.23 | 4.48 | 17.50 | 32.2 % | ACCEPTABLE |
| 328 | -3.25 | 2.41 | 22.52 | 43.9 % | ACCEPTABLE |
| 329 | -8.18 | 21.53 | 34.79 | 51.8 % | ACCEPTABLE |
| 330 | 2.05 | 4.90 | 17.78 | 32.9 % | ACCEPTABLE |
| 331 | -5.23 | 4.48 | 17.50 | 59.2 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 332 | 0.99 | 1.41 | 15.73 | 35.3 % | ACCEPTABLE |
| 333 | -8.09 | 17.96 | 30.58 | 12.9 % | ACCEPTABLE |
| 334 | -5.81 | 10.20 | 24.68 | 55.1 % | ACCEPTABLE |
| 335 | -0.26 | 4.48 | 17.50 | 41.4 % | ACCEPTABLE |
| 336 | -3.64 | 2.82 | 20.49 | 47.7 % | ACCEPTABLE |
| 337 | -7.22 | 15.00 | 28.20 | 54.8 % | ACCEPTABLE |
| 338 | -0.83 | 5.88 | 18.45 | 42.6 % | ACCEPTABLE |
| 339 | -5.23 | 4.48 | 17.50 | 59.2 % | ACCEPTABLE |
| 340 | -2.30 | 5.42 | 18.13 | 56.1 % | ACCEPTABLE |
| 341 | -7.20 | 13.06 | 25.76 | 13.4 % | ACCEPTABLE |
| 342 | -5.68 | 8.36 | 22.30 | 56.7 % | ACCEPTABLE |
| 343 | -1.92 | 4.48 | 17.50 | 55.5 % | ACCEPTABLE |
| 344 | -4.01 | 3.20 | 19.28 | 50.6 % | ACCEPTABLE |
| 345 | -7.67 | 2.32 | 16.21 | 2.3 % | ACCEPTABLE |
| 346 | -6.57 | 11.12 | 24.27 | 57.8 % | ACCEPTABLE |
| 347 | -2.44 | 5.77 | 18.37 | 56.1 % | ACCEPTABLE |
| 348 | -5.23 | 4.48 | 17.50 | 59.2 % | ACCEPTABLE |
| 349 | -3.60 | 5.89 | 18.46 | 57.9 % | ACCEPTABLE |
| 350 | -5.73 | 3.84 | 15.69 | 1.2 % | ACCEPTABLE |
| 351 | -5.84 | 11.40 | 22.79 | 1.7 % | ACCEPTABLE |
| 352 | -6.57 | 10.01 | 22.79 | 14.9 % | ACCEPTABLE |
| 353 | -1.42 | 0.56 | 15.33 | 49.3 % | ACCEPTABLE |
| 354 | -5.56 | 7.10 | 20.71 | 55.8 % | ACCEPTABLE |
| 355 | -3.02 | 4.48 | 17.50 | 59.6 % | ACCEPTABLE |
| 356 | -1.39 | 5.89 | 18.46 | 40.3 % | ACCEPTABLE |
| 357 | -3.52 | 3.84 | 15.69 | 7.2 % | ACCEPTABLE |
| 358 | -6.97 | 17.51 | 28.97 | 1.6 % | ACCEPTABLE |
| 359 | -3.63 | 11.40 | 22.79 | 6.0 % | ACCEPTABLE |
| 360 | -4.36 | 10.01 | 22.79 | 54.6 % | ACCEPTABLE |
| 361 | 0.79 | 0.56 | 15.33 | 32.5 % | ACCEPTABLE |
| 362 | -3.35 | 7.10 | 20.71 | 51.8 % | ACCEPTABLE |
| 363 | -0.81 | 4.48 | 17.50 | 39.3 % | ACCEPTABLE |
| 364 | -2.11 | 3.53 | 18.56 | 48.1 % | ACCEPTABLE |
| 365 | -2.41 | 1.58 | 14.19 | 50.3 % | ACCEPTABLE |
| 366 | -6.86 | 8.49 | 20.40 | 1.3 % | ACCEPTABLE |
| 367 | -4.71 | 6.26 | 17.55 | 1.3 % | ACCEPTABLE |
| 368 | -5.23 | 4.48 | 17.50 | 59.2 % | ACCEPTABLE |
| 369 | -4.01 | 1.48 | 15.76 | 53.9 % | ACCEPTABLE |
| 370 | -4.67 | 3.11 | 16.65 | 54.4 % | ACCEPTABLE |
| 371 | -2.08 | 0.89 | 13.79 | 50.2 % | ACCEPTABLE |
| 372 | -3.92 | 8.74 | 21.85 | 55.1 % | ACCEPTABLE |
| 373 | -1.21 | 5.47 | 18.16 | 40.0 % | ACCEPTABLE |
| 374 | -3.02 | 4.48 | 17.50 | 59.6 % | ACCEPTABLE |
| 375 | -2.04 | 5.69 | 18.31 | 54.5 % | ACCEPTABLE |
| 376 | -3.41 | 4.23 | 16.39 | 57.4 % | ACCEPTABLE |
| 377 | -5.39 | 12.07 | 24.01 | 8.1 % | ACCEPTABLE |
| 378 | -3.23 | 8.61 | 20.49 | 51.0 % | ACCEPTABLE |
| 379 | -3.93 | 8.08 | 20.92 | 58.4 % | ACCEPTABLE |
| 380 | -0.48 | 1.86 | 15.96 | 46.0 % | ACCEPTABLE |
| 381 | -3.26 | 6.24 | 19.65 | 56.3 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 382 | -1.55 | 4.48 | 17.50 | 53.7 % | ACCEPTABLE |
| 383 | -2.36 | 3.79 | 18.13 | 52.5 % | ACCEPTABLE |
| 384 | -2.66 | 2.59 | 15.31 | 58.0 % | ACCEPTABLE |
| 385 | -5.58 | 7.14 | 19.37 | 5.7 % | ACCEPTABLE |
| 386 | -4.01 | 5.52 | 17.33 | 6.2 % | ACCEPTABLE |
| 387 | -4.49 | 4.48 | 17.50 | 62.9 % | ACCEPTABLE |
| 388 | -3.51 | 5.69 | 18.31 | 58.2 % | ACCEPTABLE |
| 389 | -4.88 | 4.23 | 16.39 | 3.1 % | ACCEPTABLE |
| 390 | -6.86 | 12.07 | 24.01 | 2.1 % | ACCEPTABLE |
| 391 | -4.70 | 8.61 | 20.49 | 7.2 % | ACCEPTABLE |
| 392 | -5.40 | 8.08 | 20.92 | 61.4 % | ACCEPTABLE |
| 393 | -1.95 | 1.86 | 15.96 | 51.9 % | ACCEPTABLE |
| 394 | -4.73 | 6.24 | 19.65 | 61.4 % | ACCEPTABLE |
| 395 | -3.02 | 4.48 | 17.50 | 59.6 % | ACCEPTABLE |
| 396 | -3.83 | 3.79 | 18.13 | 57.7 % | ACCEPTABLE |
| 397 | -4.13 | 2.59 | 15.31 | 62.6 % | ACCEPTABLE |
| 398 | -7.05 | 7.14 | 19.37 | 1.6 % | ACCEPTABLE |
| 399 | -5.48 | 5.52 | 17.33 | 1.7 % | ACCEPTABLE |
| 400 | -5.96 | 4.48 | 17.50 | 7.4 % | ACCEPTABLE |
| 401 | -3.62 | 0.21 | 14.58 | 52.2 % | ACCEPTABLE |
| 402 | -5.19 | 2.59 | 16.36 | 55.3 % | ACCEPTABLE |
| 403 | -3.52 | 1.26 | 14.53 | 58.9 % | ACCEPTABLE |
| 404 | -4.52 | 0.94 | 15.51 | 55.2 % | ACCEPTABLE |
| 405 | -5.61 | 3.60 | 16.95 | 29.1 % | ACCEPTABLE |
| 406 | -3.87 | 2.01 | 14.96 | 61.4 % | ACCEPTABLE |
| 407 | -5.09 | 7.24 | 20.33 | 61.9 % | ACCEPTABLE |
| 408 | -3.31 | 5.19 | 17.97 | 58.9 % | ACCEPTABLE |
| 409 | -4.49 | 4.48 | 17.50 | 62.9 % | ACCEPTABLE |
| 410 | -3.88 | 5.38 | 18.10 | 55.1 % | ACCEPTABLE |
| 411 | -4.77 | 4.38 | 16.80 | 9.8 % | ACCEPTABLE |
| 412 | -5.98 | 9.15 | 21.43 | 6.9 % | ACCEPTABLE |
| 413 | -4.56 | 7.05 | 19.30 | 19.9 % | ACCEPTABLE |
| 414 | -5.10 | 6.84 | 19.73 | 61.8 % | ACCEPTABLE |
| 415 | -2.79 | 2.73 | 16.43 | 50.3 % | ACCEPTABLE |
| 416 | -4.66 | 5.67 | 18.94 | 61.7 % | ACCEPTABLE |
| 417 | -3.51 | 4.48 | 17.50 | 55.9 % | ACCEPTABLE |
| 418 | -4.03 | 3.99 | 17.89 | 59.1 % | ACCEPTABLE |
| 419 | -4.27 | 3.24 | 16.05 | 62.8 % | ACCEPTABLE |
| 420 | -6.19 | 6.25 | 18.71 | 4.3 % | ACCEPTABLE |
| 421 | -5.10 | 5.12 | 17.31 | 5.0 % | ACCEPTABLE |
| 422 | -5.47 | 4.48 | 17.50 | 21.6 % | ACCEPTABLE |
| 423 | -3.86 | 1.46 | 15.38 | 51.7 % | ACCEPTABLE |
| 424 | -3.25 | 0.92 | 14.72 | 58.1 % | ACCEPTABLE |
| 425 | -4.98 | 3.28 | 16.75 | 62.5 % | ACCEPTABLE |
| 426 | -3.85 | 2.29 | 15.47 | 61.1 % | ACCEPTABLE |
| 427 | -4.46 | 1.99 | 16.03 | 61.0 % | ACCEPTABLE |
| 428 | -5.24 | 3.91 | 17.14 | 63.4 % | ACCEPTABLE |
| 429 | -4.58 | 4.71 | 17.65 | 62.7 % | ACCEPTABLE |
| 430 | -5.50 | 3.80 | 16.41 | 4.9 % | ACCEPTABLE |
| 431 | -6.66 | 8.35 | 20.83 | 2.6 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 432 | -5.25 | 6.34 | 18.78 | 11.1 % | ACCEPTABLE |
| 433 | -5.83 | 6.16 | 19.27 | 63.7 % | ACCEPTABLE |
| 434 | -5.22 | 7.15 | 19.96 | 61.6 % | ACCEPTABLE |
| 435 | -6.14 | 6.12 | 18.62 | 4.9 % | ACCEPTABLE |
| 436 | -7.33 | 11.20 | 23.57 | 4.1 % | ACCEPTABLE |
| 437 | -5.91 | 8.98 | 21.31 | 7.5 % | ACCEPTABLE |
| 438 | -6.44 | 8.68 | 21.66 | 32.2 % | ACCEPTABLE |
| 439 | -4.13 | 4.26 | 18.05 | 59.4 % | ACCEPTABLE |
| 440 | -5.99 | 7.42 | 20.77 | 61.9 % | ACCEPTABLE |
| 441 | -4.85 | 6.16 | 19.27 | 61.9 % | ACCEPTABLE |
| 442 | -5.34 | 5.59 | 19.57 | 60.1 % | ACCEPTABLE |
| 443 | -5.62 | 4.85 | 17.75 | 11.9 % | ACCEPTABLE |
| 444 | -7.55 | 8.12 | 20.66 | 2.6 % | ACCEPTABLE |
| 445 | -6.46 | 6.91 | 19.19 | 2.3 % | ACCEPTABLE |
| 446 | -6.81 | 6.16 | 19.27 | 7.1 % | ACCEPTABLE |
| 447 | -5.19 | 2.88 | 16.89 | 55.1 % | ACCEPTABLE |
| 448 | -4.59 | 2.30 | 16.20 | 60.1 % | ACCEPTABLE |
| 449 | -6.33 | 4.87 | 18.43 | 58.4 % | ACCEPTABLE |
| 450 | -5.20 | 3.80 | 17.08 | 63.4 % | ACCEPTABLE |
| 451 | -5.78 | 3.44 | 17.57 | 55.8 % | ACCEPTABLE |
| 452 | -6.58 | 5.55 | 18.86 | 10.9 % | ACCEPTABLE |
| 453 | -5.43 | 4.36 | 17.43 | 30.8 % | ACCEPTABLE |
| 454 | -6.23 | 8.09 | 21.24 | 62.8 % | ACCEPTABLE |
| 455 | -5.05 | 6.70 | 19.64 | 62.0 % | ACCEPTABLE |
| 456 | -5.83 | 6.16 | 19.27 | 63.7 % | ACCEPTABLE |
| 457 | -5.44 | 6.86 | 19.75 | 58.2 % | ACCEPTABLE |
| 458 | -6.04 | 6.16 | 18.85 | 6.8 % | ACCEPTABLE |
| 459 | -6.79 | 9.36 | 21.97 | 7.1 % | ACCEPTABLE |
| 460 | -5.86 | 7.96 | 20.55 | 11.3 % | ACCEPTABLE |
| 461 | -6.24 | 7.82 | 20.84 | 63.2 % | ACCEPTABLE |
| 462 | -4.69 | 4.88 | 18.44 | 56.0 % | ACCEPTABLE |
| 463 | -5.94 | 7.01 | 20.27 | 63.4 % | ACCEPTABLE |
| 464 | -5.18 | 6.16 | 19.27 | 58.2 % | ACCEPTABLE |
| 465 | -5.49 | 5.76 | 19.45 | 61.1 % | ACCEPTABLE |
| 466 | -5.70 | 5.29 | 18.26 | 20.0 % | ACCEPTABLE |
| 467 | -6.98 | 7.46 | 20.18 | 4.3 % | ACCEPTABLE |
| 468 | -6.23 | 6.63 | 19.19 | 5.2 % | ACCEPTABLE |
| 469 | -6.48 | 6.16 | 19.27 | 11.8 % | ACCEPTABLE |
| 470 | -5.38 | 3.88 | 17.59 | 60.9 % | ACCEPTABLE |
| 471 | -4.98 | 3.48 | 17.11 | 61.0 % | ACCEPTABLE |
| 472 | -6.17 | 5.33 | 18.72 | 58.8 % | ACCEPTABLE |
| 473 | -5.41 | 4.57 | 17.78 | 63.2 % | ACCEPTABLE |
| 474 | -5.77 | 4.28 | 18.06 | 56.4 % | ACCEPTABLE |
| 475 | -6.33 | 5.76 | 19.00 | 19.9 % | ACCEPTABLE |
| 476 | -5.56 | 4.95 | 18.03 | 30.6 % | ACCEPTABLE |
| 477 | -6.09 | 7.43 | 20.57 | 63.0 % | ACCEPTABLE |
| 478 | -5.31 | 6.53 | 19.52 | 58.6 % | ACCEPTABLE |
| 479 | -5.83 | 6.16 | 19.27 | 63.7 % | ACCEPTABLE |
| 480 | -5.58 | 6.64 | 19.60 | 58.5 % | ACCEPTABLE |
| 481 | -5.97 | 6.17 | 19.00 | 11.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 482 | -6.46 | 8.23 | 21.00 | 9.9 % | ACCEPTABLE |
| 483 | -5.84 | 7.33 | 20.09 | 14.3 % | ACCEPTABLE |
| 484 | -6.10 | 7.26 | 20.31 | 63.2 % | ACCEPTABLE |
| 485 | -5.07 | 5.31 | 18.71 | 55.3 % | ACCEPTABLE |
| 486 | -5.91 | 6.73 | 19.94 | 63.3 % | ACCEPTABLE |
| 487 | -5.39 | 6.16 | 19.27 | 58.2 % | ACCEPTABLE |
| 488 | -5.60 | 5.89 | 19.38 | 62.2 % | ACCEPTABLE |
| 489 | -5.74 | 5.58 | 18.60 | 30.3 % | ACCEPTABLE |
| 490 | -6.59 | 7.02 | 19.87 | 7.8 % | ACCEPTABLE |
| 491 | -6.09 | 6.47 | 19.20 | 8.3 % | ACCEPTABLE |
| 492 | -6.27 | 6.16 | 19.27 | 21.1 % | ACCEPTABLE |
| 493 | -5.52 | 4.60 | 18.10 | 62.4 % | ACCEPTABLE |
| 494 | -5.25 | 4.33 | 17.78 | 62.7 % | ACCEPTABLE |
| 495 | -6.06 | 5.62 | 18.91 | 63.8 % | ACCEPTABLE |
| 496 | -5.79 | 6.06 | 19.21 | 64.0 % | ACCEPTABLE |
| 497 | -5.53 | 6.53 | 19.53 | 58.6 % | ACCEPTABLE |
| 498 | -5.93 | 6.07 | 18.93 | 11.8 % | ACCEPTABLE |
| 499 | -6.41 | 8.11 | 20.92 | 10.8 % | ACCEPTABLE |
| 500 | -5.79 | 7.22 | 20.02 | 19.2 % | ACCEPTABLE |
| 501 | -6.06 | 7.15 | 20.24 | 63.4 % | ACCEPTABLE |
| 502 | -5.03 | 5.21 | 18.65 | 55.0 % | ACCEPTABLE |
| 503 | -5.87 | 6.63 | 19.88 | 63.2 % | ACCEPTABLE |
| 504 | -5.35 | 6.06 | 19.21 | 58.3 % | ACCEPTABLE |
| 505 | -5.56 | 5.79 | 19.33 | 61.7 % | ACCEPTABLE |
| 506 | -5.70 | 5.48 | 18.54 | 64.3 % | ACCEPTABLE |
| 507 | -5.45 | 5.95 | 18.86 | 58.6 % | ACCEPTABLE |
| 508 | -5.84 | 5.48 | 18.26 | 8.0 % | ACCEPTABLE |
| 509 | -6.33 | 7.48 | 20.21 | 8.2 % | ACCEPTABLE |
| 510 | -5.71 | 6.61 | 19.32 | 11.5 % | ACCEPTABLE |
| 511 | -5.97 | 6.55 | 19.55 | 31.5 % | ACCEPTABLE |
| 512 | -4.94 | 4.66 | 18.00 | 55.6 % | ACCEPTABLE |
| 513 | -5.78 | 6.03 | 19.20 | 63.9 % | ACCEPTABLE |
| 514 | -5.26 | 5.48 | 18.54 | 58.3 % | ACCEPTABLE |
| 515 | -5.47 | 5.22 | 18.67 | 62.8 % | ACCEPTABLE |
| 516 | -5.61 | 4.92 | 17.88 | 15.0 % | ACCEPTABLE |
| 517 | -6.46 | 6.31 | 19.11 | 6.4 % | ACCEPTABLE |
| 518 | -5.96 | 5.77 | 18.46 | 6.5 % | ACCEPTABLE |
| 519 | -6.14 | 5.48 | 18.54 | 14.9 % | ACCEPTABLE |
| 520 | -5.39 | 3.97 | 17.42 | 62.8 % | ACCEPTABLE |
| 521 | -5.12 | 3.70 | 17.10 | 63.4 % | ACCEPTABLE |
| 522 | -5.93 | 4.95 | 18.19 | 30.8 % | ACCEPTABLE |
| 523 | -5.42 | 4.44 | 17.57 | 64.8 % | ACCEPTABLE |
| 524 | -5.16 | 4.87 | 17.85 | 58.6 % | ACCEPTABLE |
| 525 | -5.55 | 4.43 | 17.27 | 10.0 % | ACCEPTABLE |
| 526 | -6.03 | 6.33 | 19.12 | 9.7 % | ACCEPTABLE |
| 527 | -5.41 | 5.50 | 18.27 | 19.4 % | ACCEPTABLE |
| 528 | -5.69 | 5.46 | 18.53 | 64.3 % | ACCEPTABLE |
| 529 | -4.67 | 3.66 | 17.08 | 54.5 % | ACCEPTABLE |
| 530 | -5.50 | 4.98 | 18.21 | 63.0 % | ACCEPTABLE |
| 531 | -4.98 | 4.44 | 17.57 | 58.3 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 532 | -5.21 | 4.22 | 17.73 | 62.6 % | ACCEPTABLE |
| 533 | -5.33 | 3.89 | 16.93 | 21.8 % | ACCEPTABLE |
| 534 | -6.17 | 5.22 | 18.08 | 6.5 % | ACCEPTABLE |
| 535 | -5.66 | 4.69 | 17.45 | 7.4 % | ACCEPTABLE |
| 536 | -5.86 | 4.44 | 17.57 | 13.1 % | ACCEPTABLE |
| 537 | -5.12 | 3.02 | 16.54 | 62.1 % | ACCEPTABLE |
| 538 | -4.86 | 2.76 | 16.24 | 62.2 % | ACCEPTABLE |
| 539 | -5.66 | 3.95 | 17.26 | 31.3 % | ACCEPTABLE |
| 540 | -5.15 | 3.46 | 16.65 | 63.5 % | ACCEPTABLE |
| 541 | -5.39 | 3.27 | 16.85 | 62.8 % | ACCEPTABLE |
| 542 | -5.76 | 4.20 | 17.42 | 20.5 % | ACCEPTABLE |
| 543 | -5.24 | 3.68 | 16.79 | 31.1 % | ACCEPTABLE |
| 544 | -5.60 | 5.22 | 18.37 | 64.3 % | ACCEPTABLE |
| 545 | -5.07 | 4.66 | 17.71 | 58.5 % | ACCEPTABLE |
| 546 | -5.42 | 4.44 | 17.57 | 64.8 % | ACCEPTABLE |
| 547 | -5.25 | 4.73 | 17.76 | 58.8 % | ACCEPTABLE |
| 548 | -5.51 | 4.44 | 17.37 | 12.1 % | ACCEPTABLE |
| 549 | -5.82 | 5.67 | 18.58 | 12.8 % | ACCEPTABLE |
| 550 | -5.41 | 5.13 | 18.03 | 19.8 % | ACCEPTABLE |
| 551 | -5.60 | 5.11 | 18.20 | 30.5 % | ACCEPTABLE |
| 552 | -4.92 | 3.92 | 17.24 | 55.7 % | ACCEPTABLE |
| 553 | -5.48 | 4.80 | 18.00 | 63.2 % | ACCEPTABLE |
| 554 | -5.13 | 4.44 | 17.57 | 57.1 % | ACCEPTABLE |
| 555 | -5.28 | 4.29 | 17.67 | 63.4 % | ACCEPTABLE |
| 556 | -5.36 | 4.08 | 17.14 | 32.4 % | ACCEPTABLE |
| 557 | -5.92 | 4.96 | 17.91 | 9.9 % | ACCEPTABLE |
| 558 | -5.58 | 4.60 | 17.48 | 10.0 % | ACCEPTABLE |
| 559 | -5.71 | 4.44 | 17.57 | 21.6 % | ACCEPTABLE |
| 560 | -5.22 | 3.47 | 16.87 | 63.6 % | ACCEPTABLE |
| 561 | -5.04 | 3.30 | 16.66 | 63.4 % | ACCEPTABLE |
| 562 | -5.58 | 4.12 | 17.37 | 31.0 % | ACCEPTABLE |
| 563 | -5.24 | 3.78 | 16.95 | 63.4 % | ACCEPTABLE |
| 564 | -5.39 | 3.65 | 17.07 | 63.4 % | ACCEPTABLE |
| 565 | -5.65 | 4.28 | 17.47 | 31.1 % | ACCEPTABLE |
| 566 | -5.30 | 3.93 | 17.05 | 31.0 % | ACCEPTABLE |
| 567 | -5.54 | 4.96 | 18.10 | 64.5 % | ACCEPTABLE |
| 568 | -5.19 | 4.59 | 17.67 | 58.4 % | ACCEPTABLE |
| 569 | -5.42 | 4.44 | 17.57 | 64.8 % | ACCEPTABLE |
| 570 | -5.31 | 4.64 | 17.70 | 64.4 % | ACCEPTABLE |
| 571 | -5.48 | 4.44 | 17.44 | 16.3 % | ACCEPTABLE |
| 572 | -5.68 | 5.25 | 18.23 | 20.0 % | ACCEPTABLE |
| 573 | -5.41 | 4.90 | 17.87 | 30.7 % | ACCEPTABLE |
| 574 | -5.54 | 4.89 | 17.99 | 64.7 % | ACCEPTABLE |
| 575 | -5.09 | 4.09 | 17.35 | 63.0 % | ACCEPTABLE |
| 576 | -5.46 | 4.68 | 17.86 | 63.1 % | ACCEPTABLE |
| 577 | -5.23 | 4.44 | 17.57 | 64.4 % | ACCEPTABLE |
| 578 | -5.32 | 4.34 | 17.64 | 63.2 % | ACCEPTABLE |
| 579 | -5.38 | 4.20 | 17.28 | 30.8 % | ACCEPTABLE |
| 580 | -5.75 | 4.79 | 17.79 | 15.0 % | ACCEPTABLE |
| 581 | -5.52 | 4.55 | 17.51 | 15.1 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 582 | -5.61 | 4.44 | 17.57 | 21.7 % | ACCEPTABLE |
| 583 | -5.28 | 3.79 | 17.09 | 63.3 % | ACCEPTABLE |
| 584 | -5.16 | 3.67 | 16.95 | 63.2 % | ACCEPTABLE |
| 585 | -5.53 | 4.23 | 17.44 | 63.5 % | ACCEPTABLE |
| 586 | -5.30 | 4.00 | 17.16 | 63.5 % | ACCEPTABLE |
| 587 | -5.40 | 3.90 | 17.23 | 63.5 % | ACCEPTABLE |
| 588 | -5.57 | 4.34 | 17.50 | 30.8 % | ACCEPTABLE |
| 589 | -5.34 | 4.10 | 17.22 | 32.5 % | ACCEPTABLE |
| 590 | -5.50 | 4.78 | 17.92 | 64.6 % | ACCEPTABLE |
| 591 | -5.27 | 4.54 | 17.63 | 64.3 % | ACCEPTABLE |
| 592 | -5.42 | 4.44 | 17.57 | 64.8 % | ACCEPTABLE |
| 593 | -5.34 | 4.57 | 17.66 | 64.6 % | ACCEPTABLE |
| 594 | -5.46 | 4.44 | 17.48 | 30.8 % | ACCEPTABLE |
| 595 | -5.60 | 4.98 | 18.01 | 30.5 % | ACCEPTABLE |
| 596 | -5.41 | 4.74 | 17.77 | 30.7 % | ACCEPTABLE |
| 597 | -5.50 | 4.74 | 17.85 | 32.2 % | ACCEPTABLE |
| 598 | -5.20 | 4.21 | 17.42 | 63.2 % | ACCEPTABLE |
| 599 | -5.45 | 4.60 | 17.76 | 63.3 % | ACCEPTABLE |
| 600 | -5.29 | 4.44 | 17.57 | 64.5 % | ACCEPTABLE |
| 601 | -5.35 | 4.37 | 17.61 | 63.2 % | ACCEPTABLE |
| 602 | -5.39 | 4.28 | 17.38 | 30.8 % | ACCEPTABLE |
| 603 | -5.64 | 4.67 | 17.72 | 15.1 % | ACCEPTABLE |
| 604 | -5.49 | 4.51 | 17.53 | 20.3 % | ACCEPTABLE |
| 605 | -5.55 | 4.44 | 17.57 | 32.3 % | ACCEPTABLE |
| 606 | -5.33 | 4.00 | 17.25 | 63.4 % | ACCEPTABLE |
| 607 | -5.25 | 3.92 | 17.15 | 63.5 % | ACCEPTABLE |
| 608 | -5.49 | 4.30 | 17.48 | 63.6 % | ACCEPTABLE |
| 609 | -5.34 | 4.15 | 17.29 | 63.4 % | ACCEPTABLE |
| 610 | -5.40 | 4.08 | 17.34 | 63.5 % | ACCEPTABLE |
| 611 | -5.52 | 4.37 | 17.53 | 30.9 % | ACCEPTABLE |
| 612 | -5.37 | 4.21 | 17.34 | 64.8 % | ACCEPTABLE |
| 613 | -5.47 | 4.67 | 17.81 | 64.6 % | ACCEPTABLE |
| 614 | -5.32 | 4.51 | 17.61 | 64.7 % | ACCEPTABLE |
| 615 | -5.42 | 4.44 | 17.57 | 64.8 % | ACCEPTABLE |
| 616 | -5.37 | 4.53 | 17.63 | 64.6 % | ACCEPTABLE |
| 617 | -5.45 | 4.44 | 17.51 | 30.8 % | ACCEPTABLE |
| 618 | -5.54 | 4.80 | 17.86 | 32.1 % | ACCEPTABLE |
| 619 | -5.41 | 4.64 | 17.70 | 64.4 % | ACCEPTABLE |
| 620 | -5.47 | 4.64 | 17.76 | 64.5 % | ACCEPTABLE |
| 621 | -5.27 | 4.29 | 17.47 | 63.3 % | ACCEPTABLE |
| 622 | -5.44 | 4.55 | 17.70 | 63.3 % | ACCEPTABLE |
| 623 | -5.33 | 4.44 | 17.57 | 64.6 % | ACCEPTABLE |
| 624 | -5.38 | 4.39 | 17.60 | 63.4 % | ACCEPTABLE |
| 625 | -5.40 | 4.33 | 17.44 | 63.2 % | ACCEPTABLE |
| 626 | -5.57 | 4.59 | 17.67 | 30.8 % | ACCEPTABLE |
| 627 | -5.47 | 4.49 | 17.54 | 30.8 % | ACCEPTABLE |
| 628 | -5.51 | 4.44 | 17.57 | 32.4 % | ACCEPTABLE |
| 629 | -5.36 | 4.15 | 17.35 | 63.3 % | ACCEPTABLE |
| 630 | -5.31 | 4.09 | 17.29 | 63.3 % | ACCEPTABLE |
| 631 | -5.47 | 4.35 | 17.51 | 32.5 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 632 | -5.37 | 4.24 | 17.39 | 63.3 % | ACCEPTABLE |
| 633 | -5.41 | 4.20 | 17.42 | 63.2 % | ACCEPTABLE |
| 634 | -5.49 | 4.39 | 17.54 | 32.4 % | ACCEPTABLE |
| 635 | -5.38 | 4.29 | 17.41 | 63.6 % | ACCEPTABLE |
| 636 | -5.46 | 4.59 | 17.73 | 63.4 % | ACCEPTABLE |
| 637 | -5.35 | 4.49 | 17.60 | 64.4 % | ACCEPTABLE |
| 638 | -5.42 | 4.44 | 17.57 | 64.8 % | ACCEPTABLE |
| 639 | -5.39 | 4.50 | 17.61 | 64.4 % | ACCEPTABLE |
| 640 | -5.44 | 4.44 | 17.53 | 30.8 % | ACCEPTABLE |
| 641 | -5.50 | 4.68 | 17.76 | 64.5 % | ACCEPTABLE |
| 642 | -5.42 | 4.57 | 17.66 | 64.5 % | ACCEPTABLE |
| 643 | -5.46 | 4.57 | 17.69 | 64.6 % | ACCEPTABLE |
| 644 | -5.32 | 4.34 | 17.50 | 63.2 % | ACCEPTABLE |
| 645 | -5.43 | 4.51 | 17.65 | 63.3 % | ACCEPTABLE |
| 646 | -5.36 | 4.44 | 17.57 | 64.6 % | ACCEPTABLE |
| 647 | -5.39 | 4.41 | 17.59 | 63.2 % | ACCEPTABLE |
| 648 | -5.41 | 4.37 | 17.49 | 63.2 % | ACCEPTABLE |
| 649 | -5.52 | 4.54 | 17.64 | 30.8 % | ACCEPTABLE |
| 650 | -5.45 | 4.47 | 17.55 | 30.8 % | ACCEPTABLE |
| 651 | -5.48 | 4.44 | 17.57 | 64.8 % | ACCEPTABLE |
| 652 | -5.38 | 4.24 | 17.42 | 63.5 % | ACCEPTABLE |
| 653 | -5.34 | 4.21 | 17.38 | 63.6 % | ACCEPTABLE |
| 654 | -5.45 | 4.38 | 17.53 | 63.4 % | ACCEPTABLE |
| 655 | -5.38 | 4.31 | 17.45 | 63.5 % | ACCEPTABLE |
| 656 | -5.41 | 4.28 | 17.47 | 63.4 % | ACCEPTABLE |
| 657 | -5.47 | 4.41 | 17.55 | 63.3 % | ACCEPTABLE |
| 658 | -5.40 | 4.34 | 17.47 | 63.6 % | ACCEPTABLE |
| 659 | -5.44 | 4.54 | 17.67 | 64.6 % | ACCEPTABLE |
| 660 | -5.37 | 4.47 | 17.59 | 64.4 % | ACCEPTABLE |
| 661 | -5.42 | 4.44 | 17.57 | 64.8 % | ACCEPTABLE |
| 662 | -5.40 | 4.48 | 17.60 | 64.6 % | ACCEPTABLE |
| 663 | -5.43 | 4.44 | 17.54 | 64.7 % | ACCEPTABLE |
| 664 | -5.47 | 4.60 | 17.70 | 64.6 % | ACCEPTABLE |
| 665 | -5.42 | 4.53 | 17.63 | 64.6 % | ACCEPTABLE |
| 666 | -5.44 | 4.53 | 17.65 | 30.8 % | ACCEPTABLE |
| 667 | -5.35 | 4.37 | 17.53 | 63.1 % | ACCEPTABLE |
| 668 | -5.43 | 4.49 | 17.63 | 63.4 % | ACCEPTABLE |
| 669 | -5.38 | 4.44 | 17.57 | 64.6 % | ACCEPTABLE |
| 670 | -5.40 | 4.42 | 17.58 | 64.7 % | ACCEPTABLE |
| 671 | -5.41 | 4.39 | 17.51 | 63.4 % | ACCEPTABLE |
| 672 | -5.49 | 4.51 | 17.61 | 30.8 % | ACCEPTABLE |
| 673 | -5.44 | 4.46 | 17.56 | 64.5 % | ACCEPTABLE |
| 674 | -5.46 | 4.44 | 17.57 | 64.6 % | ACCEPTABLE |
| 675 | -5.39 | 4.31 | 17.47 | 63.4 % | ACCEPTABLE |
| 676 | -5.37 | 4.28 | 17.44 | 63.3 % | ACCEPTABLE |
| 677 | -5.44 | 4.40 | 17.54 | 64.7 % | ACCEPTABLE |
| 678 | -5.40 | 4.35 | 17.49 | 64.7 % | ACCEPTABLE |
| 679 | -5.41 | 4.33 | 17.50 | 63.4 % | ACCEPTABLE |
| 680 | -5.45 | 4.42 | 17.56 | 63.4 % | ACCEPTABLE |
| 681 | -5.40 | 4.37 | 17.50 | 63.6 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 682 | -5.44 | 4.51 | 17.64 | 64.7 % | ACCEPTABLE |
| 683 | -5.39 | 4.46 | 17.58 | 64.4 % | ACCEPTABLE |
| 684 | -5.28 | 4.54 | 17.57 | 65.9 % | ACCEPTABLE |
| 685 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 686 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 687 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 688 | -6.14 | 17.05 | 33.65 | 49.9 % | ACCEPTABLE |
| 689 | 7.02 | 3.42 | 16.21 | 2.4 % | ACCEPTABLE |
| 690 | -2.86 | 2.04 | 25.81 | 34.1 % | ACCEPTABLE |
| 691 | -9.65 | 33.12 | 46.42 | 55.9 % | ACCEPTABLE |
| 692 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 693 | -9.43 | 26.28 | 38.82 | 11.2 % | ACCEPTABLE |
| 694 | -6.03 | 13.08 | 28.37 | 55.7 % | ACCEPTABLE |
| 695 | 2.15 | 4.61 | 17.61 | 36.4 % | ACCEPTABLE |
| 696 | -3.30 | 2.50 | 22.59 | 41.2 % | ACCEPTABLE |
| 697 | -8.27 | 21.76 | 35.00 | 63.4 % | ACCEPTABLE |
| 698 | 1.95 | 5.10 | 17.94 | 37.2 % | ACCEPTABLE |
| 699 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 700 | 0.86 | 1.65 | 15.88 | 42.8 % | ACCEPTABLE |
| 701 | -8.19 | 18.20 | 30.80 | 10.0 % | ACCEPTABLE |
| 702 | -5.89 | 10.36 | 24.81 | 64.1 % | ACCEPTABLE |
| 703 | -0.34 | 4.61 | 17.61 | 55.9 % | ACCEPTABLE |
| 704 | -3.70 | 2.92 | 20.57 | 47.8 % | ACCEPTABLE |
| 705 | -7.31 | 15.19 | 28.37 | 67.2 % | ACCEPTABLE |
| 706 | -0.92 | 6.05 | 18.59 | 58.2 % | ACCEPTABLE |
| 707 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 708 | -2.40 | 5.62 | 18.29 | 64.8 % | ACCEPTABLE |
| 709 | -7.29 | 13.26 | 25.94 | 13.2 % | ACCEPTABLE |
| 710 | -5.75 | 8.50 | 22.43 | 63.6 % | ACCEPTABLE |
| 711 | -2.00 | 4.61 | 17.61 | 64.6 % | ACCEPTABLE |
| 712 | -4.07 | 3.31 | 19.36 | 53.2 % | ACCEPTABLE |
| 713 | -8.62 | 4.61 | 17.61 | 1.0 % | ACCEPTABLE |
| 714 | -7.74 | 2.43 | 16.29 | 2.4 % | ACCEPTABLE |
| 715 | -6.65 | 11.29 | 24.42 | 66.9 % | ACCEPTABLE |
| 716 | -2.53 | 5.93 | 18.50 | 64.9 % | ACCEPTABLE |
| 717 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 718 | -3.69 | 6.06 | 18.60 | 67.5 % | ACCEPTABLE |
| 719 | -5.82 | 3.97 | 15.80 | 1.2 % | ACCEPTABLE |
| 720 | -5.94 | 11.62 | 22.99 | 1.5 % | ACCEPTABLE |
| 721 | -6.66 | 10.19 | 22.94 | 11.5 % | ACCEPTABLE |
| 722 | -1.50 | 0.66 | 15.41 | 51.7 % | ACCEPTABLE |
| 723 | -5.64 | 7.24 | 20.83 | 71.8 % | ACCEPTABLE |
| 724 | -3.10 | 4.61 | 17.61 | 68.4 % | ACCEPTABLE |
| 725 | -4.39 | 3.64 | 18.64 | 57.6 % | ACCEPTABLE |
| 726 | -4.71 | 1.70 | 14.29 | 4.9 % | ACCEPTABLE |
| 727 | -7.52 | 4.61 | 17.61 | 2.5 % | ACCEPTABLE |
| 728 | -6.29 | 1.58 | 15.84 | 64.0 % | ACCEPTABLE |
| 729 | -6.96 | 3.23 | 16.75 | 4.5 % | ACCEPTABLE |
| 730 | -4.37 | 1.00 | 13.88 | 12.0 % | ACCEPTABLE |
| 731 | -6.21 | 8.89 | 21.99 | 72.4 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 732 | -3.51 | 5.62 | 18.29 | 67.8 % | ACCEPTABLE |
| 733 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 734 | -4.34 | 5.84 | 18.44 | 65.9 % | ACCEPTABLE |
| 735 | -5.71 | 4.36 | 16.51 | 1.9 % | ACCEPTABLE |
| 736 | -7.69 | 12.27 | 24.19 | 1.4 % | ACCEPTABLE |
| 737 | -5.53 | 8.78 | 20.65 | 2.1 % | ACCEPTABLE |
| 738 | -6.22 | 8.24 | 21.06 | 14.9 % | ACCEPTABLE |
| 739 | -2.76 | 1.97 | 16.04 | 55.6 % | ACCEPTABLE |
| 740 | -5.55 | 6.38 | 19.76 | 72.2 % | ACCEPTABLE |
| 741 | -3.84 | 4.61 | 17.61 | 66.1 % | ACCEPTABLE |
| 742 | -4.65 | 3.91 | 18.23 | 66.5 % | ACCEPTABLE |
| 743 | -4.96 | 2.72 | 15.41 | 7.1 % | ACCEPTABLE |
| 744 | -7.87 | 7.30 | 19.50 | 1.2 % | ACCEPTABLE |
| 745 | -6.31 | 5.67 | 17.47 | 1.2 % | ACCEPTABLE |
| 746 | -6.78 | 4.61 | 17.61 | 4.1 % | ACCEPTABLE |
| 747 | -4.43 | 0.30 | 14.65 | 59.5 % | ACCEPTABLE |
| 748 | -6.01 | 2.70 | 16.45 | 31.4 % | ACCEPTABLE |
| 749 | -4.34 | 1.36 | 14.61 | 73.5 % | ACCEPTABLE |
| 750 | -5.33 | 1.04 | 15.58 | 66.3 % | ACCEPTABLE |
| 751 | -6.42 | 3.72 | 17.05 | 7.0 % | ACCEPTABLE |
| 752 | -4.69 | 2.13 | 15.05 | 15.2 % | ACCEPTABLE |
| 753 | -5.92 | 7.39 | 20.46 | 72.4 % | ACCEPTABLE |
| 754 | -4.13 | 5.33 | 18.09 | 65.9 % | ACCEPTABLE |
| 755 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 756 | -4.70 | 5.53 | 18.23 | 71.3 % | ACCEPTABLE |
| 757 | -5.60 | 4.51 | 16.91 | 4.1 % | ACCEPTABLE |
| 758 | -6.80 | 9.32 | 21.59 | 3.4 % | ACCEPTABLE |
| 759 | -5.38 | 7.21 | 19.44 | 6.4 % | ACCEPTABLE |
| 760 | -5.93 | 6.99 | 19.86 | 21.1 % | ACCEPTABLE |
| 761 | -3.61 | 2.84 | 16.53 | 64.8 % | ACCEPTABLE |
| 762 | -5.48 | 5.80 | 19.05 | 73.2 % | ACCEPTABLE |
| 763 | -4.33 | 4.61 | 17.61 | 71.3 % | ACCEPTABLE |
| 764 | -4.84 | 4.11 | 17.99 | 69.4 % | ACCEPTABLE |
| 765 | -5.09 | 3.37 | 16.15 | 9.2 % | ACCEPTABLE |
| 766 | -7.02 | 6.40 | 18.84 | 1.7 % | ACCEPTABLE |
| 767 | -5.92 | 5.26 | 17.44 | 1.8 % | ACCEPTABLE |
| 768 | -6.29 | 4.61 | 17.61 | 5.6 % | ACCEPTABLE |
| 769 | -4.67 | 1.57 | 15.46 | 68.1 % | ACCEPTABLE |
| 770 | -4.06 | 1.02 | 14.80 | 60.6 % | ACCEPTABLE |
| 771 | -5.80 | 3.39 | 16.85 | 32.0 % | ACCEPTABLE |
| 772 | -4.67 | 2.40 | 15.56 | 74.4 % | ACCEPTABLE |
| 773 | -5.27 | 2.10 | 16.11 | 63.3 % | ACCEPTABLE |
| 774 | -6.06 | 4.03 | 17.24 | 9.8 % | ACCEPTABLE |
| 775 | -4.90 | 2.92 | 15.87 | 22.0 % | ACCEPTABLE |
| 776 | -5.72 | 6.43 | 19.48 | 73.3 % | ACCEPTABLE |
| 777 | -4.53 | 5.11 | 17.94 | 71.2 % | ACCEPTABLE |
| 778 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 779 | -4.92 | 5.26 | 18.04 | 72.7 % | ACCEPTABLE |
| 780 | -5.51 | 4.57 | 17.16 | 5.8 % | ACCEPTABLE |
| 781 | -6.27 | 7.59 | 20.10 | 4.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 782 | -5.33 | 6.27 | 18.75 | 9.7 % | ACCEPTABLE |
| 783 | -5.72 | 6.18 | 19.09 | 30.2 % | ACCEPTABLE |
| 784 | -4.18 | 3.43 | 16.87 | 68.6 % | ACCEPTABLE |
| 785 | -5.43 | 5.41 | 18.57 | 73.7 % | ACCEPTABLE |
| 786 | -4.66 | 4.61 | 17.61 | 72.7 % | ACCEPTABLE |
| 787 | -4.98 | 4.27 | 17.84 | 64.5 % | ACCEPTABLE |
| 788 | -5.17 | 3.79 | 16.64 | 11.2 % | ACCEPTABLE |
| 789 | -6.45 | 5.80 | 18.41 | 4.0 % | ACCEPTABLE |
| 790 | -5.70 | 5.02 | 17.47 | 4.2 % | ACCEPTABLE |
| 791 | -5.96 | 4.61 | 17.61 | 9.0 % | ACCEPTABLE |
| 792 | -4.86 | 2.50 | 16.09 | 69.8 % | ACCEPTABLE |
| 793 | -4.46 | 2.12 | 15.63 | 72.0 % | ACCEPTABLE |
| 794 | -5.65 | 3.83 | 17.11 | 30.5 % | ACCEPTABLE |
| 795 | -4.88 | 3.12 | 16.22 | 68.2 % | ACCEPTABLE |
| 796 | -5.26 | 2.87 | 16.54 | 65.2 % | ACCEPTABLE |
| 797 | -5.81 | 4.23 | 17.37 | 12.0 % | ACCEPTABLE |
| 798 | -5.04 | 3.47 | 16.44 | 21.0 % | ACCEPTABLE |
| 799 | -5.58 | 5.81 | 18.84 | 69.0 % | ACCEPTABLE |
| 800 | -4.80 | 4.95 | 17.84 | 68.2 % | ACCEPTABLE |
| 801 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 802 | -5.06 | 5.06 | 17.91 | 68.7 % | ACCEPTABLE |
| 803 | -5.44 | 4.60 | 17.31 | 8.5 % | ACCEPTABLE |
| 804 | -5.94 | 6.54 | 19.20 | 7.8 % | ACCEPTABLE |
| 805 | -5.31 | 5.69 | 18.34 | 12.2 % | ACCEPTABLE |
| 806 | -5.59 | 5.65 | 18.59 | 33.0 % | ACCEPTABLE |
| 807 | -4.55 | 3.82 | 17.11 | 65.8 % | ACCEPTABLE |
| 808 | -5.39 | 5.14 | 18.25 | 74.1 % | ACCEPTABLE |
| 809 | -4.87 | 4.61 | 17.61 | 68.8 % | ACCEPTABLE |
| 810 | -5.09 | 4.37 | 17.76 | 72.1 % | ACCEPTABLE |
| 811 | -5.22 | 4.07 | 16.96 | 14.2 % | ACCEPTABLE |
| 812 | -6.07 | 5.40 | 18.14 | 5.7 % | ACCEPTABLE |
| 813 | -5.56 | 4.88 | 17.50 | 6.0 % | ACCEPTABLE |
| 814 | -5.75 | 4.61 | 17.61 | 11.8 % | ACCEPTABLE |
| 815 | -5.00 | 3.16 | 16.55 | 72.5 % | ACCEPTABLE |
| 816 | -4.73 | 2.90 | 16.24 | 65.6 % | ACCEPTABLE |
| 817 | -5.54 | 4.10 | 17.28 | 34.0 % | ACCEPTABLE |
| 818 | -5.03 | 3.61 | 16.67 | 68.8 % | ACCEPTABLE |
| 819 | -5.26 | 3.41 | 16.86 | 72.1 % | ACCEPTABLE |
| 820 | -5.65 | 4.36 | 17.45 | 15.0 % | ACCEPTABLE |
| 821 | -5.13 | 3.84 | 16.82 | 33.9 % | ACCEPTABLE |
| 822 | -5.49 | 5.40 | 18.42 | 75.6 % | ACCEPTABLE |
| 823 | -4.97 | 4.84 | 17.76 | 68.6 % | ACCEPTABLE |
| 824 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 825 | -5.14 | 4.92 | 17.81 | 68.9 % | ACCEPTABLE |
| 826 | -5.40 | 4.61 | 17.42 | 9.8 % | ACCEPTABLE |
| 827 | -5.72 | 5.87 | 18.64 | 11.1 % | ACCEPTABLE |
| 828 | -5.31 | 5.32 | 18.08 | 19.5 % | ACCEPTABLE |
| 829 | -5.50 | 5.30 | 18.26 | 74.1 % | ACCEPTABLE |
| 830 | -4.81 | 4.08 | 17.27 | 67.4 % | ACCEPTABLE |
| 831 | -5.36 | 4.97 | 18.04 | 68.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 832 | -5.02 | 4.61 | 17.61 | 69.0 % | ACCEPTABLE |
| 833 | -5.16 | 4.45 | 17.70 | 74.6 % | ACCEPTABLE |
| 834 | -5.25 | 4.25 | 17.18 | 20.7 % | ACCEPTABLE |
| 835 | -5.81 | 5.14 | 17.96 | 8.9 % | ACCEPTABLE |
| 836 | -5.47 | 4.78 | 17.53 | 8.5 % | ACCEPTABLE |
| 837 | -5.60 | 4.61 | 17.61 | 15.1 % | ACCEPTABLE |
| 838 | -5.10 | 3.62 | 16.88 | 73.2 % | ACCEPTABLE |
| 839 | -4.92 | 3.45 | 16.68 | 74.0 % | ACCEPTABLE |
| 840 | -5.47 | 4.28 | 17.39 | 32.3 % | ACCEPTABLE |
| 841 | -5.12 | 3.94 | 16.98 | 69.0 % | ACCEPTABLE |
| 842 | -5.27 | 3.80 | 17.09 | 73.1 % | ACCEPTABLE |
| 843 | -5.53 | 4.45 | 17.50 | 20.6 % | ACCEPTABLE |
| 844 | -5.19 | 4.10 | 17.08 | 20.8 % | ACCEPTABLE |
| 845 | -5.43 | 5.14 | 18.15 | 31.9 % | ACCEPTABLE |
| 846 | -5.08 | 4.77 | 17.71 | 69.0 % | ACCEPTABLE |
| 847 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 848 | -5.20 | 4.82 | 17.75 | 69.2 % | ACCEPTABLE |
| 849 | -5.37 | 4.61 | 17.48 | 15.2 % | ACCEPTABLE |
| 850 | -5.58 | 5.44 | 18.29 | 14.1 % | ACCEPTABLE |
| 851 | -5.31 | 5.08 | 17.92 | 20.8 % | ACCEPTABLE |
| 852 | -5.43 | 5.07 | 18.04 | 30.3 % | ACCEPTABLE |
| 853 | -4.97 | 4.26 | 17.38 | 67.9 % | ACCEPTABLE |
| 854 | -5.35 | 4.85 | 17.90 | 73.9 % | ACCEPTABLE |
| 855 | -5.12 | 4.61 | 17.61 | 69.3 % | ACCEPTABLE |
| 856 | -5.21 | 4.50 | 17.67 | 74.2 % | ACCEPTABLE |
| 857 | -5.27 | 4.37 | 17.32 | 19.3 % | ACCEPTABLE |
| 858 | -5.65 | 4.96 | 17.84 | 11.7 % | ACCEPTABLE |
| 859 | -5.42 | 4.72 | 17.56 | 15.1 % | ACCEPTABLE |
| 860 | -5.50 | 4.61 | 17.61 | 20.7 % | ACCEPTABLE |
| 861 | -5.16 | 3.94 | 17.12 | 73.6 % | ACCEPTABLE |
| 862 | -5.05 | 3.83 | 16.98 | 74.6 % | ACCEPTABLE |
| 863 | -5.41 | 4.39 | 17.47 | 34.1 % | ACCEPTABLE |
| 864 | -5.19 | 4.16 | 17.19 | 74.4 % | ACCEPTABLE |
| 865 | -5.28 | 4.06 | 17.26 | 73.6 % | ACCEPTABLE |
| 866 | -5.46 | 4.50 | 17.54 | 34.0 % | ACCEPTABLE |
| 867 | -5.23 | 4.27 | 17.26 | 34.8 % | ACCEPTABLE |
| 868 | -5.39 | 4.96 | 17.97 | 76.2 % | ACCEPTABLE |
| 869 | -5.16 | 4.72 | 17.68 | 69.0 % | ACCEPTABLE |
| 870 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 871 | -5.24 | 4.75 | 17.70 | 69.2 % | ACCEPTABLE |
| 872 | -5.35 | 4.61 | 17.52 | 19.3 % | ACCEPTABLE |
| 873 | -5.49 | 5.16 | 18.06 | 20.5 % | ACCEPTABLE |
| 874 | -5.31 | 4.92 | 17.81 | 30.2 % | ACCEPTABLE |
| 875 | -5.39 | 4.91 | 17.90 | 31.6 % | ACCEPTABLE |
| 876 | -5.09 | 4.38 | 17.46 | 68.4 % | ACCEPTABLE |
| 877 | -5.33 | 4.77 | 17.80 | 69.2 % | ACCEPTABLE |
| 878 | -5.18 | 4.61 | 17.61 | 69.2 % | ACCEPTABLE |
| 879 | -5.24 | 4.54 | 17.65 | 68.6 % | ACCEPTABLE |
| 880 | -5.28 | 4.45 | 17.42 | 32.1 % | ACCEPTABLE |
| 881 | -5.53 | 4.84 | 17.76 | 20.4 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 882 | -5.38 | 4.69 | 17.57 | 15.2 % | ACCEPTABLE |
| 883 | -5.44 | 4.61 | 17.61 | 32.3 % | ACCEPTABLE |
| 884 | -5.21 | 4.16 | 17.28 | 74.0 % | ACCEPTABLE |
| 885 | -5.13 | 4.08 | 17.18 | 68.6 % | ACCEPTABLE |
| 886 | -5.38 | 4.46 | 17.52 | 74.0 % | ACCEPTABLE |
| 887 | -5.23 | 4.31 | 17.33 | 75.7 % | ACCEPTABLE |
| 888 | -5.29 | 4.24 | 17.37 | 73.9 % | ACCEPTABLE |
| 889 | -5.41 | 4.54 | 17.56 | 32.3 % | ACCEPTABLE |
| 890 | -5.26 | 4.38 | 17.37 | 33.6 % | ACCEPTABLE |
| 891 | -5.36 | 4.84 | 17.85 | 69.5 % | ACCEPTABLE |
| 892 | -5.21 | 4.68 | 17.66 | 69.2 % | ACCEPTABLE |
| 893 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 894 | -5.26 | 4.70 | 17.67 | 32.0 % | ACCEPTABLE |
| 895 | -5.34 | 4.61 | 17.55 | 21.5 % | ACCEPTABLE |
| 896 | -5.43 | 4.97 | 17.91 | 31.5 % | ACCEPTABLE |
| 897 | -5.31 | 4.82 | 17.75 | 30.3 % | ACCEPTABLE |
| 898 | -5.37 | 4.81 | 17.80 | 74.7 % | ACCEPTABLE |
| 899 | -5.16 | 4.45 | 17.51 | 68.3 % | ACCEPTABLE |
| 900 | -5.33 | 4.72 | 17.74 | 75.5 % | ACCEPTABLE |
| 901 | -5.22 | 4.61 | 17.61 | 69.3 % | ACCEPTABLE |
| 902 | -5.26 | 4.56 | 17.64 | 68.7 % | ACCEPTABLE |
| 903 | -5.29 | 4.50 | 17.48 | 32.1 % | ACCEPTABLE |
| 904 | -5.46 | 4.77 | 17.71 | 20.6 % | ACCEPTABLE |
| 905 | -5.36 | 4.66 | 17.59 | 20.7 % | ACCEPTABLE |
| 906 | -5.40 | 4.61 | 17.61 | 32.3 % | ACCEPTABLE |
| 907 | -5.24 | 4.31 | 17.39 | 74.0 % | ACCEPTABLE |
| 908 | -5.19 | 4.26 | 17.32 | 68.9 % | ACCEPTABLE |
| 909 | -5.36 | 4.51 | 17.55 | 32.3 % | ACCEPTABLE |
| 910 | -5.25 | 4.41 | 17.42 | 30.4 % | ACCEPTABLE |
| 911 | -5.30 | 4.36 | 17.45 | 74.1 % | ACCEPTABLE |
| 912 | -5.38 | 4.56 | 17.58 | 32.3 % | ACCEPTABLE |
| 913 | -5.27 | 4.46 | 17.45 | 30.4 % | ACCEPTABLE |
| 914 | -5.35 | 4.76 | 17.77 | 74.7 % | ACCEPTABLE |
| 915 | -5.24 | 4.66 | 17.64 | 30.5 % | ACCEPTABLE |
| 916 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 917 | -5.28 | 4.67 | 17.65 | 69.7 % | ACCEPTABLE |
| 918 | -5.33 | 4.61 | 17.57 | 20.1 % | ACCEPTABLE |
| 919 | -5.39 | 4.85 | 17.81 | 31.6 % | ACCEPTABLE |
| 920 | -5.31 | 4.75 | 17.70 | 32.0 % | ACCEPTABLE |
| 921 | -5.35 | 4.74 | 17.74 | 74.7 % | ACCEPTABLE |
| 922 | -5.21 | 4.51 | 17.54 | 69.3 % | ACCEPTABLE |
| 923 | -5.32 | 4.68 | 17.69 | 69.4 % | ACCEPTABLE |
| 924 | -5.25 | 4.61 | 17.61 | 69.6 % | ACCEPTABLE |
| 925 | -5.28 | 4.58 | 17.63 | 75.8 % | ACCEPTABLE |
| 926 | -5.30 | 4.54 | 17.53 | 31.8 % | ACCEPTABLE |
| 927 | -5.41 | 4.71 | 17.68 | 20.7 % | ACCEPTABLE |
| 928 | -5.34 | 4.64 | 17.59 | 19.3 % | ACCEPTABLE |
| 929 | -5.37 | 4.61 | 17.61 | 32.5 % | ACCEPTABLE |
| 930 | -5.27 | 4.41 | 17.46 | 74.2 % | ACCEPTABLE |
| 931 | -5.23 | 4.37 | 17.42 | 75.0 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 932 | -5.34 | 4.55 | 17.57 | 34.2 % | ACCEPTABLE |
| 933 | -5.27 | 4.48 | 17.48 | 69.5 % | ACCEPTABLE |
| 934 | -5.30 | 4.44 | 17.50 | 74.0 % | ACCEPTABLE |
| 935 | -5.35 | 4.58 | 17.59 | 34.2 % | ACCEPTABLE |
| 936 | -5.29 | 4.51 | 17.50 | 33.0 % | ACCEPTABLE |
| 937 | -5.33 | 4.71 | 17.72 | 76.1 % | ACCEPTABLE |
| 938 | -5.27 | 4.64 | 17.63 | 69.6 % | ACCEPTABLE |
| 939 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |
| 940 | -5.29 | 4.65 | 17.64 | 69.6 % | ACCEPTABLE |
| 941 | -5.32 | 4.61 | 17.58 | 30.4 % | ACCEPTABLE |
| 942 | -5.36 | 4.77 | 17.74 | 31.9 % | ACCEPTABLE |
| 943 | -5.31 | 4.70 | 17.67 | 30.3 % | ACCEPTABLE |
| 944 | -5.33 | 4.70 | 17.69 | 69.6 % | ACCEPTABLE |
| 945 | -5.24 | 4.54 | 17.56 | 69.3 % | ACCEPTABLE |
| 946 | -5.32 | 4.66 | 17.67 | 33.5 % | ACCEPTABLE |
| 947 | -5.27 | 4.61 | 17.61 | 69.6 % | ACCEPTABLE |
| 948 | -5.29 | 4.59 | 17.62 | 32.0 % | ACCEPTABLE |
| 949 | -5.30 | 4.56 | 17.55 | 69.6 % | ACCEPTABLE |
| 950 | -5.38 | 4.68 | 17.66 | 34.2 % | ACCEPTABLE |
| 951 | -5.33 | 4.63 | 17.60 | 31.7 % | ACCEPTABLE |
| 952 | -5.35 | 4.61 | 17.61 | 32.5 % | ACCEPTABLE |
| 953 | -5.28 | 4.48 | 17.51 | 32.5 % | ACCEPTABLE |
| 954 | -5.26 | 4.45 | 17.48 | 31.8 % | ACCEPTABLE |
| 955 | -5.33 | 4.57 | 17.58 | 32.4 % | ACCEPTABLE |
| 956 | -5.29 | 4.52 | 17.53 | 34.3 % | ACCEPTABLE |
| 957 | -5.30 | 4.50 | 17.54 | 74.3 % | ACCEPTABLE |
| 958 | -5.34 | 4.59 | 17.60 | 32.4 % | ACCEPTABLE |
| 959 | -5.29 | 4.54 | 17.54 | 69.6 % | ACCEPTABLE |
| 960 | -5.33 | 4.68 | 17.68 | 75.8 % | ACCEPTABLE |
| 961 | -5.28 | 4.63 | 17.62 | 69.6 % | ACCEPTABLE |
| 962 | -6.14 | 17.05 | 33.65 | 49.9 % | ACCEPTABLE |
| 963 | -2.81 | 23.20 | 40.60 | 36.7 % | ACCEPTABLE |
| 964 | -2.28 | 20.41 | 38.63 | 35.8 % | ACCEPTABLE |
| 965 | 3.97 | 12.49 | 29.34 | 29.5 % | ACCEPTABLE |
| 966 | 1.22 | 1.82 | 29.35 | 23.2 % | ACCEPTABLE |
| 967 | -10.19 | 6.44 | 22.80 | 57.4 % | ACCEPTABLE |
| 968 | 0.99 | 6.44 | 22.80 | 35.2 % | ACCEPTABLE |
| 969 | -6.50 | 18.69 | 34.81 | 50.9 % | ACCEPTABLE |
| 970 | 1.93 | 3.14 | 21.17 | 31.0 % | ACCEPTABLE |
| 971 | -10.19 | 6.44 | 22.80 | 57.4 % | ACCEPTABLE |
| 972 | -7.09 | 11.45 | 28.62 | 51.7 % | ACCEPTABLE |
| 973 | -2.73 | 6.44 | 22.80 | 49.1 % | ACCEPTABLE |
| 974 | -2.64 | 6.10 | 22.61 | 48.6 % | ACCEPTABLE |
| 975 | -10.19 | 6.44 | 22.80 | 57.4 % | ACCEPTABLE |
| 976 | -4.64 | 4.40 | 21.74 | 51.9 % | ACCEPTABLE |
| 977 | -10.05 | 23.42 | 35.51 | 1.6 % | ACCEPTABLE |
| 978 | -8.51 | 11.25 | 27.57 | 57.8 % | ACCEPTABLE |
| 979 | -3.29 | 10.25 | 26.94 | 49.7 % | ACCEPTABLE |
| 980 | -9.42 | 10.12 | 23.41 | 2.0 % | ACCEPTABLE |
| 981 | -8.89 | 32.60 | 44.66 | 14.9 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 982 | -1.12 | 1.60 | 22.81 | 37.3 % | ACCEPTABLE |
| 983 | -3.54 | 11.25 | 27.57 | 50.7 % | ACCEPTABLE |
| 984 | -4.31 | 5.55 | 26.53 | 41.5 % | ACCEPTABLE |
| 985 | -7.00 | 2.73 | 18.88 | 57.6 % | ACCEPTABLE |
| 986 | -9.07 | 2.54 | 20.92 | 49.6 % | ACCEPTABLE |
| 987 | -6.30 | 0.62 | 18.00 | 51.2 % | ACCEPTABLE |
| 988 | -9.96 | 5.66 | 22.38 | 56.3 % | ACCEPTABLE |
| 989 | -6.97 | 2.66 | 18.85 | 57.3 % | ACCEPTABLE |
| 990 | -3.76 | 12.12 | 28.13 | 51.5 % | ACCEPTABLE |
| 991 | -8.51 | 11.25 | 27.57 | 57.8 % | ACCEPTABLE |
| 992 | -5.35 | 11.85 | 27.96 | 52.7 % | ACCEPTABLE |
| 993 | -9.24 | 11.11 | 25.18 | 65.9 % | ACCEPTABLE |
| 994 | -6.41 | 12.73 | 26.36 | 64.0 % | ACCEPTABLE |
| 995 | -10.88 | 20.75 | 34.49 | 63.9 % | ACCEPTABLE |
| 996 | -3.79 | 3.91 | 20.83 | 50.1 % | ACCEPTABLE |
| 997 | -9.70 | 16.03 | 30.86 | 62.8 % | ACCEPTABLE |
| 998 | -5.93 | 11.11 | 25.18 | 62.0 % | ACCEPTABLE |
| 999 | -7.97 | 9.11 | 26.27 | 54.9 % | ACCEPTABLE |
| 1000 | -8.36 | 5.64 | 19.25 | 4.1 % | ACCEPTABLE |
| 1001 | -12.55 | 11.10 | 25.17 | 1.4 % | ACCEPTABLE |
| 1002 | -8.02 | 0.80 | 18.08 | 52.7 % | ACCEPTABLE |
| 1003 | -10.98 | 5.84 | 21.82 | 11.3 % | ACCEPTABLE |
| 1004 | -7.35 | 2.87 | 17.62 | 67.9 % | ACCEPTABLE |
| 1005 | -3.92 | 2.54 | 17.45 | 56.5 % | ACCEPTABLE |
| 1006 | -7.26 | 11.67 | 23.68 | 1.5 % | ACCEPTABLE |
| 1007 | -8.81 | 9.64 | 24.16 | 64.2 % | ACCEPTABLE |
| 1008 | -7.95 | 6.76 | 22.35 | 60.6 % | ACCEPTABLE |
| 1009 | -4.04 | 2.87 | 17.62 | 57.6 % | ACCEPTABLE |
| 1010 | -6.56 | 2.09 | 20.02 | 50.2 % | ACCEPTABLE |
| 1011 | -10.66 | 2.87 | 17.62 | 1.2 % | ACCEPTABLE |
| 1012 | -10.13 | 1.40 | 16.90 | 1.9 % | ACCEPTABLE |
| 1013 | -8.51 | 8.64 | 23.50 | 63.0 % | ACCEPTABLE |
| 1014 | -4.24 | 3.42 | 17.91 | 59.0 % | ACCEPTABLE |
| 1015 | -7.35 | 2.87 | 17.62 | 67.9 % | ACCEPTABLE |
| 1016 | -5.30 | 3.32 | 17.86 | 62.1 % | ACCEPTABLE |
| 1017 | -7.69 | 2.41 | 15.70 | 1.1 % | ACCEPTABLE |
| 1018 | -10.13 | 12.87 | 25.81 | 1.6 % | ACCEPTABLE |
| 1019 | -7.01 | 7.99 | 20.85 | 5.7 % | ACCEPTABLE |
| 1020 | -8.35 | 7.27 | 21.84 | 64.6 % | ACCEPTABLE |
| 1021 | -7.79 | 5.50 | 20.77 | 61.7 % | ACCEPTABLE |
| 1022 | -5.14 | 2.87 | 17.62 | 60.9 % | ACCEPTABLE |
| 1023 | -6.77 | 2.30 | 19.16 | 54.3 % | ACCEPTABLE |
| 1024 | -9.56 | 2.87 | 17.62 | 2.0 % | ACCEPTABLE |
| 1025 | -8.79 | 0.76 | 16.63 | 8.2 % | ACCEPTABLE |
| 1026 | -9.23 | 1.97 | 17.17 | 2.9 % | ACCEPTABLE |
| 1027 | -8.13 | 6.58 | 21.41 | 63.3 % | ACCEPTABLE |
| 1028 | -5.32 | 3.36 | 17.88 | 62.1 % | ACCEPTABLE |
| 1029 | -7.35 | 2.87 | 17.62 | 67.9 % | ACCEPTABLE |
| 1030 | -6.08 | 3.41 | 17.91 | 67.5 % | ACCEPTABLE |
| 1031 | -7.61 | 2.68 | 16.39 | 2.8 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1032 | -9.08 | 8.91 | 22.43 | 4.2 % | ACCEPTABLE |
| 1033 | -7.03 | 6.03 | 19.50 | 14.5 % | ACCEPTABLE |
| 1034 | -8.03 | 5.75 | 20.37 | 64.3 % | ACCEPTABLE |
| 1035 | -5.04 | 0.57 | 16.55 | 58.4 % | ACCEPTABLE |
| 1036 | -7.66 | 4.64 | 19.72 | 62.2 % | ACCEPTABLE |
| 1037 | -5.88 | 2.87 | 17.62 | 66.3 % | ACCEPTABLE |
| 1038 | -6.94 | 2.46 | 18.61 | 57.5 % | ACCEPTABLE |
| 1039 | -6.92 | 0.98 | 15.51 | 10.9 % | ACCEPTABLE |
| 1040 | -9.66 | 5.16 | 18.94 | 1.5 % | ACCEPTABLE |
| 1041 | -7.92 | 3.43 | 16.83 | 1.8 % | ACCEPTABLE |
| 1042 | -8.82 | 2.87 | 17.62 | 4.6 % | ACCEPTABLE |
| 1043 | -8.36 | 1.60 | 16.99 | 12.7 % | ACCEPTABLE |
| 1044 | -6.61 | 0.21 | 15.17 | 66.7 % | ACCEPTABLE |
| 1045 | -7.78 | 0.01 | 16.34 | 59.3 % | ACCEPTABLE |
| 1046 | -8.62 | 2.31 | 17.33 | 6.5 % | ACCEPTABLE |
| 1047 | -6.80 | 0.69 | 15.38 | 19.5 % | ACCEPTABLE |
| 1048 | -7.88 | 5.29 | 20.09 | 63.5 % | ACCEPTABLE |
| 1049 | -6.02 | 3.25 | 17.82 | 67.1 % | ACCEPTABLE |
| 1050 | -7.35 | 2.87 | 17.62 | 67.9 % | ACCEPTABLE |
| 1051 | -6.54 | 3.33 | 17.87 | 68.2 % | ACCEPTABLE |
| 1052 | -5.75 | 3.84 | 18.16 | 63.3 % | ACCEPTABLE |
| 1053 | -6.74 | 3.25 | 17.09 | 11.4 % | ACCEPTABLE |
| 1054 | -7.68 | 7.25 | 20.98 | 20.6 % | ACCEPTABLE |
| 1055 | -6.32 | 5.43 | 19.11 | 66.9 % | ACCEPTABLE |
| 1056 | -7.01 | 5.30 | 19.74 | 68.0 % | ACCEPTABLE |
| 1057 | -4.98 | 1.75 | 17.07 | 57.8 % | ACCEPTABLE |
| 1058 | -6.75 | 4.54 | 19.29 | 66.7 % | ACCEPTABLE |
| 1059 | -5.56 | 3.33 | 17.87 | 62.4 % | ACCEPTABLE |
| 1060 | -6.23 | 3.02 | 18.48 | 63.1 % | ACCEPTABLE |
| 1061 | -6.28 | 2.07 | 16.44 | 63.9 % | ACCEPTABLE |
| 1062 | -8.10 | 4.91 | 18.79 | 5.6 % | ACCEPTABLE |
| 1063 | -6.92 | 3.72 | 17.36 | 7.9 % | ACCEPTABLE |
| 1064 | -7.52 | 3.33 | 17.87 | 69.5 % | ACCEPTABLE |
| 1065 | -6.73 | 3.84 | 18.16 | 69.6 % | ACCEPTABLE |
| 1066 | -5.96 | 4.41 | 18.49 | 64.5 % | ACCEPTABLE |
| 1067 | -6.94 | 3.76 | 17.39 | 6.2 % | ACCEPTABLE |
| 1068 | -7.91 | 7.92 | 21.43 | 9.7 % | ACCEPTABLE |
| 1069 | -6.55 | 6.04 | 19.51 | 68.7 % | ACCEPTABLE |
| 1070 | -7.22 | 5.89 | 20.10 | 68.9 % | ACCEPTABLE |
| 1071 | -5.15 | 2.21 | 17.30 | 59.2 % | ACCEPTABLE |
| 1072 | -6.94 | 5.06 | 19.60 | 67.4 % | ACCEPTABLE |
| 1073 | -5.75 | 3.84 | 18.16 | 63.3 % | ACCEPTABLE |
| 1074 | -6.40 | 3.49 | 18.73 | 64.4 % | ACCEPTABLE |
| 1075 | -6.47 | 2.57 | 16.71 | 65.6 % | ACCEPTABLE |
| 1076 | -8.31 | 5.48 | 19.15 | 4.1 % | ACCEPTABLE |
| 1077 | -7.14 | 4.27 | 17.70 | 4.5 % | ACCEPTABLE |
| 1078 | -7.71 | 3.84 | 18.16 | 14.0 % | ACCEPTABLE |
| 1079 | -6.32 | 1.14 | 16.39 | 60.0 % | ACCEPTABLE |
| 1080 | -5.70 | 0.58 | 15.74 | 59.3 % | ACCEPTABLE |
| 1081 | -7.38 | 2.95 | 17.67 | 68.2 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1082 | -6.21 | 1.90 | 16.36 | 63.1 % | ACCEPTABLE |
| 1083 | -6.92 | 1.68 | 17.04 | 64.5 % | ACCEPTABLE |
| 1084 | -7.56 | 3.43 | 17.93 | 30.4 % | ACCEPTABLE |
| 1085 | -6.36 | 2.28 | 16.55 | 64.6 % | ACCEPTABLE |
| 1086 | -7.09 | 5.51 | 19.87 | 68.1 % | ACCEPTABLE |
| 1087 | -5.87 | 4.17 | 18.35 | 63.9 % | ACCEPTABLE |
| 1088 | -6.73 | 3.84 | 18.16 | 69.6 % | ACCEPTABLE |
| 1089 | -6.23 | 4.26 | 18.40 | 69.6 % | ACCEPTABLE |
| 1090 | -6.88 | 3.81 | 17.66 | 13.4 % | ACCEPTABLE |
| 1091 | -7.50 | 6.45 | 20.23 | 19.5 % | ACCEPTABLE |
| 1092 | -6.59 | 5.26 | 19.01 | 66.7 % | ACCEPTABLE |
| 1093 | -7.06 | 5.19 | 19.44 | 68.8 % | ACCEPTABLE |
| 1094 | -5.68 | 2.76 | 17.57 | 66.6 % | ACCEPTABLE |
| 1095 | -6.87 | 4.66 | 19.12 | 67.8 % | ACCEPTABLE |
| 1096 | -6.08 | 3.84 | 18.16 | 68.2 % | ACCEPTABLE |
| 1097 | -6.50 | 3.60 | 18.53 | 65.7 % | ACCEPTABLE |
| 1098 | -6.57 | 3.00 | 17.19 | 65.6 % | ACCEPTABLE |
| 1099 | -7.78 | 4.93 | 18.81 | 6.7 % | ACCEPTABLE |
| 1100 | -6.99 | 4.12 | 17.84 | 10.4 % | ACCEPTABLE |
| 1101 | -7.38 | 3.84 | 18.16 | 28.7 % | ACCEPTABLE |
| 1102 | -6.44 | 1.98 | 16.92 | 61.4 % | ACCEPTABLE |
| 1103 | -6.03 | 1.59 | 16.47 | 61.2 % | ACCEPTABLE |
| 1104 | -7.18 | 3.27 | 17.85 | 63.8 % | ACCEPTABLE |
| 1105 | -6.39 | 2.54 | 16.95 | 63.9 % | ACCEPTABLE |
| 1106 | -6.84 | 2.36 | 17.37 | 61.5 % | ACCEPTABLE |
| 1107 | -7.29 | 3.57 | 18.01 | 64.6 % | ACCEPTABLE |
| 1108 | -6.48 | 2.78 | 17.08 | 64.6 % | ACCEPTABLE |
| 1109 | -6.97 | 4.94 | 19.29 | 68.4 % | ACCEPTABLE |
| 1110 | -6.16 | 4.07 | 18.29 | 69.2 % | ACCEPTABLE |
| 1111 | -6.73 | 3.84 | 18.16 | 69.6 % | ACCEPTABLE |
| 1112 | -6.40 | 4.14 | 18.33 | 69.2 % | ACCEPTABLE |
| 1113 | -6.83 | 3.83 | 17.83 | 66.9 % | ACCEPTABLE |
| 1114 | -7.23 | 5.54 | 19.49 | 71.4 % | ACCEPTABLE |
| 1115 | -6.93 | 5.91 | 19.72 | 72.4 % | ACCEPTABLE |
| 1116 | -6.63 | 6.30 | 19.97 | 67.3 % | ACCEPTABLE |
| 1117 | -7.05 | 5.92 | 19.42 | 11.4 % | ACCEPTABLE |
| 1118 | -7.48 | 7.85 | 21.30 | 15.2 % | ACCEPTABLE |
| 1119 | -6.88 | 6.99 | 20.43 | 31.2 % | ACCEPTABLE |
| 1120 | -7.17 | 6.93 | 20.69 | 72.2 % | ACCEPTABLE |
| 1121 | -6.20 | 5.09 | 19.21 | 64.2 % | ACCEPTABLE |
| 1122 | -7.02 | 6.49 | 20.40 | 71.0 % | ACCEPTABLE |
| 1123 | -6.49 | 5.91 | 19.72 | 66.2 % | ACCEPTABLE |
| 1124 | -6.74 | 5.68 | 19.89 | 68.7 % | ACCEPTABLE |
| 1125 | -6.84 | 5.32 | 19.04 | 33.2 % | ACCEPTABLE |
| 1126 | -7.66 | 6.74 | 20.26 | 8.2 % | ACCEPTABLE |
| 1127 | -7.14 | 6.16 | 19.59 | 9.2 % | ACCEPTABLE |
| 1128 | -7.37 | 5.91 | 19.72 | 19.9 % | ACCEPTABLE |
| 1129 | -6.68 | 4.45 | 18.67 | 69.1 % | ACCEPTABLE |
| 1130 | -6.41 | 4.17 | 18.34 | 69.3 % | ACCEPTABLE |
| 1131 | -7.20 | 5.45 | 19.43 | 71.0 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1132 | -6.69 | 4.91 | 18.79 | 72.1 % | ACCEPTABLE |
| 1133 | -6.95 | 4.72 | 18.99 | 68.8 % | ACCEPTABLE |
| 1134 | -7.29 | 5.69 | 19.58 | 30.0 % | ACCEPTABLE |
| 1135 | -6.76 | 5.13 | 18.92 | 72.5 % | ACCEPTABLE |
| 1136 | -6.46 | 5.51 | 19.16 | 67.4 % | ACCEPTABLE |
| 1137 | -6.88 | 5.13 | 18.61 | 10.2 % | ACCEPTABLE |
| 1138 | -7.31 | 7.00 | 20.43 | 11.2 % | ACCEPTABLE |
| 1139 | -6.70 | 6.17 | 19.59 | 20.2 % | ACCEPTABLE |
| 1140 | -7.00 | 6.12 | 19.85 | 72.7 % | ACCEPTABLE |
| 1141 | -6.71 | 6.53 | 20.12 | 67.9 % | ACCEPTABLE |
| 1142 | -7.13 | 6.13 | 19.56 | 9.3 % | ACCEPTABLE |
| 1143 | -7.56 | 8.09 | 21.46 | 11.9 % | ACCEPTABLE |
| 1144 | -6.96 | 7.22 | 20.58 | 18.6 % | ACCEPTABLE |
| 1145 | -7.24 | 7.16 | 20.83 | 72.6 % | ACCEPTABLE |
| 1146 | -6.27 | 5.29 | 19.33 | 64.8 % | ACCEPTABLE |
| 1147 | -7.08 | 6.70 | 20.53 | 71.7 % | ACCEPTABLE |
| 1148 | -6.56 | 6.12 | 19.85 | 66.9 % | ACCEPTABLE |
| 1149 | -6.80 | 5.88 | 20.01 | 69.4 % | ACCEPTABLE |
| 1150 | -6.91 | 5.53 | 19.17 | 19.9 % | ACCEPTABLE |
| 1151 | -7.73 | 6.96 | 20.41 | 6.7 % | ACCEPTABLE |
| 1152 | -7.22 | 6.38 | 19.73 | 7.8 % | ACCEPTABLE |
| 1153 | -7.44 | 6.12 | 19.85 | 14.1 % | ACCEPTABLE |
| 1154 | -6.74 | 4.64 | 18.77 | 69.7 % | ACCEPTABLE |
| 1155 | -6.48 | 4.36 | 18.45 | 69.9 % | ACCEPTABLE |
| 1156 | -7.27 | 5.65 | 19.55 | 71.6 % | ACCEPTABLE |
| 1157 | -6.75 | 5.11 | 18.90 | 72.5 % | ACCEPTABLE |
| 1158 | -7.01 | 4.91 | 19.10 | 69.4 % | ACCEPTABLE |
| 1159 | -7.36 | 5.89 | 19.70 | 20.0 % | ACCEPTABLE |
| 1160 | -6.83 | 5.33 | 19.04 | 31.6 % | ACCEPTABLE |
| 1161 | -7.17 | 6.94 | 20.68 | 72.6 % | ACCEPTABLE |
| 1162 | -6.64 | 6.33 | 19.99 | 67.3 % | ACCEPTABLE |
| 1163 | -7.00 | 6.12 | 19.85 | 72.7 % | ACCEPTABLE |
| 1164 | -6.81 | 6.40 | 20.03 | 67.7 % | ACCEPTABLE |
| 1165 | -7.09 | 6.13 | 19.66 | 14.5 % | ACCEPTABLE |
| 1166 | -7.37 | 7.41 | 20.90 | 15.3 % | ACCEPTABLE |
| 1167 | -6.97 | 6.84 | 20.33 | 29.4 % | ACCEPTABLE |
| 1168 | -7.16 | 6.81 | 20.50 | 72.6 % | ACCEPTABLE |
| 1169 | -6.51 | 5.57 | 19.50 | 65.8 % | ACCEPTABLE |
| 1170 | -7.06 | 6.51 | 20.30 | 72.2 % | ACCEPTABLE |
| 1171 | -6.71 | 6.12 | 19.85 | 67.0 % | ACCEPTABLE |
| 1172 | -6.87 | 5.96 | 19.95 | 70.6 % | ACCEPTABLE |
| 1173 | -6.94 | 5.73 | 19.40 | 31.5 % | ACCEPTABLE |
| 1174 | -7.49 | 6.68 | 20.22 | 11.1 % | ACCEPTABLE |
| 1175 | -7.14 | 6.29 | 19.76 | 11.3 % | ACCEPTABLE |
| 1176 | -7.29 | 6.12 | 19.85 | 21.1 % | ACCEPTABLE |
| 1177 | -6.82 | 5.11 | 19.11 | 70.7 % | ACCEPTABLE |
| 1178 | -6.65 | 4.92 | 18.89 | 71.1 % | ACCEPTABLE |
| 1179 | -7.18 | 5.81 | 19.65 | 72.1 % | ACCEPTABLE |
| 1180 | -6.84 | 5.44 | 19.21 | 72.7 % | ACCEPTABLE |
| 1181 | -7.00 | 5.30 | 19.33 | 70.6 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1182 | -7.24 | 5.97 | 19.75 | 31.1 % | ACCEPTABLE |
| 1183 | -6.89 | 5.59 | 19.31 | 73.0 % | ACCEPTABLE |
| 1184 | -6.70 | 5.86 | 19.48 | 67.8 % | ACCEPTABLE |
| 1185 | -6.97 | 5.60 | 19.11 | 14.5 % | ACCEPTABLE |
| 1186 | -7.26 | 6.85 | 20.33 | 14.3 % | ACCEPTABLE |
| 1187 | -6.85 | 6.29 | 19.77 | 20.1 % | ACCEPTABLE |
| 1188 | -7.05 | 6.26 | 19.95 | 72.9 % | ACCEPTABLE |
| 1189 | -6.40 | 5.05 | 18.97 | 65.7 % | ACCEPTABLE |
| 1190 | -6.95 | 5.97 | 19.76 | 72.5 % | ACCEPTABLE |
| 1191 | -6.60 | 5.59 | 19.31 | 66.9 % | ACCEPTABLE |
| 1192 | -6.76 | 5.44 | 19.42 | 70.7 % | ACCEPTABLE |
| 1193 | -6.83 | 5.20 | 18.86 | 31.4 % | ACCEPTABLE |
| 1194 | -7.38 | 6.13 | 19.66 | 9.3 % | ACCEPTABLE |
| 1195 | -7.03 | 5.75 | 19.21 | 10.1 % | ACCEPTABLE |
| 1196 | -7.18 | 5.59 | 19.31 | 19.4 % | ACCEPTABLE |
| 1197 | -6.72 | 4.61 | 18.60 | 71.0 % | ACCEPTABLE |
| 1198 | -6.54 | 4.42 | 18.38 | 71.2 % | ACCEPTABLE |
| 1199 | -7.07 | 5.29 | 19.12 | 30.3 % | ACCEPTABLE |
| 1200 | -6.73 | 4.93 | 18.69 | 73.0 % | ACCEPTABLE |
| 1201 | -6.53 | 5.19 | 18.85 | 67.4 % | ACCEPTABLE |
| 1202 | -6.81 | 4.93 | 18.49 | 15.1 % | ACCEPTABLE |
| 1203 | -7.09 | 6.14 | 19.67 | 15.6 % | ACCEPTABLE |
| 1204 | -6.69 | 5.61 | 19.12 | 20.2 % | ACCEPTABLE |
| 1205 | -6.89 | 5.58 | 19.30 | 73.0 % | ACCEPTABLE |
| 1206 | -6.25 | 4.41 | 18.37 | 65.4 % | ACCEPTABLE |
| 1207 | -6.79 | 5.30 | 19.13 | 72.2 % | ACCEPTABLE |
| 1208 | -6.44 | 4.93 | 18.69 | 66.9 % | ACCEPTABLE |
| 1209 | -6.60 | 4.79 | 18.81 | 70.3 % | ACCEPTABLE |
| 1210 | -6.67 | 4.55 | 18.25 | 30.7 % | ACCEPTABLE |
| 1211 | -7.21 | 5.45 | 19.02 | 9.1 % | ACCEPTABLE |
| 1212 | -6.87 | 5.08 | 18.58 | 12.0 % | ACCEPTABLE |
| 1213 | -7.02 | 4.93 | 18.69 | 19.2 % | ACCEPTABLE |
| 1214 | -6.56 | 3.98 | 18.01 | 70.3 % | ACCEPTABLE |
| 1215 | -6.38 | 3.80 | 17.80 | 70.7 % | ACCEPTABLE |
| 1216 | -6.92 | 4.65 | 18.52 | 32.1 % | ACCEPTABLE |
| 1217 | -6.57 | 4.29 | 18.09 | 72.6 % | ACCEPTABLE |
| 1218 | -6.74 | 4.16 | 18.23 | 70.4 % | ACCEPTABLE |
| 1219 | -6.97 | 4.79 | 18.60 | 30.3 % | ACCEPTABLE |
| 1220 | -6.62 | 4.42 | 18.17 | 73.1 % | ACCEPTABLE |
| 1221 | -6.42 | 4.67 | 18.32 | 67.6 % | ACCEPTABLE |
| 1222 | -6.70 | 4.42 | 17.96 | 11.3 % | ACCEPTABLE |
| 1223 | -6.98 | 5.60 | 19.12 | 14.5 % | ACCEPTABLE |
| 1224 | -6.58 | 5.08 | 18.58 | 20.3 % | ACCEPTABLE |
| 1225 | -6.78 | 5.06 | 18.77 | 33.3 % | ACCEPTABLE |
| 1226 | -6.14 | 3.91 | 17.87 | 65.3 % | ACCEPTABLE |
| 1227 | -6.68 | 4.79 | 18.60 | 72.4 % | ACCEPTABLE |
| 1228 | -6.33 | 4.42 | 18.17 | 66.7 % | ACCEPTABLE |
| 1229 | -6.50 | 4.29 | 18.30 | 70.6 % | ACCEPTABLE |
| 1230 | -6.55 | 4.05 | 17.74 | 19.6 % | ACCEPTABLE |
| 1231 | -7.10 | 4.93 | 18.49 | 9.1 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1232 | -6.75 | 4.56 | 18.05 | 11.3 % | ACCEPTABLE |
| 1233 | -6.91 | 4.42 | 18.17 | 19.3 % | ACCEPTABLE |
| 1234 | -6.45 | 3.50 | 17.52 | 70.7 % | ACCEPTABLE |
| 1235 | -6.27 | 3.32 | 17.31 | 70.7 % | ACCEPTABLE |
| 1236 | -6.81 | 4.14 | 18.00 | 20.8 % | ACCEPTABLE |
| 1237 | -6.46 | 3.79 | 17.58 | 72.9 % | ACCEPTABLE |
| 1238 | -6.63 | 3.68 | 17.73 | 70.6 % | ACCEPTABLE |
| 1239 | -6.86 | 4.29 | 18.09 | 19.4 % | ACCEPTABLE |
| 1240 | -6.51 | 3.92 | 17.66 | 21.1 % | ACCEPTABLE |
| 1241 | -6.73 | 4.93 | 18.69 | 73.0 % | ACCEPTABLE |
| 1242 | -6.38 | 4.55 | 18.25 | 67.1 % | ACCEPTABLE |
| 1243 | -6.62 | 4.42 | 18.17 | 73.1 % | ACCEPTABLE |
| 1244 | -6.49 | 4.59 | 18.27 | 73.3 % | ACCEPTABLE |
| 1245 | -6.36 | 4.76 | 18.38 | 67.5 % | ACCEPTABLE |
| 1246 | -6.54 | 4.59 | 18.13 | 14.6 % | ACCEPTABLE |
| 1247 | -6.73 | 5.38 | 18.90 | 21.6 % | ACCEPTABLE |
| 1248 | -6.46 | 5.03 | 18.55 | 30.0 % | ACCEPTABLE |
| 1249 | -6.60 | 5.02 | 18.67 | 73.6 % | ACCEPTABLE |
| 1250 | -6.47 | 5.20 | 18.78 | 67.9 % | ACCEPTABLE |
| 1251 | -6.65 | 5.02 | 18.54 | 14.7 % | ACCEPTABLE |
| 1252 | -6.84 | 5.83 | 19.32 | 21.5 % | ACCEPTABLE |
| 1253 | -6.57 | 5.47 | 18.96 | 20.3 % | ACCEPTABLE |
| 1254 | -6.71 | 5.46 | 19.08 | 31.7 % | ACCEPTABLE |
| 1255 | -6.28 | 4.67 | 18.45 | 66.4 % | ACCEPTABLE |
| 1256 | -6.64 | 5.27 | 18.96 | 73.3 % | ACCEPTABLE |
| 1257 | -6.41 | 5.02 | 18.67 | 67.4 % | ACCEPTABLE |
| 1258 | -6.51 | 4.92 | 18.75 | 72.2 % | ACCEPTABLE |
| 1259 | -6.56 | 4.77 | 18.38 | 33.5 % | ACCEPTABLE |
| 1260 | -6.92 | 5.37 | 18.89 | 11.3 % | ACCEPTABLE |
| 1261 | -6.69 | 5.12 | 18.60 | 14.6 % | ACCEPTABLE |
| 1262 | -6.79 | 5.02 | 18.67 | 20.4 % | ACCEPTABLE |
| 1263 | -6.48 | 4.37 | 18.20 | 72.3 % | ACCEPTABLE |
| 1264 | -6.36 | 4.25 | 18.06 | 72.8 % | ACCEPTABLE |
| 1265 | -6.72 | 4.83 | 18.55 | 30.6 % | ACCEPTABLE |
| 1266 | -6.49 | 4.59 | 18.26 | 73.4 % | ACCEPTABLE |
| 1267 | -6.60 | 4.50 | 18.35 | 72.4 % | ACCEPTABLE |
| 1268 | -6.76 | 4.93 | 18.61 | 20.4 % | ACCEPTABLE |
| 1269 | -6.52 | 4.68 | 18.32 | 32.0 % | ACCEPTABLE |
| 1270 | -6.68 | 5.37 | 19.02 | 33.5 % | ACCEPTABLE |
| 1271 | -6.44 | 5.11 | 18.73 | 67.7 % | ACCEPTABLE |
| 1272 | -6.60 | 5.02 | 18.67 | 73.6 % | ACCEPTABLE |
| 1273 | -6.52 | 5.14 | 18.75 | 67.8 % | ACCEPTABLE |
| 1274 | -6.64 | 5.02 | 18.58 | 20.1 % | ACCEPTABLE |
| 1275 | -6.76 | 5.55 | 19.10 | 20.1 % | ACCEPTABLE |
| 1276 | -6.58 | 5.32 | 18.86 | 31.6 % | ACCEPTABLE |
| 1277 | -6.67 | 5.31 | 18.95 | 31.8 % | ACCEPTABLE |
| 1278 | -6.38 | 4.79 | 18.52 | 66.6 % | ACCEPTABLE |
| 1279 | -6.63 | 5.19 | 18.87 | 73.4 % | ACCEPTABLE |
| 1280 | -6.47 | 5.02 | 18.67 | 67.4 % | ACCEPTABLE |
| 1281 | -6.54 | 4.95 | 18.72 | 72.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1282 | -6.57 | 4.85 | 18.47 | 33.7 % | ACCEPTABLE |
| 1283 | -6.82 | 5.25 | 18.82 | 20.1 % | ACCEPTABLE |
| 1284 | -6.66 | 5.09 | 18.62 | 16.0 % | ACCEPTABLE |
| 1285 | -6.73 | 5.02 | 18.67 | 31.7 % | ACCEPTABLE |
| 1286 | -6.52 | 4.59 | 18.35 | 72.9 % | ACCEPTABLE |
| 1287 | -6.44 | 4.50 | 18.26 | 72.9 % | ACCEPTABLE |
| 1288 | -6.68 | 4.89 | 18.59 | 31.7 % | ACCEPTABLE |
| 1289 | -6.53 | 4.73 | 18.40 | 32.0 % | ACCEPTABLE |
| 1290 | -6.60 | 4.67 | 18.45 | 72.8 % | ACCEPTABLE |
| 1291 | -6.71 | 4.96 | 18.63 | 33.5 % | ACCEPTABLE |
| 1292 | -6.55 | 4.79 | 18.44 | 33.7 % | ACCEPTABLE |
| 1293 | -6.65 | 5.25 | 18.91 | 73.2 % | ACCEPTABLE |
| 1294 | -6.49 | 5.08 | 18.71 | 67.6 % | ACCEPTABLE |
| 1295 | -6.60 | 5.02 | 18.67 | 73.6 % | ACCEPTABLE |
| 1296 | -6.54 | 5.10 | 18.72 | 31.5 % | ACCEPTABLE |
| 1297 | -6.62 | 5.02 | 18.61 | 33.6 % | ACCEPTABLE |
| 1298 | -6.71 | 5.37 | 18.95 | 31.7 % | ACCEPTABLE |
| 1299 | -6.59 | 5.22 | 18.80 | 29.9 % | ACCEPTABLE |
| 1300 | -6.65 | 5.21 | 18.85 | 31.8 % | ACCEPTABLE |
| 1301 | -6.46 | 4.86 | 18.57 | 67.2 % | ACCEPTABLE |
| 1302 | -6.62 | 5.13 | 18.80 | 73.4 % | ACCEPTABLE |
| 1303 | -6.51 | 5.02 | 18.67 | 67.6 % | ACCEPTABLE |
| 1304 | -6.56 | 4.98 | 18.70 | 73.2 % | ACCEPTABLE |
| 1305 | -6.58 | 4.91 | 18.54 | 73.5 % | ACCEPTABLE |
| 1306 | -6.74 | 5.18 | 18.77 | 20.1 % | ACCEPTABLE |
| 1307 | -6.64 | 5.07 | 18.64 | 33.6 % | ACCEPTABLE |
| 1308 | -6.69 | 5.02 | 18.67 | 33.5 % | ACCEPTABLE |
| 1309 | -6.55 | 4.73 | 18.46 | 73.2 % | ACCEPTABLE |
| 1310 | -6.49 | 4.67 | 18.39 | 73.2 % | ACCEPTABLE |
| 1311 | -6.65 | 4.94 | 18.62 | 31.7 % | ACCEPTABLE |
| 1312 | -6.55 | 4.83 | 18.49 | 31.9 % | ACCEPTABLE |
| 1313 | -6.60 | 4.78 | 18.52 | 73.1 % | ACCEPTABLE |
| 1314 | -6.67 | 4.98 | 18.64 | 31.7 % | ACCEPTABLE |
| 1315 | -6.57 | 4.87 | 18.51 | 31.9 % | ACCEPTABLE |
| 1316 | -6.63 | 5.17 | 18.83 | 73.2 % | ACCEPTABLE |
| 1317 | -6.53 | 5.06 | 18.70 | 67.6 % | ACCEPTABLE |
| 1318 | -6.60 | 5.02 | 18.67 | 73.6 % | ACCEPTABLE |
| 1319 | -6.56 | 5.07 | 18.70 | 67.8 % | ACCEPTABLE |
| 1320 | -6.62 | 5.02 | 18.63 | 31.9 % | ACCEPTABLE |
| 1321 | -6.67 | 5.26 | 18.86 | 33.5 % | ACCEPTABLE |
| 1322 | -6.59 | 5.15 | 18.75 | 29.9 % | ACCEPTABLE |
| 1323 | -6.63 | 5.15 | 18.79 | 73.3 % | ACCEPTABLE |
| 1324 | -6.50 | 4.92 | 18.61 | 67.4 % | ACCEPTABLE |
| 1325 | -6.61 | 5.09 | 18.76 | 73.4 % | ACCEPTABLE |
| 1326 | -6.54 | 5.02 | 18.67 | 67.8 % | ACCEPTABLE |
| 1327 | -6.57 | 4.99 | 18.69 | 73.3 % | ACCEPTABLE |
| 1328 | -6.59 | 4.95 | 18.58 | 73.4 % | ACCEPTABLE |
| 1329 | -6.70 | 5.12 | 18.74 | 21.6 % | ACCEPTABLE |
| 1330 | -6.63 | 5.05 | 18.65 | 31.8 % | ACCEPTABLE |
| 1331 | -6.66 | 5.02 | 18.67 | 31.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1332 | -6.56 | 4.83 | 18.53 | 73.1 % | ACCEPTABLE |
| 1333 | -6.53 | 4.79 | 18.48 | 73.2 % | ACCEPTABLE |
| 1334 | -6.64 | 4.96 | 18.64 | 31.8 % | ACCEPTABLE |
| 1335 | -6.57 | 4.89 | 18.55 | 73.6 % | ACCEPTABLE |
| 1336 | -6.53 | 4.94 | 18.58 | 73.5 % | ACCEPTABLE |
| 1337 | -6.59 | 4.89 | 18.51 | 31.7 % | ACCEPTABLE |
| 1338 | -6.64 | 5.12 | 18.74 | 33.6 % | ACCEPTABLE |
| 1339 | -6.56 | 5.02 | 18.63 | 32.7 % | ACCEPTABLE |
| 1340 | -6.60 | 5.02 | 18.67 | 73.6 % | ACCEPTABLE |
| 1341 | -6.47 | 4.79 | 18.49 | 67.1 % | ACCEPTABLE |
| 1342 | -6.58 | 4.96 | 18.64 | 73.4 % | ACCEPTABLE |
| 1343 | -6.51 | 4.89 | 18.55 | 73.6 % | ACCEPTABLE |
| 1344 | -6.47 | 4.94 | 18.58 | 67.5 % | ACCEPTABLE |
| 1345 | -6.53 | 4.89 | 18.51 | 73.4 % | ACCEPTABLE |
| 1346 | -6.58 | 5.12 | 18.74 | 29.9 % | ACCEPTABLE |
| 1347 | -6.50 | 5.02 | 18.63 | 29.9 % | ACCEPTABLE |
| 1348 | -6.54 | 5.02 | 18.67 | 67.8 % | ACCEPTABLE |
| 1349 | -6.41 | 4.79 | 18.49 | 67.2 % | ACCEPTABLE |
| 1350 | -6.52 | 4.96 | 18.64 | 67.4 % | ACCEPTABLE |
| 1351 | -6.45 | 4.89 | 18.55 | 67.7 % | ACCEPTABLE |
| 1352 | -6.48 | 4.86 | 18.57 | 67.1 % | ACCEPTABLE |
| 1353 | -6.50 | 4.82 | 18.46 | 73.7 % | ACCEPTABLE |
| 1354 | -6.46 | 4.87 | 18.49 | 67.7 % | ACCEPTABLE |
| 1355 | -6.52 | 4.82 | 18.42 | 73.6 % | ACCEPTABLE |
| 1356 | -6.57 | 5.05 | 18.65 | 30.9 % | ACCEPTABLE |
| 1357 | -6.49 | 4.95 | 18.54 | 31.5 % | ACCEPTABLE |
| 1358 | -6.53 | 4.95 | 18.58 | 67.7 % | ACCEPTABLE |
| 1359 | -6.40 | 4.72 | 18.40 | 67.2 % | ACCEPTABLE |
| 1360 | -6.51 | 4.89 | 18.55 | 73.6 % | ACCEPTABLE |
| 1361 | -6.44 | 4.82 | 18.46 | 67.7 % | ACCEPTABLE |
| 1362 | -6.47 | 4.79 | 18.48 | 67.1 % | ACCEPTABLE |
| 1363 | -6.49 | 4.75 | 18.37 | 73.5 % | ACCEPTABLE |
| 1364 | -6.60 | 4.92 | 18.52 | 20.3 % | ACCEPTABLE |
| 1365 | -6.53 | 4.85 | 18.44 | 31.9 % | ACCEPTABLE |
| 1366 | -6.56 | 4.82 | 18.46 | 32.0 % | ACCEPTABLE |
| 1367 | -6.46 | 4.63 | 18.32 | 73.5 % | ACCEPTABLE |
| 1368 | -6.43 | 4.59 | 18.28 | 73.4 % | ACCEPTABLE |
| 1369 | -6.54 | 4.76 | 18.43 | 31.8 % | ACCEPTABLE |
| 1370 | -6.47 | 4.69 | 18.34 | 32.0 % | ACCEPTABLE |
| 1371 | -6.50 | 4.66 | 18.36 | 73.4 % | ACCEPTABLE |
| 1372 | -6.55 | 4.79 | 18.44 | 33.7 % | ACCEPTABLE |
| 1373 | -6.48 | 4.72 | 18.36 | 73.8 % | ACCEPTABLE |
| 1374 | -6.44 | 4.77 | 18.39 | 67.8 % | ACCEPTABLE |
| 1375 | -6.50 | 4.72 | 18.32 | 31.9 % | ACCEPTABLE |
| 1376 | -6.55 | 4.95 | 18.55 | 33.6 % | ACCEPTABLE |
| 1377 | -6.47 | 4.85 | 18.44 | 29.9 % | ACCEPTABLE |
| 1378 | -6.51 | 4.85 | 18.48 | 73.5 % | ACCEPTABLE |
| 1379 | -6.38 | 4.62 | 18.30 | 67.1 % | ACCEPTABLE |
| 1380 | -6.49 | 4.79 | 18.45 | 73.6 % | ACCEPTABLE |
| 1381 | -6.42 | 4.72 | 18.36 | 67.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1382 | -6.45 | 4.69 | 18.38 | 73.1 % | ACCEPTABLE |
| 1383 | -6.47 | 4.65 | 18.27 | 32.0 % | ACCEPTABLE |
| 1384 | -6.58 | 4.82 | 18.42 | 31.7 % | ACCEPTABLE |
| 1385 | -6.51 | 4.75 | 18.34 | 21.8 % | ACCEPTABLE |
| 1386 | -6.54 | 4.72 | 18.36 | 31.8 % | ACCEPTABLE |
| 1387 | -6.44 | 4.53 | 18.22 | 73.5 % | ACCEPTABLE |
| 1388 | -6.41 | 4.49 | 18.18 | 73.5 % | ACCEPTABLE |
| 1389 | -6.52 | 4.67 | 18.33 | 31.8 % | ACCEPTABLE |
| 1390 | -6.45 | 4.59 | 18.24 | 33.8 % | ACCEPTABLE |
| 1391 | -6.48 | 4.56 | 18.26 | 73.4 % | ACCEPTABLE |
| 1392 | -6.53 | 4.69 | 18.34 | 31.8 % | ACCEPTABLE |
| 1393 | -6.46 | 4.62 | 18.26 | 32.0 % | ACCEPTABLE |
| 1394 | -6.50 | 4.82 | 18.46 | 73.7 % | ACCEPTABLE |
| 1395 | -6.43 | 4.75 | 18.38 | 67.8 % | ACCEPTABLE |
| 1396 | -6.48 | 4.72 | 18.36 | 73.8 % | ACCEPTABLE |
| 1397 | -6.46 | 4.76 | 18.38 | 67.7 % | ACCEPTABLE |
| 1398 | -6.49 | 4.72 | 18.33 | 33.7 % | ACCEPTABLE |
| 1399 | -6.53 | 4.87 | 18.48 | 73.6 % | ACCEPTABLE |
| 1400 | -6.47 | 4.81 | 18.41 | 31.6 % | ACCEPTABLE |
| 1401 | -6.50 | 4.81 | 18.44 | 73.4 % | ACCEPTABLE |
| 1402 | -6.42 | 4.65 | 18.32 | 67.4 % | ACCEPTABLE |
| 1403 | -6.49 | 4.77 | 18.42 | 73.7 % | ACCEPTABLE |
| 1404 | -6.44 | 4.72 | 18.36 | 67.7 % | ACCEPTABLE |
| 1405 | -6.46 | 4.70 | 18.38 | 73.2 % | ACCEPTABLE |
| 1406 | -6.47 | 4.67 | 18.30 | 33.8 % | ACCEPTABLE |
| 1407 | -6.54 | 4.79 | 18.40 | 31.9 % | ACCEPTABLE |
| 1408 | -6.50 | 4.74 | 18.34 | 31.9 % | ACCEPTABLE |
| 1409 | -6.52 | 4.72 | 18.36 | 32.0 % | ACCEPTABLE |
| 1410 | -6.46 | 4.59 | 18.27 | 73.3 % | ACCEPTABLE |
| 1411 | -6.43 | 4.57 | 18.24 | 73.3 % | ACCEPTABLE |
| 1412 | -6.50 | 4.68 | 18.34 | 32.0 % | ACCEPTABLE |
| 1413 | -6.46 | 4.63 | 18.28 | 32.0 % | ACCEPTABLE |
| 1414 | -6.48 | 4.62 | 18.30 | 73.3 % | ACCEPTABLE |
| 1415 | -6.51 | 4.70 | 18.35 | 33.8 % | ACCEPTABLE |
| 1416 | -6.47 | 4.65 | 18.29 | 32.0 % | ACCEPTABLE |
| 1417 | -6.49 | 4.79 | 18.43 | 73.8 % | ACCEPTABLE |
| 1418 | -6.45 | 4.74 | 18.37 | 67.8 % | ACCEPTABLE |
| 1419 | -5.31 | 4.61 | 17.61 | 76.4 % | ACCEPTABLE |

# Slope stability analysis

## Input data

### Project

Task : Global Stability - Slip Verification
Part : Counterfort Wall
Description : Phase 1 - Mooring and Traffic Surcharge
Customer : TNPA
Author : YH
Date : 1/23/2019
Project ID : Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment
Project number : S2001-109

### Settings

(input for current task)

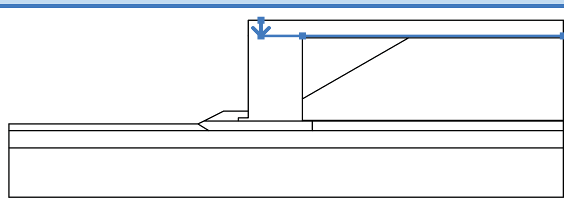
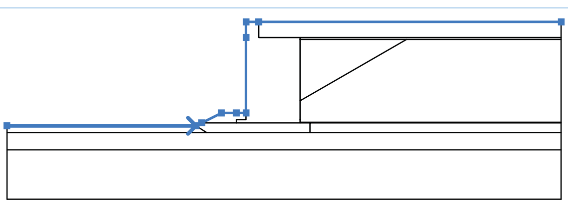
### Stability analysis

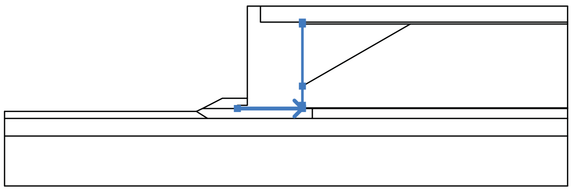
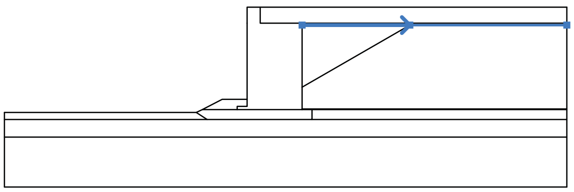
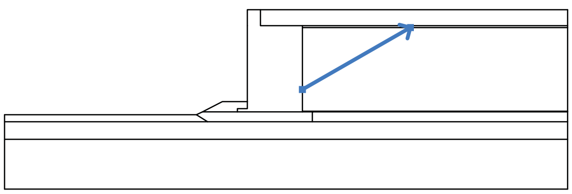
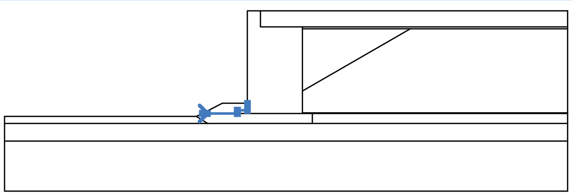
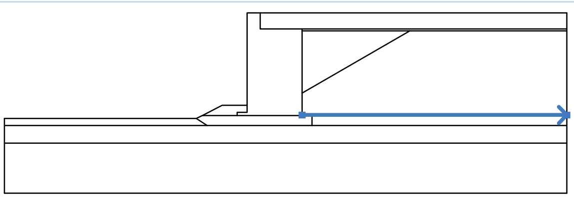
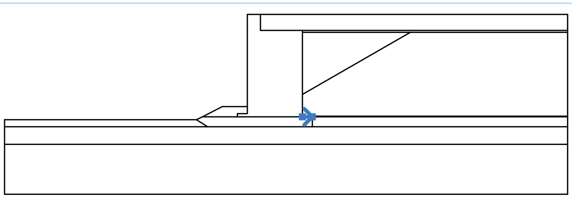
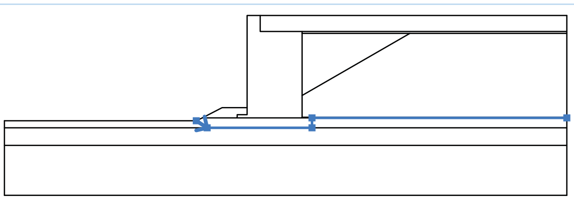
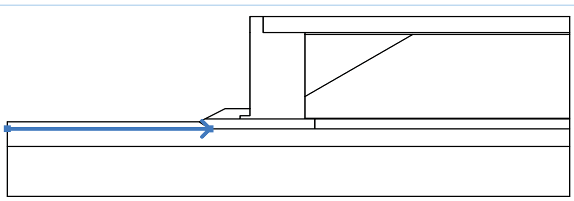
Earthquake analysis : Standard
Verification methodology : according to EN 1997
Design approach : 1 - reduction of actions and soil parameters

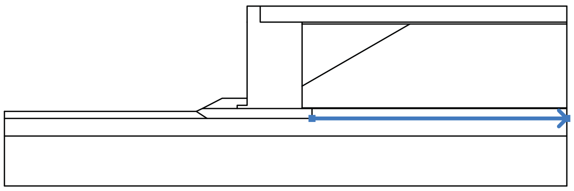
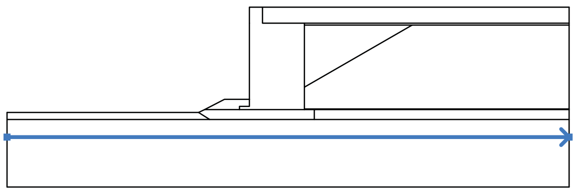
| Partial factors on actions (A) | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Permanent design situation** | | | | | | | | | |
| | | Combination 1 | | | | Combination 2 | | | |
| | | Unfavourable | | Favourable | | Unfavourable | | Favourable | |
| Permanent actions : | $\gamma_G$ = | 1.35 | [–] | 1.00 | [–] | 1.00 | [–] | 1.00 | [–] |
| Variable actions : | $\gamma_Q$ = | 1.50 | [–] | 0.00 | [–] | 1.30 | [–] | 0.00 | [–] |
| Water load : | $\gamma_w$ = | 1.35 | [–] | | | 1.00 | [–] | | |

| Partial factors for soil parameters (M) | | | | | |
|---|---|---|---|---|---|
| **Permanent design situation** | | | | | |
| | | Combination 1 | | Combination 2 | |
| Partial factor on internal friction : | $\gamma_\phi$ = | 1.00 | [–] | 1.25 | [–] |
| Partial factor on effective cohesion : | $\gamma_c$ = | 1.00 | [–] | 1.25 | [–] |
| Partial factor on undrained shear strength : | $\gamma_{cu}$ = | 1.00 | [–] | 1.40 | [–] |

### Interface

| No. | Interface location | Coordinates of interface points [m] x | z | x | z | x | z |
|---|---|---|---|---|---|---|---|
| 1 |  | 0.00 | 0.00 | 0.00 | -1.60 | 4.20 | -1.60 |
| | | 30.72 | -1.60 | | | | |
| 2 |  | -25.60 | -10.54 | -6.40 | -10.54 | -5.80 | -10.24 |
| | | -3.80 | -9.24 | -2.30 | -9.24 | -1.30 | -9.24 |
| | | -1.30 | -1.60 | -1.30 | 0.00 | 0.00 | 0.00 |
| | | 30.72 | 0.00 | | | | |

| No. | Interface location | Coordinates of interface points [m] | | | | | |
|---|---|---|---|---|---|---|---|
| | | x | z | x | z | x | z |
| 3 |  | -2.30 | -10.24 | 4.20 | -10.24 | 4.20 | -10.20 |
| | | 4.20 | -9.94 | 4.20 | -8.01 | 4.20 | -1.80 |
| | | 4.20 | -1.60 | | | | |
| 4 |  | 4.20 | -1.80 | 15.00 | -1.80 | 30.72 | -1.80 |
| 5 |  | 4.20 | -8.01 | 15.00 | -1.80 | | |
| 6 |  | -5.80 | -10.24 | -5.30 | -10.24 | -2.30 | -10.24 |
| | | -2.30 | -9.94 | -1.30 | -9.94 | -1.30 | -9.24 |
| 7 |  | 4.20 | -10.20 | 30.72 | -10.20 | | |
| 8 |  | 4.20 | -10.24 | 5.20 | -10.24 | | |
| 9 |  | -6.40 | -10.54 | -5.30 | -11.24 | 5.20 | -11.24 |
| | | 5.20 | -10.24 | 30.72 | -10.24 | | |
| 10 |  | -25.60 | -11.23 | -5.30 | -11.24 | | |

| No. | Interface location | Coordinates of interface points [m] | | | | | |
|---|---|---|---|---|---|---|---|
| | | x | z | x | z | x | z |
| 11 |  | 5.20 | -11.24 | 30.72 | -11.24 | | |
| 12 |  | -25.60 | -13.00 | 30.72 | -13.00 | | |

## Soil parameters - effective stress state

| No. | Name | Pattern | $\varphi_{ef}$ [°] | $c_{ef}$ [kPa] | $\gamma$ [kN/m$^3$] |
|---|---|---|---|---|---|
| 1 | Backfill quarry run | | 40.00 | 0.00 | 18.50 |
| 2 | Existing scour rock (Quarry Run) | | 40.00 | 0.00 | 18.50 |
| 3 | Scour rock | | 45.00 | 0.00 | 19.50 |
| 4 | Pavement Layers | | 45.00 | 0.00 | 20.00 |
| 5 | Marine sediment | | 30.00 | 0.00 | 17.50 |
| 6 | Alluvial gravel and cobbles | | 35.00 | 0.00 | 19.00 |

## Soil parameters - uplift

| No. | Name | Pattern | $\gamma_{sat}$ [kN/m$^3$] | $\gamma_s$ [kN/m$^3$] | n [–] |
|---|---|---|---|---|---|
| 1 | Backfill quarry run | | 19.50 | | |
| 2 | Existing scour rock (Quarry Run) | | 19.50 | | |

| No. | Name | Pattern | $\gamma_{sat}$ [kN/m$^3$] | $\gamma_s$ [kN/m$^3$] | n [–] |
|---|---|---|---|---|---|
| 3 | Scour rock | | 20.50 | | |
| 4 | Pavement Layers | | 21.00 | | |
| 5 | Marine sediment | | 18.50 | | |
| 6 | Alluvial gravel and cobbles | | 20.00 | | |

## Soil parameters

**Backfill quarry run**

| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 18.50 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 40.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |
| Saturated unit weight : | $\gamma_{sat}$ = | 19.50 kN/m$^3$ |

**Existing scour rock (Quarry Run)**

| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 18.50 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 40.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |
| Saturated unit weight : | $\gamma_{sat}$ = | 19.50 kN/m$^3$ |

**Scour rock**

| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 19.50 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 45.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |
| Saturated unit weight : | $\gamma_{sat}$ = | 20.50 kN/m$^3$ |

**Pavement Layers**

| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 20.00 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 45.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |
| Saturated unit weight : | $\gamma_{sat}$ = | 21.00 kN/m$^3$ |

**Marine sediment**

| | | |
|---|---|---|
| Unit weight : | $\gamma$ = | 17.50 kN/m$^3$ |
| Stress-state : | effective | |
| Angle of internal friction : | $\varphi_{ef}$ = | 30.00 ° |
| Cohesion of soil : | $c_{ef}$ = | 0.00 kPa |

Saturated unit weight : $\gamma_{sat}$ = 18.50 kN/m³

**Alluvial gravel and cobbles**

Unit weight : $\gamma$ = 19.00 kN/m³
Stress-state : effective
Angle of internal friction : $\varphi_{ef}$ = 35.00 °
Cohesion of soil : $c_{ef}$ = 0.00 kPa
Saturated unit weight : $\gamma_{sat}$ = 20.00 kN/m³

### Rigid bodies

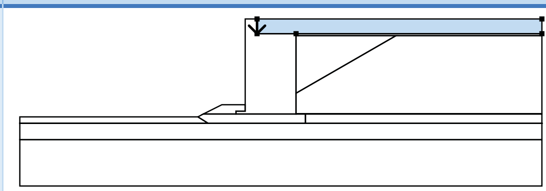
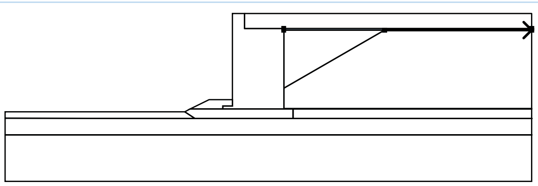
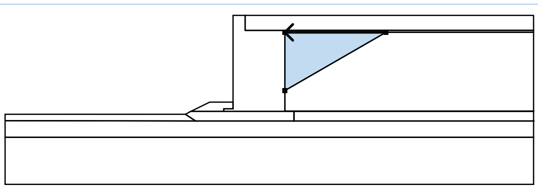
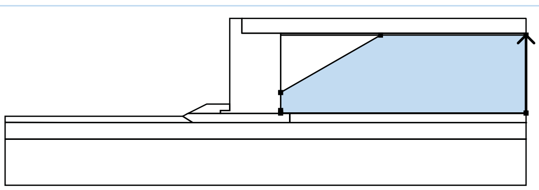
| No. | Name | Sample | $\gamma$ [kN/m³] |
|---|---|---|---|
| 1 | Wall material | | 23.00 |

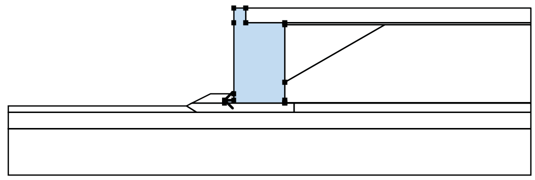
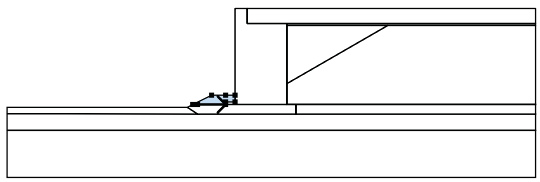
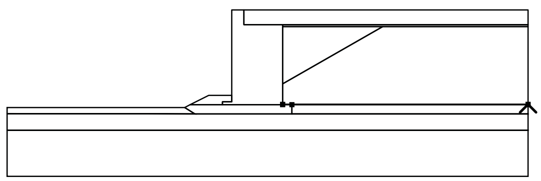
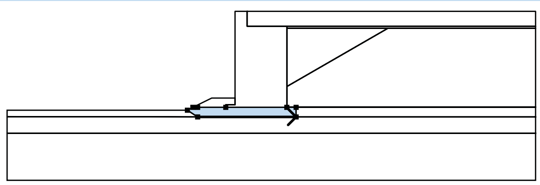
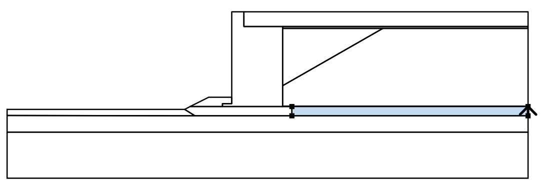
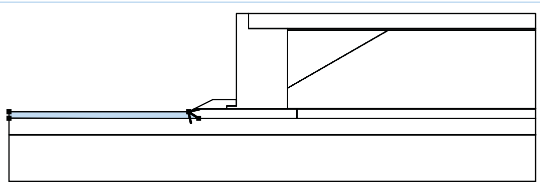
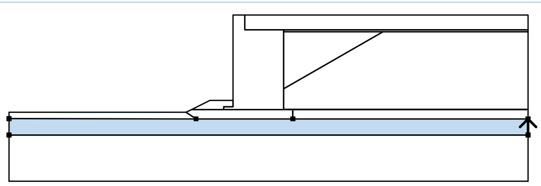
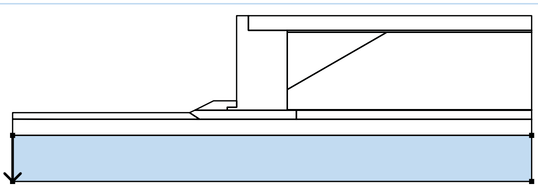
### Tensile crack

Tensile crack not input.

## Input data (Stage of construction 3)

### Assigning and surfaces

| No. | Surface position | Coordinates of surface points [m] x | z | x | z | Assigned soil |
|---|---|---|---|---|---|---|
| 1 |  | 0.00 | 0.00 | 0.00 | -1.60 | Pavement Layers |
| | | 4.20 | -1.60 | 30.72 | -1.60 | |
| | | 30.72 | 0.00 | | | |
| 2 |  | 15.00 | -1.80 | 30.72 | -1.80 | Pavement Layers |
| | | 30.72 | -1.60 | 4.20 | -1.60 | |
| | | 4.20 | -1.80 | | | |
| 3 |  | 15.00 | -1.80 | 4.20 | -1.80 | Backfill quarry run |
| | | 4.20 | -8.01 | | | |
| 4 |  | 30.72 | -10.20 | 30.72 | -1.80 | Marine sediment |
| | | 15.00 | -1.80 | 4.20 | -8.01 | |
| | | 4.20 | -9.94 | 4.20 | -10.20 | |

| No. | Surface position | Coordinates of surface points [m] x | z | x | z | Assigned soil |
|---|---|---|---|---|---|---|
| 5 |  | -1.30 | -9.94 | -2.30 | -9.94 | Wall material |
| | | -2.30 | -10.24 | 4.20 | -10.24 | |
| | | 4.20 | -10.20 | 4.20 | -9.94 | |
| | | 4.20 | -8.01 | 4.20 | -1.80 | |
| | | 4.20 | -1.60 | 0.00 | -1.60 | |
| | | 0.00 | 0.00 | -1.30 | 0.00 | |
| | | -1.30 | -1.60 | -1.30 | -9.24 | |
| 6 |  | -5.30 | -10.24 | -2.30 | -10.24 | Scour rock |
| | | -2.30 | -9.94 | -1.30 | -9.94 | |
| | | -1.30 | -9.24 | -2.30 | -9.24 | |
| | | -3.80 | -9.24 | -5.80 | -10.24 | |
| 7 |  | 30.72 | -10.24 | 30.72 | -10.20 | Marine sediment |
| | | 4.20 | -10.20 | 4.20 | -10.24 | |
| | | 5.20 | -10.24 | | | |
| 8 |  | -5.30 | -11.24 | 5.20 | -11.24 | Existing scour rock (Quarry Run) |
| | | 5.20 | -10.24 | 4.20 | -10.24 | |
| | | -2.30 | -10.24 | -5.30 | -10.24 | |
| | | -5.80 | -10.24 | -6.40 | -10.54 | |
| 9 |  | 30.72 | -11.24 | 30.72 | -10.24 | Marine sediment |
| | | 5.20 | -10.24 | 5.20 | -11.24 | |
| 10 |  | -5.30 | -11.24 | -6.40 | -10.54 | Marine sediment |
| | | -25.60 | -10.54 | -25.60 | -11.23 | |
| 11 |  | 30.72 | -13.00 | 30.72 | -11.24 | Marine sediment |
| | | 5.20 | -11.24 | -5.30 | -11.24 | |
| | | -25.60 | -11.23 | -25.60 | -13.00 | |
| 12 |  | -25.60 | -13.00 | -25.60 | -18.00 | Alluvial gravel and cobbles |
| | | 30.72 | -18.00 | 30.72 | -13.00 | |

### Surcharge

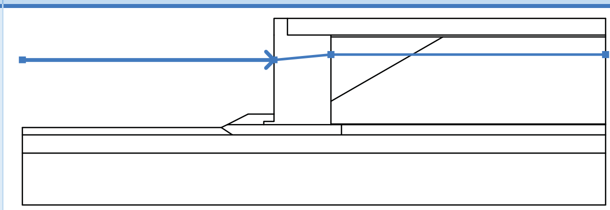
| No. | Surcharge | | Type | Type of action | Location | Origin | Length | Width | Slope | Magnitude | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | new | change | | | z [m] | x [m] | l [m] | b [m] | α [°] | q, $q_1$, f, F | $q_2$ | unit |
| 1 | No | No | strip | variable | on terrain | x = 0.00 | l = 30.72 | | 0.00 | 20.00 | | kN/m2 |
| 2 | No | No | strip | permanent | on terrain | x = 0.00 | l = 30.72 | | 0.00 | 7.50 | | kN/m2 |
| 3 | No | No | line | variable | z = 0.00 | x = -1.30 | | | 90.00 | 15.30 | | kN/m |

### Surcharges

| No. | Name |
|---|---|
| 1 | Traffic Surcharge |
| 2 | Pavement |
| 3 | Mooring Load |

### Water

Water type : GWT

| No. | GWT location | Coordinates of GWT points [m] | | | | | |
|---|---|---|---|---|---|---|---|
| | | x | z | x | z | x | z |
| 1 |  | -25.60 | -4.00 | -1.30 | -4.00 | 4.20 | -3.50 |
| | | 30.72 | -3.50 | | | | |

### Tensile crack

Tensile crack not input.

### Earthquake

Earthquake not included.

### Settings of the stage of construction

Design situation : permanent

## Results (Stage of construction 3)

### Analysis 1 (stage 3)

**Circular slip surface**

| Slip surface parameters | | | | | | | |
|---|---|---|---|---|---|---|---|
| Center : | x = | -5.31 | [m] | Angles : | $\alpha_1$ = | -30.65 | [°] |
| | z = | 4.61 | [m] | | $\alpha_2$ = | 74.82 | [°] |
| Radius : | R = | 17.61 | [m] | | | | |
| The slip surface after optimization. | | | | | | | |

**Slope stability verification (Morgenstern-Price)**
**Combination 1**
Utilization : 66.6 %

**Slope stability ACCEPTABLE**
**Combination 2**
Utilization : 76.9 %

**Slope stability ACCEPTABLE**
Optimized slip surface for : Combination 2

**Optimization of circular slip surface (Morgenstern-Price)**

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 2 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 3 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 4 | -6.14 | 17.05 | 33.65 | 48.4 % | ACCEPTABLE |
| 5 | 7.02 | 3.42 | 16.21 | 3.9 % | ACCEPTABLE |
| 6 | -2.86 | 2.04 | 25.81 | 39.7 % | ACCEPTABLE |
| 7 | -9.65 | 33.12 | 46.42 | 38.9 % | ACCEPTABLE |
| 8 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 9 | -9.43 | 26.28 | 38.82 | 7.2 % | ACCEPTABLE |
| 10 | -6.03 | 13.08 | 28.37 | 51.8 % | ACCEPTABLE |
| 11 | 2.15 | 4.61 | 17.61 | 35.1 % | ACCEPTABLE |
| 12 | -3.30 | 2.50 | 22.59 | 44.2 % | ACCEPTABLE |
| 13 | -8.27 | 21.76 | 35.00 | 54.7 % | ACCEPTABLE |
| 14 | 1.95 | 5.10 | 17.94 | 35.3 % | ACCEPTABLE |
| 15 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 16 | 0.86 | 1.65 | 15.88 | 37.6 % | ACCEPTABLE |
| 17 | -8.19 | 18.20 | 30.80 | 9.8 % | ACCEPTABLE |
| 18 | -5.89 | 10.36 | 24.81 | 60.3 % | ACCEPTABLE |
| 19 | -0.34 | 4.61 | 17.61 | 44.3 % | ACCEPTABLE |
| 20 | -3.70 | 2.92 | 20.57 | 48.3 % | ACCEPTABLE |
| 21 | -7.31 | 15.19 | 28.37 | 57.9 % | ACCEPTABLE |
| 22 | -0.92 | 6.05 | 18.59 | 44.5 % | ACCEPTABLE |
| 23 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 24 | -2.40 | 5.62 | 18.29 | 56.8 % | ACCEPTABLE |
| 25 | -7.29 | 13.26 | 25.94 | 13.5 % | ACCEPTABLE |
| 26 | -5.75 | 8.50 | 22.43 | 57.3 % | ACCEPTABLE |
| 27 | -2.00 | 4.61 | 17.61 | 57.6 % | ACCEPTABLE |
| 28 | -4.07 | 3.31 | 19.36 | 51.2 % | ACCEPTABLE |
| 29 | -7.74 | 2.43 | 16.29 | 1.9 % | ACCEPTABLE |
| 30 | -6.65 | 11.29 | 24.42 | 58.1 % | ACCEPTABLE |
| 31 | -2.53 | 5.93 | 18.50 | 56.6 % | ACCEPTABLE |
| 32 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 33 | -3.69 | 6.06 | 18.60 | 58.7 % | ACCEPTABLE |
| 34 | -5.82 | 3.97 | 15.80 | 1.2 % | ACCEPTABLE |
| 35 | -5.94 | 11.62 | 22.99 | 1.6 % | ACCEPTABLE |
| 36 | -6.66 | 10.19 | 22.94 | 11.7 % | ACCEPTABLE |
| 37 | -1.50 | 0.66 | 15.41 | 50.8 % | ACCEPTABLE |
| 38 | -5.64 | 7.24 | 20.83 | 62.9 % | ACCEPTABLE |
| 39 | -3.10 | 4.61 | 17.61 | 60.9 % | ACCEPTABLE |
| 40 | -4.39 | 3.64 | 18.64 | 54.7 % | ACCEPTABLE |
| 41 | -4.71 | 1.70 | 14.29 | 5.0 % | ACCEPTABLE |
| 42 | -7.52 | 4.61 | 17.61 | 2.4 % | ACCEPTABLE |
| 43 | -6.29 | 1.58 | 15.84 | 56.4 % | ACCEPTABLE |
| 44 | -6.96 | 3.23 | 16.75 | 4.4 % | ACCEPTABLE |
| 45 | -4.37 | 1.00 | 13.88 | 12.0 % | ACCEPTABLE |
| 46 | -6.21 | 8.89 | 21.99 | 63.9 % | ACCEPTABLE |
| 47 | -3.51 | 5.62 | 18.29 | 59.4 % | ACCEPTABLE |
| 48 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 49 | -4.34 | 5.84 | 18.44 | 55.8 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 50 | -5.71 | 4.36 | 16.51 | 2.0 % | ACCEPTABLE |
| 51 | -7.69 | 12.27 | 24.19 | 1.5 % | ACCEPTABLE |
| 52 | -5.53 | 8.78 | 20.65 | 2.1 % | ACCEPTABLE |
| 53 | -6.22 | 8.24 | 21.06 | 15.0 % | ACCEPTABLE |
| 54 | -2.76 | 1.97 | 16.04 | 51.1 % | ACCEPTABLE |
| 55 | -5.55 | 6.38 | 19.76 | 63.7 % | ACCEPTABLE |
| 56 | -3.84 | 4.61 | 17.61 | 57.2 % | ACCEPTABLE |
| 57 | -4.65 | 3.91 | 18.23 | 63.0 % | ACCEPTABLE |
| 58 | -4.96 | 2.72 | 15.41 | 7.2 % | ACCEPTABLE |
| 59 | -7.87 | 7.30 | 19.50 | 1.2 % | ACCEPTABLE |
| 60 | -6.31 | 5.67 | 17.47 | 1.3 % | ACCEPTABLE |
| 61 | -6.78 | 4.61 | 17.61 | 3.9 % | ACCEPTABLE |
| 62 | -4.43 | 0.30 | 14.65 | 54.7 % | ACCEPTABLE |
| 63 | -6.01 | 2.70 | 16.45 | 30.6 % | ACCEPTABLE |
| 64 | -4.34 | 1.36 | 14.61 | 64.8 % | ACCEPTABLE |
| 65 | -5.33 | 1.04 | 15.58 | 63.1 % | ACCEPTABLE |
| 66 | -6.42 | 3.72 | 17.05 | 6.8 % | ACCEPTABLE |
| 67 | -4.69 | 2.13 | 15.05 | 15.1 % | ACCEPTABLE |
| 68 | -5.92 | 7.39 | 20.46 | 63.6 % | ACCEPTABLE |
| 69 | -4.13 | 5.33 | 18.09 | 56.4 % | ACCEPTABLE |
| 70 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 71 | -4.70 | 5.53 | 18.23 | 61.9 % | ACCEPTABLE |
| 72 | -5.60 | 4.51 | 16.91 | 4.1 % | ACCEPTABLE |
| 73 | -6.80 | 9.32 | 21.59 | 3.6 % | ACCEPTABLE |
| 74 | -5.38 | 7.21 | 19.44 | 6.7 % | ACCEPTABLE |
| 75 | -5.93 | 6.99 | 19.86 | 21.3 % | ACCEPTABLE |
| 76 | -3.61 | 2.84 | 16.53 | 59.5 % | ACCEPTABLE |
| 77 | -5.48 | 5.80 | 19.05 | 65.3 % | ACCEPTABLE |
| 78 | -4.33 | 4.61 | 17.61 | 62.8 % | ACCEPTABLE |
| 79 | -4.84 | 4.11 | 17.99 | 63.0 % | ACCEPTABLE |
| 80 | -5.09 | 3.37 | 16.15 | 9.0 % | ACCEPTABLE |
| 81 | -7.02 | 6.40 | 18.84 | 1.8 % | ACCEPTABLE |
| 82 | -5.92 | 5.26 | 17.44 | 1.9 % | ACCEPTABLE |
| 83 | -6.29 | 4.61 | 17.61 | 5.5 % | ACCEPTABLE |
| 84 | -4.67 | 1.57 | 15.46 | 60.8 % | ACCEPTABLE |
| 85 | -4.06 | 1.02 | 14.80 | 52.7 % | ACCEPTABLE |
| 86 | -5.80 | 3.39 | 16.85 | 29.8 % | ACCEPTABLE |
| 87 | -4.67 | 2.40 | 15.56 | 65.1 % | ACCEPTABLE |
| 88 | -5.27 | 2.10 | 16.11 | 55.2 % | ACCEPTABLE |
| 89 | -6.06 | 4.03 | 17.24 | 9.6 % | ACCEPTABLE |
| 90 | -4.90 | 2.92 | 15.87 | 21.4 % | ACCEPTABLE |
| 91 | -5.72 | 6.43 | 19.48 | 64.4 % | ACCEPTABLE |
| 92 | -4.53 | 5.11 | 17.94 | 62.3 % | ACCEPTABLE |
| 93 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 94 | -4.92 | 5.26 | 18.04 | 62.8 % | ACCEPTABLE |
| 95 | -5.51 | 4.57 | 17.16 | 5.8 % | ACCEPTABLE |
| 96 | -6.27 | 7.59 | 20.10 | 5.1 % | ACCEPTABLE |
| 97 | -5.33 | 6.27 | 18.75 | 10.0 % | ACCEPTABLE |
| 98 | -5.72 | 6.18 | 19.09 | 28.9 % | ACCEPTABLE |
| 99 | -4.18 | 3.43 | 16.87 | 60.1 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 100 | -5.43 | 5.41 | 18.57 | 65.4 % | ACCEPTABLE |
| 101 | -4.66 | 4.61 | 17.61 | 63.4 % | ACCEPTABLE |
| 102 | -4.98 | 4.27 | 17.84 | 55.5 % | ACCEPTABLE |
| 103 | -5.17 | 3.79 | 16.64 | 10.9 % | ACCEPTABLE |
| 104 | -6.45 | 5.80 | 18.41 | 3.9 % | ACCEPTABLE |
| 105 | -5.70 | 5.02 | 17.47 | 4.2 % | ACCEPTABLE |
| 106 | -5.96 | 4.61 | 17.61 | 8.9 % | ACCEPTABLE |
| 107 | -4.86 | 2.50 | 16.09 | 62.2 % | ACCEPTABLE |
| 108 | -4.46 | 2.12 | 15.63 | 63.4 % | ACCEPTABLE |
| 109 | -5.65 | 3.83 | 17.11 | 28.4 % | ACCEPTABLE |
| 110 | -4.88 | 3.12 | 16.22 | 57.3 % | ACCEPTABLE |
| 111 | -5.26 | 2.87 | 16.54 | 55.6 % | ACCEPTABLE |
| 112 | -5.81 | 4.23 | 17.37 | 11.7 % | ACCEPTABLE |
| 113 | -5.04 | 3.47 | 16.44 | 20.4 % | ACCEPTABLE |
| 114 | -5.58 | 5.81 | 18.84 | 59.2 % | ACCEPTABLE |
| 115 | -4.80 | 4.95 | 17.84 | 58.2 % | ACCEPTABLE |
| 116 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 117 | -5.06 | 5.06 | 17.91 | 58.5 % | ACCEPTABLE |
| 118 | -5.44 | 4.60 | 17.31 | 8.3 % | ACCEPTABLE |
| 119 | -5.94 | 6.54 | 19.20 | 7.6 % | ACCEPTABLE |
| 120 | -5.31 | 5.69 | 18.34 | 12.3 % | ACCEPTABLE |
| 121 | -5.59 | 5.65 | 18.59 | 31.0 % | ACCEPTABLE |
| 122 | -4.55 | 3.82 | 17.11 | 55.8 % | ACCEPTABLE |
| 123 | -5.39 | 5.14 | 18.25 | 65.6 % | ACCEPTABLE |
| 124 | -4.87 | 4.61 | 17.61 | 58.9 % | ACCEPTABLE |
| 125 | -5.09 | 4.37 | 17.76 | 63.5 % | ACCEPTABLE |
| 126 | -5.22 | 4.07 | 16.96 | 13.7 % | ACCEPTABLE |
| 127 | -6.07 | 5.40 | 18.14 | 5.7 % | ACCEPTABLE |
| 128 | -5.56 | 4.88 | 17.50 | 5.9 % | ACCEPTABLE |
| 129 | -5.75 | 4.61 | 17.61 | 11.8 % | ACCEPTABLE |
| 130 | -5.00 | 3.16 | 16.55 | 64.0 % | ACCEPTABLE |
| 131 | -4.73 | 2.90 | 16.24 | 55.4 % | ACCEPTABLE |
| 132 | -5.54 | 4.10 | 17.28 | 32.2 % | ACCEPTABLE |
| 133 | -5.03 | 3.61 | 16.67 | 59.1 % | ACCEPTABLE |
| 134 | -5.26 | 3.41 | 16.86 | 63.7 % | ACCEPTABLE |
| 135 | -5.65 | 4.36 | 17.45 | 14.9 % | ACCEPTABLE |
| 136 | -5.13 | 3.84 | 16.82 | 31.9 % | ACCEPTABLE |
| 137 | -5.49 | 5.40 | 18.42 | 65.7 % | ACCEPTABLE |
| 138 | -4.97 | 4.84 | 17.76 | 58.6 % | ACCEPTABLE |
| 139 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 140 | -5.14 | 4.92 | 17.81 | 58.8 % | ACCEPTABLE |
| 141 | -5.40 | 4.61 | 17.42 | 9.6 % | ACCEPTABLE |
| 142 | -5.72 | 5.87 | 18.64 | 10.8 % | ACCEPTABLE |
| 143 | -5.31 | 5.32 | 18.08 | 19.1 % | ACCEPTABLE |
| 144 | -5.50 | 5.30 | 18.26 | 64.6 % | ACCEPTABLE |
| 145 | -4.81 | 4.08 | 17.27 | 57.2 % | ACCEPTABLE |
| 146 | -5.36 | 4.97 | 18.04 | 59.2 % | ACCEPTABLE |
| 147 | -5.02 | 4.61 | 17.61 | 59.1 % | ACCEPTABLE |
| 148 | -5.16 | 4.45 | 17.70 | 64.6 % | ACCEPTABLE |
| 149 | -5.25 | 4.25 | 17.18 | 19.6 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 150 | -5.81 | 5.14 | 17.96 | 8.9 % | ACCEPTABLE |
| 151 | -5.47 | 4.78 | 17.53 | 8.3 % | ACCEPTABLE |
| 152 | -5.60 | 4.61 | 17.61 | 14.9 % | ACCEPTABLE |
| 153 | -5.10 | 3.62 | 16.88 | 64.0 % | ACCEPTABLE |
| 154 | -4.92 | 3.45 | 16.68 | 64.9 % | ACCEPTABLE |
| 155 | -5.47 | 4.28 | 17.39 | 30.6 % | ACCEPTABLE |
| 156 | -5.12 | 3.94 | 16.98 | 59.2 % | ACCEPTABLE |
| 157 | -5.27 | 3.80 | 17.09 | 64.0 % | ACCEPTABLE |
| 158 | -5.53 | 4.45 | 17.50 | 20.1 % | ACCEPTABLE |
| 159 | -5.19 | 4.10 | 17.08 | 19.7 % | ACCEPTABLE |
| 160 | -5.43 | 5.14 | 18.15 | 29.3 % | ACCEPTABLE |
| 161 | -5.08 | 4.77 | 17.71 | 58.9 % | ACCEPTABLE |
| 162 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 163 | -5.20 | 4.82 | 17.75 | 59.1 % | ACCEPTABLE |
| 164 | -5.37 | 4.61 | 17.48 | 14.6 % | ACCEPTABLE |
| 165 | -5.58 | 5.44 | 18.29 | 13.6 % | ACCEPTABLE |
| 166 | -5.31 | 5.08 | 17.92 | 19.6 % | ACCEPTABLE |
| 167 | -5.43 | 5.07 | 18.04 | 27.8 % | ACCEPTABLE |
| 168 | -4.97 | 4.26 | 17.38 | 58.7 % | ACCEPTABLE |
| 169 | -5.35 | 4.85 | 17.90 | 64.9 % | ACCEPTABLE |
| 170 | -5.12 | 4.61 | 17.61 | 59.3 % | ACCEPTABLE |
| 171 | -5.21 | 4.50 | 17.67 | 65.9 % | ACCEPTABLE |
| 172 | -5.27 | 4.37 | 17.32 | 18.4 % | ACCEPTABLE |
| 173 | -5.65 | 4.96 | 17.84 | 11.7 % | ACCEPTABLE |
| 174 | -5.42 | 4.72 | 17.56 | 14.8 % | ACCEPTABLE |
| 175 | -5.50 | 4.61 | 17.61 | 20.1 % | ACCEPTABLE |
| 176 | -5.16 | 3.94 | 17.12 | 64.0 % | ACCEPTABLE |
| 177 | -5.05 | 3.83 | 16.98 | 65.0 % | ACCEPTABLE |
| 178 | -5.41 | 4.39 | 17.47 | 32.1 % | ACCEPTABLE |
| 179 | -5.19 | 4.16 | 17.19 | 65.2 % | ACCEPTABLE |
| 180 | -5.28 | 4.06 | 17.26 | 64.0 % | ACCEPTABLE |
| 181 | -5.46 | 4.50 | 17.54 | 32.0 % | ACCEPTABLE |
| 182 | -5.23 | 4.27 | 17.26 | 32.5 % | ACCEPTABLE |
| 183 | -5.39 | 4.96 | 17.97 | 66.1 % | ACCEPTABLE |
| 184 | -5.16 | 4.72 | 17.68 | 58.9 % | ACCEPTABLE |
| 185 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 186 | -5.24 | 4.75 | 17.70 | 59.1 % | ACCEPTABLE |
| 187 | -5.35 | 4.61 | 17.52 | 18.3 % | ACCEPTABLE |
| 188 | -5.49 | 5.16 | 18.06 | 19.4 % | ACCEPTABLE |
| 189 | -5.31 | 4.92 | 17.81 | 27.6 % | ACCEPTABLE |
| 190 | -5.39 | 4.91 | 17.90 | 29.9 % | ACCEPTABLE |
| 191 | -5.09 | 4.38 | 17.46 | 58.9 % | ACCEPTABLE |
| 192 | -5.33 | 4.77 | 17.80 | 59.4 % | ACCEPTABLE |
| 193 | -5.18 | 4.61 | 17.61 | 59.2 % | ACCEPTABLE |
| 194 | -5.24 | 4.54 | 17.65 | 59.2 % | ACCEPTABLE |
| 195 | -5.28 | 4.45 | 17.42 | 29.3 % | ACCEPTABLE |
| 196 | -5.53 | 4.84 | 17.76 | 19.8 % | ACCEPTABLE |
| 197 | -5.38 | 4.69 | 17.57 | 14.6 % | ACCEPTABLE |
| 198 | -5.44 | 4.61 | 17.61 | 30.5 % | ACCEPTABLE |
| 199 | -5.21 | 4.16 | 17.28 | 65.2 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 200 | -5.13 | 4.08 | 17.18 | 59.1 % | ACCEPTABLE |
| 201 | -5.38 | 4.46 | 17.52 | 65.0 % | ACCEPTABLE |
| 202 | -5.23 | 4.31 | 17.33 | 66.6 % | ACCEPTABLE |
| 203 | -5.16 | 4.45 | 17.42 | 59.2 % | ACCEPTABLE |
| 204 | -5.27 | 4.31 | 17.24 | 19.6 % | ACCEPTABLE |
| 205 | -5.41 | 4.85 | 17.77 | 20.8 % | ACCEPTABLE |
| 206 | -5.22 | 4.61 | 17.53 | 27.8 % | ACCEPTABLE |
| 207 | -5.31 | 4.61 | 17.61 | 66.3 % | ACCEPTABLE |
| 208 | -5.01 | 4.08 | 17.18 | 58.9 % | ACCEPTABLE |
| 209 | -5.25 | 4.47 | 17.52 | 59.2 % | ACCEPTABLE |
| 210 | -5.10 | 4.31 | 17.33 | 59.2 % | ACCEPTABLE |
| 211 | -5.16 | 4.24 | 17.37 | 64.7 % | ACCEPTABLE |
| 212 | -5.20 | 4.15 | 17.14 | 31.1 % | ACCEPTABLE |
| 213 | -5.45 | 4.54 | 17.48 | 14.9 % | ACCEPTABLE |
| 214 | -5.30 | 4.38 | 17.29 | 16.1 % | ACCEPTABLE |
| 215 | -5.36 | 4.31 | 17.33 | 32.1 % | ACCEPTABLE |
| 216 | -5.13 | 3.87 | 17.01 | 63.8 % | ACCEPTABLE |
| 217 | -5.06 | 3.79 | 16.91 | 65.2 % | ACCEPTABLE |
| 218 | -5.30 | 4.17 | 17.24 | 30.7 % | ACCEPTABLE |
| 219 | -5.15 | 4.01 | 17.05 | 65.4 % | ACCEPTABLE |
| 220 | -5.21 | 3.95 | 17.10 | 63.8 % | ACCEPTABLE |
| 221 | -5.33 | 4.24 | 17.28 | 30.6 % | ACCEPTABLE |
| 222 | -5.18 | 4.08 | 17.10 | 65.3 % | ACCEPTABLE |
| 223 | -5.28 | 4.54 | 17.57 | 66.6 % | ACCEPTABLE |
| 224 | -5.21 | 4.68 | 17.66 | 59.2 % | ACCEPTABLE |
| 225 | -5.32 | 4.54 | 17.48 | 19.6 % | ACCEPTABLE |
| 226 | -5.46 | 5.08 | 18.01 | 19.4 % | ACCEPTABLE |
| 227 | -5.28 | 4.85 | 17.77 | 59.1 % | ACCEPTABLE |
| 228 | -5.36 | 4.84 | 17.85 | 59.4 % | ACCEPTABLE |
| 229 | -5.06 | 4.31 | 17.42 | 58.7 % | ACCEPTABLE |
| 230 | -5.30 | 4.70 | 17.76 | 59.3 % | ACCEPTABLE |
| 231 | -5.15 | 4.54 | 17.57 | 59.2 % | ACCEPTABLE |
| 232 | -5.21 | 4.47 | 17.61 | 57.7 % | ACCEPTABLE |
| 233 | -5.25 | 4.38 | 17.38 | 27.9 % | ACCEPTABLE |
| 234 | -5.50 | 4.77 | 17.72 | 16.0 % | ACCEPTABLE |
| 235 | -5.35 | 4.61 | 17.53 | 20.8 % | ACCEPTABLE |
| 236 | -5.41 | 4.54 | 17.57 | 30.5 % | ACCEPTABLE |
| 237 | -5.18 | 4.09 | 17.24 | 65.1 % | ACCEPTABLE |
| 238 | -5.11 | 4.02 | 17.15 | 65.0 % | ACCEPTABLE |
| 239 | -5.35 | 4.40 | 17.48 | 65.1 % | ACCEPTABLE |
| 240 | -5.20 | 4.24 | 17.29 | 66.2 % | ACCEPTABLE |
| 241 | -5.26 | 4.17 | 17.33 | 63.7 % | ACCEPTABLE |
| 242 | -5.38 | 4.47 | 17.52 | 65.1 % | ACCEPTABLE |
| 243 | -5.23 | 4.31 | 17.33 | 66.6 % | ACCEPTABLE |
| 244 | -5.33 | 4.77 | 17.81 | 66.2 % | ACCEPTABLE |
| 245 | -5.18 | 4.61 | 17.62 | 59.1 % | ACCEPTABLE |
| 246 | -5.28 | 4.54 | 17.57 | 66.6 % | ACCEPTABLE |
| 247 | -5.23 | 4.63 | 17.63 | 59.3 % | ACCEPTABLE |
| 248 | -5.31 | 4.54 | 17.51 | 30.0 % | ACCEPTABLE |
| 249 | -5.40 | 4.90 | 17.86 | 29.9 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 250 | -5.28 | 4.74 | 17.70 | 27.9 % | ACCEPTABLE |
| 251 | -5.33 | 4.74 | 17.76 | 59.5 % | ACCEPTABLE |
| 252 | -5.13 | 4.39 | 17.47 | 58.8 % | ACCEPTABLE |
| 253 | -5.30 | 4.65 | 17.70 | 66.1 % | ACCEPTABLE |
| 254 | -5.19 | 4.54 | 17.57 | 59.3 % | ACCEPTABLE |
| 255 | -5.23 | 4.49 | 17.60 | 59.1 % | ACCEPTABLE |
| 256 | -5.26 | 4.43 | 17.44 | 29.4 % | ACCEPTABLE |
| 257 | -5.43 | 4.70 | 17.67 | 21.3 % | ACCEPTABLE |
| 258 | -5.33 | 4.59 | 17.54 | 19.6 % | ACCEPTABLE |
| 259 | -5.37 | 4.54 | 17.57 | 30.5 % | ACCEPTABLE |
| 260 | -5.21 | 4.24 | 17.35 | 65.1 % | ACCEPTABLE |
| 261 | -5.16 | 4.19 | 17.29 | 59.0 % | ACCEPTABLE |
| 262 | -5.33 | 4.44 | 17.51 | 65.3 % | ACCEPTABLE |
| 263 | -5.23 | 4.34 | 17.38 | 65.2 % | ACCEPTABLE |
| 264 | -5.27 | 4.29 | 17.41 | 63.9 % | ACCEPTABLE |
| 265 | -5.35 | 4.49 | 17.54 | 65.1 % | ACCEPTABLE |
| 266 | -5.24 | 4.39 | 17.41 | 28.0 % | ACCEPTABLE |
| 267 | -5.32 | 4.69 | 17.73 | 65.2 % | ACCEPTABLE |
| 268 | -5.21 | 4.59 | 17.60 | 59.2 % | ACCEPTABLE |
| 269 | -5.28 | 4.54 | 17.57 | 66.6 % | ACCEPTABLE |
| 270 | -5.25 | 4.60 | 17.61 | 59.5 % | ACCEPTABLE |
| 271 | -5.30 | 4.54 | 17.53 | 30.1 % | ACCEPTABLE |
| 272 | -5.36 | 4.78 | 17.76 | 27.9 % | ACCEPTABLE |
| 273 | -5.28 | 4.68 | 17.66 | 59.5 % | ACCEPTABLE |
| 274 | -5.32 | 4.67 | 17.70 | 65.1 % | ACCEPTABLE |
| 275 | -5.18 | 4.44 | 17.50 | 59.1 % | ACCEPTABLE |
| 276 | -5.29 | 4.61 | 17.65 | 59.3 % | ACCEPTABLE |
| 277 | -5.22 | 4.54 | 17.57 | 59.6 % | ACCEPTABLE |
| 278 | -5.25 | 4.51 | 17.59 | 66.1 % | ACCEPTABLE |
| 279 | -5.27 | 4.47 | 17.49 | 30.1 % | ACCEPTABLE |
| 280 | -5.38 | 4.64 | 17.64 | 32.0 % | ACCEPTABLE |
| 281 | -5.31 | 4.57 | 17.55 | 31.6 % | ACCEPTABLE |
| 282 | -5.34 | 4.54 | 17.57 | 30.5 % | ACCEPTABLE |
| 283 | -5.24 | 4.34 | 17.42 | 65.2 % | ACCEPTABLE |
| 284 | -5.20 | 4.30 | 17.38 | 66.1 % | ACCEPTABLE |
| 285 | -5.31 | 4.48 | 17.53 | 65.0 % | ACCEPTABLE |
| 286 | -5.24 | 4.41 | 17.44 | 59.4 % | ACCEPTABLE |
| 287 | -5.27 | 4.38 | 17.46 | 65.1 % | ACCEPTABLE |
| 288 | -5.32 | 4.51 | 17.55 | 30.6 % | ACCEPTABLE |
| 289 | -5.26 | 4.44 | 17.47 | 30.7 % | ACCEPTABLE |
| 290 | -5.30 | 4.64 | 17.68 | 66.3 % | ACCEPTABLE |
| 291 | -5.24 | 4.57 | 17.59 | 59.5 % | ACCEPTABLE |
| 292 | -5.28 | 4.54 | 17.57 | 66.6 % | ACCEPTABLE |
| 293 | -5.26 | 4.58 | 17.60 | 59.4 % | ACCEPTABLE |
| 294 | -5.29 | 4.54 | 17.54 | 59.5 % | ACCEPTABLE |
| 295 | -5.33 | 4.70 | 17.70 | 59.6 % | ACCEPTABLE |
| 296 | -5.28 | 4.63 | 17.63 | 59.6 % | ACCEPTABLE |
| 297 | -5.30 | 4.63 | 17.65 | 59.5 % | ACCEPTABLE |
| 298 | -5.21 | 4.47 | 17.53 | 59.0 % | ACCEPTABLE |
| 299 | -5.29 | 4.59 | 17.63 | 66.4 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 300 | -5.24 | 4.54 | 17.57 | 59.6 % | ACCEPTABLE |
| 301 | -5.26 | 4.52 | 17.58 | 65.9 % | ACCEPTABLE |
| 302 | -5.27 | 4.49 | 17.51 | 59.4 % | ACCEPTABLE |
| 303 | -5.35 | 4.61 | 17.61 | 30.6 % | ACCEPTABLE |
| 304 | -5.30 | 4.56 | 17.56 | 66.3 % | ACCEPTABLE |
| 305 | -5.32 | 4.54 | 17.57 | 30.6 % | ACCEPTABLE |
| 306 | -5.25 | 4.41 | 17.47 | 65.0 % | ACCEPTABLE |
| 307 | -5.23 | 4.38 | 17.44 | 66.1 % | ACCEPTABLE |
| 308 | -5.30 | 4.50 | 17.54 | 65.1 % | ACCEPTABLE |
| 309 | -5.26 | 4.45 | 17.49 | 65.1 % | ACCEPTABLE |
| 310 | -5.27 | 4.43 | 17.50 | 65.1 % | ACCEPTABLE |
| 311 | -5.31 | 4.52 | 17.56 | 30.6 % | ACCEPTABLE |
| 312 | -5.26 | 4.47 | 17.50 | 59.5 % | ACCEPTABLE |
| 313 | -5.30 | 4.61 | 17.64 | 66.3 % | ACCEPTABLE |
| 314 | -5.25 | 4.56 | 17.58 | 59.4 % | ACCEPTABLE |
| 315 | 7.05 | 3.36 | 16.19 | 4.1 % | ACCEPTABLE |
| 316 | -2.85 | 2.00 | 25.80 | 39.6 % | ACCEPTABLE |
| 317 | 0.95 | 25.30 | 38.92 | 30.3 % | ACCEPTABLE |
| 318 | 1.10 | 2.49 | 29.53 | 29.1 % | ACCEPTABLE |
| 319 | 0.60 | 5.14 | 30.36 | 30.7 % | ACCEPTABLE |
| 320 | -5.23 | 4.48 | 17.50 | 59.6 % | ACCEPTABLE |
| 321 | 7.09 | 3.30 | 16.12 | 4.1 % | ACCEPTABLE |
| 322 | -2.85 | 2.00 | 25.80 | 39.6 % | ACCEPTABLE |
| 323 | -9.60 | 32.91 | 46.23 | 39.0 % | ACCEPTABLE |
| 324 | -5.23 | 4.48 | 17.50 | 59.6 % | ACCEPTABLE |
| 325 | -9.33 | 25.96 | 38.53 | 14.7 % | ACCEPTABLE |
| 326 | -5.96 | 12.92 | 28.23 | 51.8 % | ACCEPTABLE |
| 327 | 2.23 | 4.48 | 17.50 | 34.0 % | ACCEPTABLE |
| 328 | -3.25 | 2.41 | 22.52 | 44.2 % | ACCEPTABLE |
| 329 | -8.18 | 21.53 | 34.79 | 52.0 % | ACCEPTABLE |
| 330 | 2.05 | 4.90 | 17.78 | 34.7 % | ACCEPTABLE |
| 331 | -5.23 | 4.48 | 17.50 | 59.6 % | ACCEPTABLE |
| 332 | 0.99 | 1.41 | 15.73 | 36.9 % | ACCEPTABLE |
| 333 | -8.09 | 17.96 | 30.58 | 12.7 % | ACCEPTABLE |
| 334 | -5.81 | 10.20 | 24.68 | 55.7 % | ACCEPTABLE |
| 335 | -0.26 | 4.48 | 17.50 | 43.0 % | ACCEPTABLE |
| 336 | -3.64 | 2.82 | 20.49 | 48.2 % | ACCEPTABLE |
| 337 | -7.22 | 15.00 | 28.20 | 55.1 % | ACCEPTABLE |
| 338 | -0.83 | 5.88 | 18.45 | 44.0 % | ACCEPTABLE |
| 339 | -5.23 | 4.48 | 17.50 | 59.6 % | ACCEPTABLE |
| 340 | -2.30 | 5.42 | 18.13 | 57.1 % | ACCEPTABLE |
| 341 | -7.20 | 13.06 | 25.76 | 13.2 % | ACCEPTABLE |
| 342 | -5.68 | 8.36 | 22.30 | 57.4 % | ACCEPTABLE |
| 343 | -1.92 | 4.48 | 17.50 | 56.5 % | ACCEPTABLE |
| 344 | -4.01 | 3.20 | 19.28 | 51.2 % | ACCEPTABLE |
| 345 | -7.67 | 2.32 | 16.21 | 2.1 % | ACCEPTABLE |
| 346 | -6.57 | 11.12 | 24.27 | 58.2 % | ACCEPTABLE |
| 347 | -2.44 | 5.77 | 18.37 | 57.1 % | ACCEPTABLE |
| 348 | -5.23 | 4.48 | 17.50 | 59.6 % | ACCEPTABLE |
| 349 | -3.60 | 5.89 | 18.46 | 59.0 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 350 | -5.73 | 3.84 | 15.69 | 1.2 % | ACCEPTABLE |
| 351 | -5.84 | 11.40 | 22.79 | 1.7 % | ACCEPTABLE |
| 352 | -6.57 | 10.01 | 22.79 | 14.7 % | ACCEPTABLE |
| 353 | -1.42 | 0.56 | 15.33 | 50.7 % | ACCEPTABLE |
| 354 | -5.56 | 7.10 | 20.71 | 56.3 % | ACCEPTABLE |
| 355 | -3.02 | 4.48 | 17.50 | 60.9 % | ACCEPTABLE |
| 356 | -1.39 | 5.89 | 18.46 | 41.3 % | ACCEPTABLE |
| 357 | -3.52 | 3.84 | 15.69 | 7.1 % | ACCEPTABLE |
| 358 | -6.97 | 17.51 | 28.97 | 1.5 % | ACCEPTABLE |
| 359 | -3.63 | 11.40 | 22.79 | 5.9 % | ACCEPTABLE |
| 360 | -4.36 | 10.01 | 22.79 | 55.1 % | ACCEPTABLE |
| 361 | 0.79 | 0.56 | 15.33 | 33.7 % | ACCEPTABLE |
| 362 | -3.35 | 7.10 | 20.71 | 52.6 % | ACCEPTABLE |
| 363 | -0.81 | 4.48 | 17.50 | 40.4 % | ACCEPTABLE |
| 364 | -2.11 | 3.53 | 18.56 | 48.8 % | ACCEPTABLE |
| 365 | -2.41 | 1.58 | 14.19 | 51.3 % | ACCEPTABLE |
| 366 | -6.86 | 8.49 | 20.40 | 1.3 % | ACCEPTABLE |
| 367 | -4.71 | 6.26 | 17.55 | 1.3 % | ACCEPTABLE |
| 368 | -5.23 | 4.48 | 17.50 | 59.6 % | ACCEPTABLE |
| 369 | -4.01 | 1.48 | 15.76 | 54.7 % | ACCEPTABLE |
| 370 | -4.67 | 3.11 | 16.65 | 54.9 % | ACCEPTABLE |
| 371 | -2.08 | 0.89 | 13.79 | 51.3 % | ACCEPTABLE |
| 372 | -3.92 | 8.74 | 21.85 | 55.7 % | ACCEPTABLE |
| 373 | -1.21 | 5.47 | 18.16 | 41.0 % | ACCEPTABLE |
| 374 | -3.02 | 4.48 | 17.50 | 60.9 % | ACCEPTABLE |
| 375 | -2.04 | 5.69 | 18.31 | 55.9 % | ACCEPTABLE |
| 376 | -3.41 | 4.23 | 16.39 | 58.3 % | ACCEPTABLE |
| 377 | -5.39 | 12.07 | 24.01 | 8.1 % | ACCEPTABLE |
| 378 | -3.23 | 8.61 | 20.49 | 51.9 % | ACCEPTABLE |
| 379 | -3.93 | 8.08 | 20.92 | 59.5 % | ACCEPTABLE |
| 380 | -0.48 | 1.86 | 15.96 | 47.5 % | ACCEPTABLE |
| 381 | -3.26 | 6.24 | 19.65 | 57.3 % | ACCEPTABLE |
| 382 | -1.55 | 4.48 | 17.50 | 55.1 % | ACCEPTABLE |
| 383 | -2.36 | 3.79 | 18.13 | 53.8 % | ACCEPTABLE |
| 384 | -2.66 | 2.59 | 15.31 | 59.3 % | ACCEPTABLE |
| 385 | -5.58 | 7.14 | 19.37 | 5.6 % | ACCEPTABLE |
| 386 | -4.01 | 5.52 | 17.33 | 6.1 % | ACCEPTABLE |
| 387 | -4.49 | 4.48 | 17.50 | 63.4 % | ACCEPTABLE |
| 388 | -3.51 | 5.69 | 18.31 | 59.3 % | ACCEPTABLE |
| 389 | -4.88 | 4.23 | 16.39 | 3.0 % | ACCEPTABLE |
| 390 | -6.86 | 12.07 | 24.01 | 2.1 % | ACCEPTABLE |
| 391 | -4.70 | 8.61 | 20.49 | 7.1 % | ACCEPTABLE |
| 392 | -5.40 | 8.08 | 20.92 | 61.8 % | ACCEPTABLE |
| 393 | -1.95 | 1.86 | 15.96 | 53.4 % | ACCEPTABLE |
| 394 | -4.73 | 6.24 | 19.65 | 61.9 % | ACCEPTABLE |
| 395 | -3.02 | 4.48 | 17.50 | 60.9 % | ACCEPTABLE |
| 396 | -3.83 | 3.79 | 18.13 | 58.5 % | ACCEPTABLE |
| 397 | -4.13 | 2.59 | 15.31 | 63.0 % | ACCEPTABLE |
| 398 | -7.05 | 7.14 | 19.37 | 1.6 % | ACCEPTABLE |
| 399 | -5.48 | 5.52 | 17.33 | 1.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 400 | -5.96 | 4.48 | 17.50 | 7.2 % | ACCEPTABLE |
| 401 | -3.62 | 0.21 | 14.58 | 53.0 % | ACCEPTABLE |
| 402 | -5.19 | 2.59 | 16.36 | 55.3 % | ACCEPTABLE |
| 403 | -3.52 | 1.26 | 14.53 | 59.4 % | ACCEPTABLE |
| 404 | -4.52 | 0.94 | 15.51 | 55.6 % | ACCEPTABLE |
| 405 | -5.61 | 3.60 | 16.95 | 28.6 % | ACCEPTABLE |
| 406 | -3.87 | 2.01 | 14.96 | 61.9 % | ACCEPTABLE |
| 407 | -5.09 | 7.24 | 20.33 | 62.3 % | ACCEPTABLE |
| 408 | -3.31 | 5.19 | 17.97 | 60.1 % | ACCEPTABLE |
| 409 | -4.49 | 4.48 | 17.50 | 63.4 % | ACCEPTABLE |
| 410 | -3.88 | 5.38 | 18.10 | 55.6 % | ACCEPTABLE |
| 411 | -4.77 | 4.38 | 16.80 | 9.6 % | ACCEPTABLE |
| 412 | -5.98 | 9.15 | 21.43 | 6.7 % | ACCEPTABLE |
| 413 | -4.56 | 7.05 | 19.30 | 19.7 % | ACCEPTABLE |
| 414 | -5.10 | 6.84 | 19.73 | 62.3 % | ACCEPTABLE |
| 415 | -2.79 | 2.73 | 16.43 | 51.2 % | ACCEPTABLE |
| 416 | -4.66 | 5.67 | 18.94 | 62.2 % | ACCEPTABLE |
| 417 | -3.51 | 4.48 | 17.50 | 56.6 % | ACCEPTABLE |
| 418 | -4.03 | 3.99 | 17.89 | 59.9 % | ACCEPTABLE |
| 419 | -4.27 | 3.24 | 16.05 | 63.2 % | ACCEPTABLE |
| 420 | -6.19 | 6.25 | 18.71 | 4.2 % | ACCEPTABLE |
| 421 | -5.10 | 5.12 | 17.31 | 4.9 % | ACCEPTABLE |
| 422 | -5.47 | 4.48 | 17.50 | 21.3 % | ACCEPTABLE |
| 423 | -3.86 | 1.46 | 15.38 | 52.3 % | ACCEPTABLE |
| 424 | -3.25 | 0.92 | 14.72 | 59.0 % | ACCEPTABLE |
| 425 | -4.98 | 3.28 | 16.75 | 63.3 % | ACCEPTABLE |
| 426 | -3.85 | 2.29 | 15.47 | 61.7 % | ACCEPTABLE |
| 427 | -4.46 | 1.99 | 16.03 | 62.0 % | ACCEPTABLE |
| 428 | -5.24 | 3.91 | 17.14 | 64.0 % | ACCEPTABLE |
| 429 | -4.58 | 4.71 | 17.65 | 63.2 % | ACCEPTABLE |
| 430 | -5.50 | 3.80 | 16.41 | 4.8 % | ACCEPTABLE |
| 431 | -6.66 | 8.35 | 20.83 | 2.6 % | ACCEPTABLE |
| 432 | -5.25 | 6.34 | 18.78 | 10.9 % | ACCEPTABLE |
| 433 | -5.83 | 6.16 | 19.27 | 64.2 % | ACCEPTABLE |
| 434 | -5.22 | 7.15 | 19.96 | 62.0 % | ACCEPTABLE |
| 435 | -6.14 | 6.12 | 18.62 | 4.7 % | ACCEPTABLE |
| 436 | -7.33 | 11.20 | 23.57 | 4.1 % | ACCEPTABLE |
| 437 | -5.91 | 8.98 | 21.31 | 7.3 % | ACCEPTABLE |
| 438 | -6.44 | 8.68 | 21.66 | 32.0 % | ACCEPTABLE |
| 439 | -4.13 | 4.26 | 18.05 | 60.2 % | ACCEPTABLE |
| 440 | -5.99 | 7.42 | 20.77 | 62.4 % | ACCEPTABLE |
| 441 | -4.85 | 6.16 | 19.27 | 62.4 % | ACCEPTABLE |
| 442 | -5.34 | 5.59 | 19.57 | 61.0 % | ACCEPTABLE |
| 443 | -5.62 | 4.85 | 17.75 | 11.7 % | ACCEPTABLE |
| 444 | -7.55 | 8.12 | 20.66 | 2.5 % | ACCEPTABLE |
| 445 | -6.46 | 6.91 | 19.19 | 2.2 % | ACCEPTABLE |
| 446 | -6.81 | 6.16 | 19.27 | 6.9 % | ACCEPTABLE |
| 447 | -5.19 | 2.88 | 16.89 | 55.3 % | ACCEPTABLE |
| 448 | -4.59 | 2.30 | 16.20 | 61.1 % | ACCEPTABLE |
| 449 | -6.33 | 4.87 | 18.43 | 58.4 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 450 | -5.20 | 3.80 | 17.08 | 64.0 % | ACCEPTABLE |
| 451 | -5.78 | 3.44 | 17.57 | 56.1 % | ACCEPTABLE |
| 452 | -6.58 | 5.55 | 18.86 | 10.7 % | ACCEPTABLE |
| 453 | -5.43 | 4.36 | 17.43 | 30.6 % | ACCEPTABLE |
| 454 | -6.23 | 8.09 | 21.24 | 63.3 % | ACCEPTABLE |
| 455 | -5.05 | 6.70 | 19.64 | 62.4 % | ACCEPTABLE |
| 456 | -5.83 | 6.16 | 19.27 | 64.2 % | ACCEPTABLE |
| 457 | -5.44 | 6.86 | 19.75 | 58.5 % | ACCEPTABLE |
| 458 | -6.04 | 6.16 | 18.85 | 6.7 % | ACCEPTABLE |
| 459 | -6.79 | 9.36 | 21.97 | 7.0 % | ACCEPTABLE |
| 460 | -5.86 | 7.96 | 20.55 | 11.1 % | ACCEPTABLE |
| 461 | -6.24 | 7.82 | 20.84 | 63.7 % | ACCEPTABLE |
| 462 | -4.69 | 4.88 | 18.44 | 56.5 % | ACCEPTABLE |
| 463 | -5.94 | 7.01 | 20.27 | 63.9 % | ACCEPTABLE |
| 464 | -5.18 | 6.16 | 19.27 | 58.5 % | ACCEPTABLE |
| 465 | -5.49 | 5.76 | 19.45 | 62.0 % | ACCEPTABLE |
| 466 | -5.70 | 5.29 | 18.26 | 19.7 % | ACCEPTABLE |
| 467 | -6.98 | 7.46 | 20.18 | 4.2 % | ACCEPTABLE |
| 468 | -6.23 | 6.63 | 19.19 | 5.1 % | ACCEPTABLE |
| 469 | -6.48 | 6.16 | 19.27 | 11.5 % | ACCEPTABLE |
| 470 | -5.38 | 3.88 | 17.59 | 61.9 % | ACCEPTABLE |
| 471 | -4.98 | 3.48 | 17.11 | 61.9 % | ACCEPTABLE |
| 472 | -6.17 | 5.33 | 18.72 | 58.8 % | ACCEPTABLE |
| 473 | -5.41 | 4.57 | 17.78 | 63.8 % | ACCEPTABLE |
| 474 | -5.77 | 4.28 | 18.06 | 56.4 % | ACCEPTABLE |
| 475 | -6.33 | 5.76 | 19.00 | 19.5 % | ACCEPTABLE |
| 476 | -5.56 | 4.95 | 18.03 | 30.4 % | ACCEPTABLE |
| 477 | -6.09 | 7.43 | 20.57 | 63.5 % | ACCEPTABLE |
| 478 | -5.31 | 6.53 | 19.52 | 58.9 % | ACCEPTABLE |
| 479 | -5.83 | 6.16 | 19.27 | 64.2 % | ACCEPTABLE |
| 480 | -5.58 | 6.64 | 19.60 | 58.8 % | ACCEPTABLE |
| 481 | -5.97 | 6.17 | 19.00 | 11.5 % | ACCEPTABLE |
| 482 | -6.46 | 8.23 | 21.00 | 9.7 % | ACCEPTABLE |
| 483 | -5.84 | 7.33 | 20.09 | 14.1 % | ACCEPTABLE |
| 484 | -6.10 | 7.26 | 20.31 | 63.7 % | ACCEPTABLE |
| 485 | -5.07 | 5.31 | 18.71 | 55.6 % | ACCEPTABLE |
| 486 | -5.91 | 6.73 | 19.94 | 63.8 % | ACCEPTABLE |
| 487 | -5.39 | 6.16 | 19.27 | 58.6 % | ACCEPTABLE |
| 488 | -5.60 | 5.89 | 19.38 | 62.8 % | ACCEPTABLE |
| 489 | -5.74 | 5.58 | 18.60 | 30.0 % | ACCEPTABLE |
| 490 | -6.59 | 7.02 | 19.87 | 7.6 % | ACCEPTABLE |
| 491 | -6.09 | 6.47 | 19.20 | 8.1 % | ACCEPTABLE |
| 492 | -6.27 | 6.16 | 19.27 | 20.7 % | ACCEPTABLE |
| 493 | -5.52 | 4.60 | 18.10 | 63.1 % | ACCEPTABLE |
| 494 | -5.25 | 4.33 | 17.78 | 63.3 % | ACCEPTABLE |
| 495 | -6.06 | 5.62 | 18.91 | 63.9 % | ACCEPTABLE |
| 496 | -5.55 | 5.09 | 18.27 | 65.0 % | ACCEPTABLE |
| 497 | -5.29 | 5.53 | 18.56 | 58.9 % | ACCEPTABLE |
| 498 | -5.68 | 5.08 | 17.98 | 12.6 % | ACCEPTABLE |
| 499 | -6.16 | 7.04 | 19.88 | 11.5 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 500 | -5.54 | 6.18 | 19.01 | 28.8 % | ACCEPTABLE |
| 501 | -5.82 | 6.13 | 19.25 | 64.3 % | ACCEPTABLE |
| 502 | -4.80 | 4.29 | 17.76 | 55.1 % | ACCEPTABLE |
| 503 | -5.63 | 5.64 | 18.92 | 63.4 % | ACCEPTABLE |
| 504 | -5.11 | 5.09 | 18.27 | 58.7 % | ACCEPTABLE |
| 505 | -5.33 | 4.85 | 18.42 | 62.3 % | ACCEPTABLE |
| 506 | -5.46 | 4.53 | 17.61 | 30.5 % | ACCEPTABLE |
| 507 | -6.30 | 5.90 | 18.81 | 7.7 % | ACCEPTABLE |
| 508 | -5.79 | 5.36 | 18.16 | 8.3 % | ACCEPTABLE |
| 509 | -5.99 | 5.09 | 18.27 | 19.8 % | ACCEPTABLE |
| 510 | -5.25 | 3.62 | 17.20 | 62.6 % | ACCEPTABLE |
| 511 | -4.99 | 3.36 | 16.88 | 62.8 % | ACCEPTABLE |
| 512 | -5.79 | 4.59 | 17.95 | 64.2 % | ACCEPTABLE |
| 513 | -5.28 | 4.08 | 17.32 | 64.2 % | ACCEPTABLE |
| 514 | -5.52 | 3.88 | 17.51 | 62.7 % | ACCEPTABLE |
| 515 | -5.89 | 4.85 | 18.11 | 31.9 % | ACCEPTABLE |
| 516 | -5.37 | 4.31 | 17.47 | 64.0 % | ACCEPTABLE |
| 517 | -5.73 | 5.89 | 19.09 | 64.3 % | ACCEPTABLE |
| 518 | -5.20 | 5.32 | 18.42 | 58.8 % | ACCEPTABLE |
| 519 | -5.55 | 5.09 | 18.27 | 65.0 % | ACCEPTABLE |
| 520 | -5.38 | 5.39 | 18.47 | 58.8 % | ACCEPTABLE |
| 521 | -5.64 | 5.09 | 18.08 | 19.8 % | ACCEPTABLE |
| 522 | -5.95 | 6.36 | 19.32 | 19.6 % | ACCEPTABLE |
| 523 | -5.54 | 5.81 | 18.75 | 59.0 % | ACCEPTABLE |
| 524 | -5.73 | 5.78 | 18.92 | 64.5 % | ACCEPTABLE |
| 525 | -5.05 | 4.55 | 17.93 | 55.8 % | ACCEPTABLE |
| 526 | -5.60 | 5.46 | 18.71 | 63.1 % | ACCEPTABLE |
| 527 | -5.26 | 5.09 | 18.27 | 59.0 % | ACCEPTABLE |
| 528 | -5.40 | 4.93 | 18.36 | 63.3 % | ACCEPTABLE |
| 529 | -5.49 | 4.72 | 17.83 | 65.3 % | ACCEPTABLE |
| 530 | -5.32 | 5.02 | 18.03 | 59.1 % | ACCEPTABLE |
| 531 | -5.58 | 4.72 | 17.63 | 14.7 % | ACCEPTABLE |
| 532 | -5.89 | 5.97 | 18.86 | 15.6 % | ACCEPTABLE |
| 533 | -5.48 | 5.43 | 18.30 | 18.3 % | ACCEPTABLE |
| 534 | -5.67 | 5.40 | 18.47 | 64.8 % | ACCEPTABLE |
| 535 | -4.99 | 4.19 | 17.49 | 56.2 % | ACCEPTABLE |
| 536 | -5.55 | 5.08 | 18.26 | 65.0 % | ACCEPTABLE |
| 537 | -5.20 | 4.72 | 17.83 | 58.9 % | ACCEPTABLE |
| 538 | -5.34 | 4.56 | 17.93 | 63.7 % | ACCEPTABLE |
| 539 | -5.43 | 4.35 | 17.40 | 21.4 % | ACCEPTABLE |
| 540 | -5.99 | 5.25 | 18.18 | 8.9 % | ACCEPTABLE |
| 541 | -5.65 | 4.89 | 17.75 | 10.5 % | ACCEPTABLE |
| 542 | -5.78 | 4.72 | 17.83 | 19.9 % | ACCEPTABLE |
| 543 | -5.28 | 3.74 | 17.11 | 64.1 % | ACCEPTABLE |
| 544 | -5.11 | 3.56 | 16.90 | 64.1 % | ACCEPTABLE |
| 545 | -5.65 | 4.39 | 17.62 | 64.1 % | ACCEPTABLE |
| 546 | -5.31 | 4.05 | 17.20 | 65.4 % | ACCEPTABLE |
| 547 | -5.13 | 4.33 | 17.38 | 58.8 % | ACCEPTABLE |
| 548 | -5.39 | 4.04 | 17.00 | 12.9 % | ACCEPTABLE |
| 549 | -5.71 | 5.26 | 18.18 | 14.6 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 550 | -5.29 | 4.73 | 17.64 | 27.8 % | ACCEPTABLE |
| 551 | -5.49 | 4.71 | 17.82 | 65.3 % | ACCEPTABLE |
| 552 | -4.81 | 3.54 | 16.89 | 55.4 % | ACCEPTABLE |
| 553 | -5.37 | 4.40 | 17.62 | 64.0 % | ACCEPTABLE |
| 554 | -5.02 | 4.05 | 17.20 | 58.7 % | ACCEPTABLE |
| 555 | -5.17 | 3.90 | 17.31 | 64.0 % | ACCEPTABLE |
| 556 | -5.25 | 3.69 | 16.78 | 30.8 % | ACCEPTABLE |
| 557 | -5.81 | 4.56 | 17.53 | 9.7 % | ACCEPTABLE |
| 558 | -5.46 | 4.21 | 17.10 | 11.8 % | ACCEPTABLE |
| 559 | -5.60 | 4.05 | 17.20 | 20.1 % | ACCEPTABLE |
| 560 | -5.11 | 3.11 | 16.52 | 63.8 % | ACCEPTABLE |
| 561 | -4.93 | 2.93 | 16.31 | 64.0 % | ACCEPTABLE |
| 562 | -5.47 | 3.74 | 17.01 | 64.5 % | ACCEPTABLE |
| 563 | -5.13 | 3.40 | 16.60 | 64.1 % | ACCEPTABLE |
| 564 | -5.29 | 3.28 | 16.73 | 64.0 % | ACCEPTABLE |
| 565 | -5.54 | 3.90 | 17.10 | 30.7 % | ACCEPTABLE |
| 566 | -5.19 | 3.55 | 16.69 | 64.2 % | ACCEPTABLE |
| 567 | -5.43 | 4.56 | 17.72 | 65.3 % | ACCEPTABLE |
| 568 | -5.08 | 4.20 | 17.29 | 58.9 % | ACCEPTABLE |
| 569 | -5.31 | 4.05 | 17.20 | 65.4 % | ACCEPTABLE |
| 570 | -5.19 | 4.24 | 17.32 | 65.2 % | ACCEPTABLE |
| 571 | -5.37 | 4.05 | 17.07 | 20.1 % | ACCEPTABLE |
| 572 | -5.57 | 4.84 | 17.84 | 21.2 % | ACCEPTABLE |
| 573 | -5.30 | 4.50 | 17.49 | 30.6 % | ACCEPTABLE |
| 574 | -5.43 | 4.49 | 17.61 | 30.6 % | ACCEPTABLE |
| 575 | -4.98 | 3.71 | 16.99 | 63.9 % | ACCEPTABLE |
| 576 | -5.35 | 4.29 | 17.48 | 63.9 % | ACCEPTABLE |
| 577 | -5.12 | 4.05 | 17.20 | 64.9 % | ACCEPTABLE |
| 578 | -5.21 | 3.95 | 17.27 | 63.9 % | ACCEPTABLE |
| 579 | -5.27 | 3.81 | 16.92 | 30.8 % | ACCEPTABLE |
| 580 | -5.64 | 4.39 | 17.42 | 11.9 % | ACCEPTABLE |
| 581 | -5.41 | 4.15 | 17.13 | 16.0 % | ACCEPTABLE |
| 582 | -5.50 | 4.05 | 17.20 | 20.2 % | ACCEPTABLE |
| 583 | -5.17 | 3.41 | 16.74 | 64.0 % | ACCEPTABLE |
| 584 | -5.06 | 3.30 | 16.60 | 64.3 % | ACCEPTABLE |
| 585 | -5.42 | 3.85 | 17.07 | 64.3 % | ACCEPTABLE |
| 586 | -5.19 | 3.62 | 16.80 | 64.1 % | ACCEPTABLE |
| 587 | -5.29 | 3.53 | 16.88 | 64.1 % | ACCEPTABLE |
| 588 | -5.46 | 3.95 | 17.14 | 30.8 % | ACCEPTABLE |
| 589 | -5.23 | 3.72 | 16.86 | 64.4 % | ACCEPTABLE |
| 590 | -5.39 | 4.39 | 17.55 | 63.9 % | ACCEPTABLE |
| 591 | -5.16 | 4.15 | 17.26 | 65.0 % | ACCEPTABLE |
| 592 | -5.31 | 4.05 | 17.20 | 65.4 % | ACCEPTABLE |
| 593 | -5.23 | 4.18 | 17.28 | 65.1 % | ACCEPTABLE |
| 594 | -5.35 | 4.05 | 17.11 | 32.2 % | ACCEPTABLE |
| 595 | -5.48 | 4.57 | 17.62 | 20.0 % | ACCEPTABLE |
| 596 | -5.30 | 4.34 | 17.39 | 65.1 % | ACCEPTABLE |
| 597 | -5.39 | 4.34 | 17.47 | 64.2 % | ACCEPTABLE |
| 598 | -5.09 | 3.83 | 17.06 | 64.0 % | ACCEPTABLE |
| 599 | -5.34 | 4.21 | 17.39 | 64.0 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 600 | -5.18 | 4.05 | 17.20 | 65.1 % | ACCEPTABLE |
| 601 | -5.25 | 3.98 | 17.25 | 64.1 % | ACCEPTABLE |
| 602 | -5.28 | 3.89 | 17.01 | 64.0 % | ACCEPTABLE |
| 603 | -5.53 | 4.28 | 17.34 | 20.0 % | ACCEPTABLE |
| 604 | -5.38 | 4.12 | 17.16 | 20.1 % | ACCEPTABLE |
| 605 | -5.44 | 4.05 | 17.20 | 30.7 % | ACCEPTABLE |
| 606 | -5.22 | 3.62 | 16.89 | 64.2 % | ACCEPTABLE |
| 607 | -5.14 | 3.54 | 16.80 | 64.3 % | ACCEPTABLE |
| 608 | -5.38 | 3.92 | 17.12 | 64.2 % | ACCEPTABLE |
| 609 | -5.23 | 3.76 | 16.93 | 64.2 % | ACCEPTABLE |
| 610 | -5.30 | 3.70 | 16.98 | 64.3 % | ACCEPTABLE |
| 611 | -5.41 | 3.98 | 17.16 | 64.0 % | ACCEPTABLE |
| 612 | -5.26 | 3.83 | 16.97 | 64.3 % | ACCEPTABLE |
| 613 | -5.36 | 4.28 | 17.43 | 64.1 % | ACCEPTABLE |
| 614 | -5.21 | 4.12 | 17.24 | 65.2 % | ACCEPTABLE |
| 615 | -5.31 | 4.05 | 17.20 | 65.4 % | ACCEPTABLE |
| 616 | -5.26 | 4.14 | 17.26 | 65.2 % | ACCEPTABLE |
| 617 | -5.34 | 4.05 | 17.14 | 65.3 % | ACCEPTABLE |
| 618 | -5.43 | 4.40 | 17.48 | 30.5 % | ACCEPTABLE |
| 619 | -5.30 | 4.25 | 17.32 | 30.6 % | ACCEPTABLE |
| 620 | -5.36 | 4.24 | 17.38 | 64.1 % | ACCEPTABLE |
| 621 | -5.16 | 3.90 | 17.11 | 63.9 % | ACCEPTABLE |
| 622 | -5.33 | 4.16 | 17.33 | 64.2 % | ACCEPTABLE |
| 623 | -5.22 | 4.05 | 17.20 | 65.1 % | ACCEPTABLE |
| 624 | -5.27 | 4.01 | 17.23 | 63.9 % | ACCEPTABLE |
| 625 | -5.29 | 3.94 | 17.07 | 30.8 % | ACCEPTABLE |
| 626 | -5.46 | 4.20 | 17.30 | 30.7 % | ACCEPTABLE |
| 627 | -5.35 | 4.10 | 17.17 | 30.6 % | ACCEPTABLE |
| 628 | -5.40 | 4.05 | 17.20 | 30.7 % | ACCEPTABLE |
| 629 | -5.25 | 3.76 | 16.99 | 64.1 % | ACCEPTABLE |
| 630 | -5.20 | 3.71 | 16.93 | 64.1 % | ACCEPTABLE |
| 631 | -5.36 | 3.96 | 17.14 | 64.1 % | ACCEPTABLE |
| 632 | -5.26 | 3.86 | 17.02 | 64.2 % | ACCEPTABLE |
| 633 | -5.30 | 3.81 | 17.05 | 64.0 % | ACCEPTABLE |
| 634 | -5.38 | 4.01 | 17.17 | 64.1 % | ACCEPTABLE |
| 635 | -5.27 | 3.90 | 17.05 | 64.2 % | ACCEPTABLE |
| 636 | -5.35 | 4.20 | 17.35 | 63.9 % | ACCEPTABLE |
| 637 | -5.24 | 4.09 | 17.23 | 63.8 % | ACCEPTABLE |
| 638 | -5.31 | 4.05 | 17.20 | 65.4 % | ACCEPTABLE |
| 639 | -5.28 | 4.11 | 17.24 | 65.2 % | ACCEPTABLE |
| 640 | -5.33 | 4.05 | 17.16 | 32.3 % | ACCEPTABLE |
| 641 | -5.39 | 4.28 | 17.39 | 65.2 % | ACCEPTABLE |
| 642 | -5.31 | 4.18 | 17.28 | 65.2 % | ACCEPTABLE |
| 643 | -5.35 | 4.18 | 17.32 | 65.4 % | ACCEPTABLE |
| 644 | -5.32 | 4.24 | 17.36 | 65.3 % | ACCEPTABLE |
| 645 | -5.37 | 4.18 | 17.28 | 65.2 % | ACCEPTABLE |
| 646 | -5.43 | 4.41 | 17.51 | 65.2 % | ACCEPTABLE |
| 647 | -5.35 | 4.31 | 17.40 | 30.7 % | ACCEPTABLE |
| 648 | -5.39 | 4.31 | 17.44 | 64.1 % | ACCEPTABLE |
| 649 | -5.25 | 4.08 | 17.26 | 64.0 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 650 | -5.36 | 4.25 | 17.40 | 63.9 % | ACCEPTABLE |
| 651 | -5.29 | 4.18 | 17.32 | 65.2 % | ACCEPTABLE |
| 652 | -5.32 | 4.15 | 17.34 | 63.9 % | ACCEPTABLE |
| 653 | -5.34 | 4.11 | 17.24 | 65.4 % | ACCEPTABLE |
| 654 | -5.31 | 4.17 | 17.28 | 65.3 % | ACCEPTABLE |
| 655 | -5.36 | 4.11 | 17.20 | 32.2 % | ACCEPTABLE |
| 656 | -5.42 | 4.34 | 17.43 | 30.6 % | ACCEPTABLE |
| 657 | -5.34 | 4.24 | 17.32 | 30.7 % | ACCEPTABLE |
| 658 | -5.38 | 4.24 | 17.36 | 32.2 % | ACCEPTABLE |
| 659 | -5.24 | 4.01 | 17.18 | 63.9 % | ACCEPTABLE |
| 660 | -5.35 | 4.18 | 17.32 | 65.4 % | ACCEPTABLE |
| 661 | -5.28 | 4.11 | 17.24 | 65.2 % | ACCEPTABLE |
| 662 | -5.31 | 4.08 | 17.26 | 64.0 % | ACCEPTABLE |
| 663 | -5.33 | 4.04 | 17.16 | 65.4 % | ACCEPTABLE |
| 664 | -5.44 | 4.21 | 17.30 | 32.1 % | ACCEPTABLE |
| 665 | -5.37 | 4.14 | 17.22 | 30.6 % | ACCEPTABLE |
| 666 | -5.40 | 4.11 | 17.24 | 30.8 % | ACCEPTABLE |
| 667 | -5.30 | 3.92 | 17.10 | 64.1 % | ACCEPTABLE |
| 668 | -5.26 | 3.88 | 17.06 | 64.1 % | ACCEPTABLE |
| 669 | -5.37 | 4.05 | 17.20 | 30.7 % | ACCEPTABLE |
| 670 | -5.30 | 3.98 | 17.12 | 64.0 % | ACCEPTABLE |
| 671 | -5.33 | 3.95 | 17.14 | 64.1 % | ACCEPTABLE |
| 672 | -5.39 | 4.08 | 17.22 | 64.0 % | ACCEPTABLE |
| 673 | -5.32 | 4.01 | 17.14 | 65.4 % | ACCEPTABLE |
| 674 | -5.29 | 4.07 | 17.18 | 65.3 % | ACCEPTABLE |
| 675 | -5.34 | 4.01 | 17.10 | 30.7 % | ACCEPTABLE |
| 676 | -5.40 | 4.24 | 17.33 | 30.6 % | ACCEPTABLE |
| 677 | -5.32 | 4.14 | 17.22 | 30.7 % | ACCEPTABLE |
| 678 | -5.36 | 4.14 | 17.26 | 65.3 % | ACCEPTABLE |
| 679 | -5.22 | 3.91 | 17.08 | 63.8 % | ACCEPTABLE |
| 680 | -5.33 | 4.08 | 17.22 | 64.0 % | ACCEPTABLE |
| 681 | -5.26 | 4.01 | 17.14 | 65.2 % | ACCEPTABLE |
| 682 | -5.29 | 3.98 | 17.16 | 64.0 % | ACCEPTABLE |
| 683 | -5.31 | 3.94 | 17.06 | 30.8 % | ACCEPTABLE |
| 684 | -5.42 | 4.11 | 17.20 | 32.2 % | ACCEPTABLE |
| 685 | -5.35 | 4.04 | 17.12 | 32.2 % | ACCEPTABLE |
| 686 | -5.38 | 4.01 | 17.14 | 30.7 % | ACCEPTABLE |
| 687 | -5.28 | 3.82 | 17.00 | 64.1 % | ACCEPTABLE |
| 688 | -5.24 | 3.78 | 16.96 | 64.0 % | ACCEPTABLE |
| 689 | -5.35 | 3.95 | 17.10 | 64.2 % | ACCEPTABLE |
| 690 | -5.28 | 3.88 | 17.02 | 64.3 % | ACCEPTABLE |
| 691 | -5.31 | 3.85 | 17.04 | 64.1 % | ACCEPTABLE |
| 692 | -5.37 | 3.98 | 17.12 | 64.0 % | ACCEPTABLE |
| 693 | -5.30 | 3.91 | 17.04 | 64.0 % | ACCEPTABLE |
| 694 | -5.34 | 4.11 | 17.24 | 65.4 % | ACCEPTABLE |
| 695 | -5.27 | 4.04 | 17.16 | 65.3 % | ACCEPTABLE |
| 696 | -5.32 | 4.01 | 17.14 | 65.4 % | ACCEPTABLE |
| 697 | -5.30 | 4.05 | 17.16 | 65.2 % | ACCEPTABLE |
| 698 | -5.33 | 4.01 | 17.11 | 32.2 % | ACCEPTABLE |
| 699 | -5.37 | 4.16 | 17.26 | 65.2 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 700 | -5.32 | 4.10 | 17.19 | 32.2 % | ACCEPTABLE |
| 701 | -5.34 | 4.10 | 17.22 | 32.3 % | ACCEPTABLE |
| 702 | -5.25 | 3.94 | 17.10 | 63.9 % | ACCEPTABLE |
| 703 | -5.33 | 4.06 | 17.20 | 65.4 % | ACCEPTABLE |
| 704 | -5.31 | 4.10 | 17.22 | 32.3 % | ACCEPTABLE |
| 705 | -5.34 | 4.06 | 17.17 | 32.3 % | ACCEPTABLE |
| 706 | -5.38 | 4.21 | 17.32 | 65.5 % | ACCEPTABLE |
| 707 | -5.36 | 4.25 | 17.35 | 30.7 % | ACCEPTABLE |
| 708 | -5.39 | 4.21 | 17.29 | 32.1 % | ACCEPTABLE |
| 709 | -5.43 | 4.37 | 17.45 | 30.6 % | ACCEPTABLE |
| 710 | -5.38 | 4.30 | 17.38 | 65.1 % | ACCEPTABLE |
| 711 | -5.40 | 4.30 | 17.40 | 65.2 % | ACCEPTABLE |
| 712 | -5.31 | 4.14 | 17.28 | 63.9 % | ACCEPTABLE |
| 713 | -5.39 | 4.26 | 17.38 | 32.2 % | ACCEPTABLE |
| 714 | -5.34 | 4.21 | 17.32 | 65.1 % | ACCEPTABLE |
| 715 | -5.36 | 4.19 | 17.33 | 64.1 % | ACCEPTABLE |
| 716 | -5.37 | 4.16 | 17.26 | 65.2 % | ACCEPTABLE |
| 717 | -5.45 | 4.28 | 17.36 | 30.6 % | ACCEPTABLE |
| 718 | -5.40 | 4.23 | 17.31 | 32.1 % | ACCEPTABLE |
| 719 | -5.42 | 4.21 | 17.32 | 65.3 % | ACCEPTABLE |
| 720 | -5.35 | 4.08 | 17.22 | 64.0 % | ACCEPTABLE |
| 721 | -5.33 | 4.06 | 17.20 | 65.4 % | ACCEPTABLE |
| 722 | -5.40 | 4.17 | 17.29 | 65.3 % | ACCEPTABLE |
| 723 | -5.36 | 4.12 | 17.24 | 65.3 % | ACCEPTABLE |
| 724 | -5.37 | 4.10 | 17.25 | 64.0 % | ACCEPTABLE |
| 725 | -5.41 | 4.19 | 17.31 | 32.2 % | ACCEPTABLE |
| 726 | -5.36 | 4.14 | 17.25 | 32.3 % | ACCEPTABLE |
| 727 | -5.40 | 4.28 | 17.39 | 65.2 % | ACCEPTABLE |
| 728 | -5.35 | 4.23 | 17.33 | 65.1 % | ACCEPTABLE |
| 729 | -5.28 | 4.54 | 17.57 | 66.6 % | ACCEPTABLE |
| 730 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 731 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 732 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 733 | -6.14 | 17.05 | 33.65 | 50.2 % | ACCEPTABLE |
| 734 | 7.02 | 3.42 | 16.21 | 2.8 % | ACCEPTABLE |
| 735 | -2.86 | 2.04 | 25.81 | 34.2 % | ACCEPTABLE |
| 736 | -9.65 | 33.12 | 46.42 | 56.1 % | ACCEPTABLE |
| 737 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 738 | -9.43 | 26.28 | 38.82 | 11.1 % | ACCEPTABLE |
| 739 | -6.03 | 13.08 | 28.37 | 56.1 % | ACCEPTABLE |
| 740 | 2.15 | 4.61 | 17.61 | 38.4 % | ACCEPTABLE |
| 741 | -3.30 | 2.50 | 22.59 | 41.4 % | ACCEPTABLE |
| 742 | -8.27 | 21.76 | 35.00 | 63.7 % | ACCEPTABLE |
| 743 | 1.95 | 5.10 | 17.94 | 39.2 % | ACCEPTABLE |
| 744 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 745 | 0.86 | 1.65 | 15.88 | 44.4 % | ACCEPTABLE |
| 746 | -8.19 | 18.20 | 30.80 | 9.8 % | ACCEPTABLE |
| 747 | -5.89 | 10.36 | 24.81 | 64.7 % | ACCEPTABLE |
| 748 | -0.34 | 4.61 | 17.61 | 57.6 % | ACCEPTABLE |
| 749 | -3.70 | 2.92 | 20.57 | 48.1 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 750 | -8.87 | 1.13 | 15.63 | 1.3 % | ACCEPTABLE |
| 751 | -7.31 | 15.19 | 28.37 | 67.5 % | ACCEPTABLE |
| 752 | -0.92 | 6.05 | 18.59 | 59.8 % | ACCEPTABLE |
| 753 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 754 | -2.40 | 5.62 | 18.29 | 65.9 % | ACCEPTABLE |
| 755 | -7.29 | 13.26 | 25.94 | 12.9 % | ACCEPTABLE |
| 756 | -5.75 | 8.50 | 22.43 | 64.2 % | ACCEPTABLE |
| 757 | -2.00 | 4.61 | 17.61 | 65.8 % | ACCEPTABLE |
| 758 | -4.07 | 3.31 | 19.36 | 53.6 % | ACCEPTABLE |
| 759 | -7.74 | 2.43 | 16.29 | 2.2 % | ACCEPTABLE |
| 760 | -6.65 | 11.29 | 24.42 | 67.2 % | ACCEPTABLE |
| 761 | -2.53 | 5.93 | 18.50 | 65.9 % | ACCEPTABLE |
| 762 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 763 | -3.69 | 6.06 | 18.60 | 68.6 % | ACCEPTABLE |
| 764 | -5.82 | 3.97 | 15.80 | 1.1 % | ACCEPTABLE |
| 765 | -5.94 | 11.62 | 22.99 | 1.5 % | ACCEPTABLE |
| 766 | -6.66 | 10.19 | 22.94 | 11.3 % | ACCEPTABLE |
| 767 | -1.50 | 0.66 | 15.41 | 53.1 % | ACCEPTABLE |
| 768 | -5.64 | 7.24 | 20.83 | 72.4 % | ACCEPTABLE |
| 769 | -3.10 | 4.61 | 17.61 | 69.8 % | ACCEPTABLE |
| 770 | -4.39 | 3.64 | 18.64 | 58.1 % | ACCEPTABLE |
| 771 | -4.71 | 1.70 | 14.29 | 4.7 % | ACCEPTABLE |
| 772 | -7.52 | 4.61 | 17.61 | 2.4 % | ACCEPTABLE |
| 773 | -6.29 | 1.58 | 15.84 | 63.5 % | ACCEPTABLE |
| 774 | -6.96 | 3.23 | 16.75 | 4.4 % | ACCEPTABLE |
| 775 | -4.37 | 1.00 | 13.88 | 11.7 % | ACCEPTABLE |
| 776 | -6.21 | 8.89 | 21.99 | 72.8 % | ACCEPTABLE |
| 777 | -3.51 | 5.62 | 18.29 | 69.1 % | ACCEPTABLE |
| 778 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 779 | -4.34 | 5.84 | 18.44 | 66.5 % | ACCEPTABLE |
| 780 | -5.71 | 4.36 | 16.51 | 1.9 % | ACCEPTABLE |
| 781 | -7.69 | 12.27 | 24.19 | 1.4 % | ACCEPTABLE |
| 782 | -5.53 | 8.78 | 20.65 | 2.0 % | ACCEPTABLE |
| 783 | -6.22 | 8.24 | 21.06 | 14.7 % | ACCEPTABLE |
| 784 | -2.76 | 1.97 | 16.04 | 56.6 % | ACCEPTABLE |
| 785 | -5.55 | 6.38 | 19.76 | 72.7 % | ACCEPTABLE |
| 786 | -3.84 | 4.61 | 17.61 | 66.9 % | ACCEPTABLE |
| 787 | -4.65 | 3.91 | 18.23 | 67.4 % | ACCEPTABLE |
| 788 | -4.96 | 2.72 | 15.41 | 6.9 % | ACCEPTABLE |
| 789 | -7.87 | 7.30 | 19.50 | 1.1 % | ACCEPTABLE |
| 790 | -6.31 | 5.67 | 17.47 | 1.2 % | ACCEPTABLE |
| 791 | -6.78 | 4.61 | 17.61 | 4.0 % | ACCEPTABLE |
| 792 | -4.43 | 0.30 | 14.65 | 59.6 % | ACCEPTABLE |
| 793 | -6.01 | 2.70 | 16.45 | 31.0 % | ACCEPTABLE |
| 794 | -4.34 | 1.36 | 14.61 | 74.1 % | ACCEPTABLE |
| 795 | -5.33 | 1.04 | 15.58 | 66.7 % | ACCEPTABLE |
| 796 | -6.42 | 3.72 | 17.05 | 6.8 % | ACCEPTABLE |
| 797 | -4.69 | 2.13 | 15.05 | 14.9 % | ACCEPTABLE |
| 798 | -5.92 | 7.39 | 20.46 | 72.8 % | ACCEPTABLE |
| 799 | -4.13 | 5.33 | 18.09 | 66.6 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 800 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 801 | -4.70 | 5.53 | 18.23 | 72.2 % | ACCEPTABLE |
| 802 | -5.60 | 4.51 | 16.91 | 4.0 % | ACCEPTABLE |
| 803 | -6.80 | 9.32 | 21.59 | 3.3 % | ACCEPTABLE |
| 804 | -5.38 | 7.21 | 19.44 | 6.3 % | ACCEPTABLE |
| 805 | -5.93 | 6.99 | 19.86 | 20.8 % | ACCEPTABLE |
| 806 | -3.61 | 2.84 | 16.53 | 66.0 % | ACCEPTABLE |
| 807 | -5.48 | 5.80 | 19.05 | 73.7 % | ACCEPTABLE |
| 808 | -4.33 | 4.61 | 17.61 | 72.2 % | ACCEPTABLE |
| 809 | -4.84 | 4.11 | 17.99 | 70.4 % | ACCEPTABLE |
| 810 | -5.09 | 3.37 | 16.15 | 9.0 % | ACCEPTABLE |
| 811 | -7.02 | 6.40 | 18.84 | 1.7 % | ACCEPTABLE |
| 812 | -5.92 | 5.26 | 17.44 | 1.8 % | ACCEPTABLE |
| 813 | -6.29 | 4.61 | 17.61 | 5.4 % | ACCEPTABLE |
| 814 | -4.67 | 1.57 | 15.46 | 68.4 % | ACCEPTABLE |
| 815 | -4.06 | 1.02 | 14.80 | 61.3 % | ACCEPTABLE |
| 816 | -5.80 | 3.39 | 16.85 | 31.4 % | ACCEPTABLE |
| 817 | -4.67 | 2.40 | 15.56 | 75.0 % | ACCEPTABLE |
| 818 | -5.27 | 2.10 | 16.11 | 63.5 % | ACCEPTABLE |
| 819 | -6.06 | 4.03 | 17.24 | 9.5 % | ACCEPTABLE |
| 820 | -4.90 | 2.92 | 15.87 | 21.7 % | ACCEPTABLE |
| 821 | -5.72 | 6.43 | 19.48 | 73.8 % | ACCEPTABLE |
| 822 | -4.53 | 5.11 | 17.94 | 72.1 % | ACCEPTABLE |
| 823 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 824 | -4.92 | 5.26 | 18.04 | 73.1 % | ACCEPTABLE |
| 825 | -5.51 | 4.57 | 17.16 | 5.7 % | ACCEPTABLE |
| 826 | -6.27 | 7.59 | 20.10 | 4.6 % | ACCEPTABLE |
| 827 | -5.33 | 6.27 | 18.75 | 9.5 % | ACCEPTABLE |
| 828 | -5.72 | 6.18 | 19.09 | 29.8 % | ACCEPTABLE |
| 829 | -4.18 | 3.43 | 16.87 | 69.0 % | ACCEPTABLE |
| 830 | -5.43 | 5.41 | 18.57 | 74.3 % | ACCEPTABLE |
| 831 | -4.66 | 4.61 | 17.61 | 73.1 % | ACCEPTABLE |
| 832 | -4.98 | 4.27 | 17.84 | 65.0 % | ACCEPTABLE |
| 833 | -5.17 | 3.79 | 16.64 | 10.9 % | ACCEPTABLE |
| 834 | -6.45 | 5.80 | 18.41 | 3.8 % | ACCEPTABLE |
| 835 | -5.70 | 5.02 | 17.47 | 4.1 % | ACCEPTABLE |
| 836 | -5.96 | 4.61 | 17.61 | 8.8 % | ACCEPTABLE |
| 837 | -4.86 | 2.50 | 16.09 | 70.7 % | ACCEPTABLE |
| 838 | -4.46 | 2.12 | 15.63 | 72.9 % | ACCEPTABLE |
| 839 | -5.65 | 3.83 | 17.11 | 29.9 % | ACCEPTABLE |
| 840 | -4.88 | 3.12 | 16.22 | 68.5 % | ACCEPTABLE |
| 841 | -5.26 | 2.87 | 16.54 | 65.0 % | ACCEPTABLE |
| 842 | -5.81 | 4.23 | 17.37 | 11.6 % | ACCEPTABLE |
| 843 | -5.04 | 3.47 | 16.44 | 20.7 % | ACCEPTABLE |
| 844 | -5.58 | 5.81 | 18.84 | 69.3 % | ACCEPTABLE |
| 845 | -4.80 | 4.95 | 17.84 | 68.5 % | ACCEPTABLE |
| 846 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 847 | -5.06 | 5.06 | 17.91 | 69.0 % | ACCEPTABLE |
| 848 | -5.44 | 4.60 | 17.31 | 8.3 % | ACCEPTABLE |
| 849 | -5.94 | 6.54 | 19.20 | 7.6 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 850 | -5.31 | 5.69 | 18.34 | 11.9 % | ACCEPTABLE |
| 851 | -5.59 | 5.65 | 18.59 | 32.7 % | ACCEPTABLE |
| 852 | -4.55 | 3.82 | 17.11 | 66.0 % | ACCEPTABLE |
| 853 | -5.39 | 5.14 | 18.25 | 74.7 % | ACCEPTABLE |
| 854 | -4.87 | 4.61 | 17.61 | 69.1 % | ACCEPTABLE |
| 855 | -5.09 | 4.37 | 17.76 | 72.6 % | ACCEPTABLE |
| 856 | -5.22 | 4.07 | 16.96 | 13.9 % | ACCEPTABLE |
| 857 | -6.07 | 5.40 | 18.14 | 5.5 % | ACCEPTABLE |
| 858 | -5.56 | 4.88 | 17.50 | 5.9 % | ACCEPTABLE |
| 859 | -5.75 | 4.61 | 17.61 | 11.6 % | ACCEPTABLE |
| 860 | -5.00 | 3.16 | 16.55 | 73.0 % | ACCEPTABLE |
| 861 | -4.73 | 2.90 | 16.24 | 65.9 % | ACCEPTABLE |
| 862 | -5.54 | 4.10 | 17.28 | 33.6 % | ACCEPTABLE |
| 863 | -5.03 | 3.61 | 16.67 | 69.2 % | ACCEPTABLE |
| 864 | -5.26 | 3.41 | 16.86 | 72.7 % | ACCEPTABLE |
| 865 | -5.65 | 4.36 | 17.45 | 14.7 % | ACCEPTABLE |
| 866 | -5.13 | 3.84 | 16.82 | 33.5 % | ACCEPTABLE |
| 867 | -5.49 | 5.40 | 18.42 | 76.1 % | ACCEPTABLE |
| 868 | -4.97 | 4.84 | 17.76 | 68.9 % | ACCEPTABLE |
| 869 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 870 | -5.14 | 4.92 | 17.81 | 69.2 % | ACCEPTABLE |
| 871 | -5.40 | 4.61 | 17.42 | 9.6 % | ACCEPTABLE |
| 872 | -5.72 | 5.87 | 18.64 | 10.9 % | ACCEPTABLE |
| 873 | -5.31 | 5.32 | 18.08 | 19.1 % | ACCEPTABLE |
| 874 | -5.50 | 5.30 | 18.26 | 74.6 % | ACCEPTABLE |
| 875 | -4.81 | 4.08 | 17.27 | 67.7 % | ACCEPTABLE |
| 876 | -5.36 | 4.97 | 18.04 | 69.0 % | ACCEPTABLE |
| 877 | -5.02 | 4.61 | 17.61 | 69.3 % | ACCEPTABLE |
| 878 | -5.16 | 4.45 | 17.70 | 75.2 % | ACCEPTABLE |
| 879 | -5.25 | 4.25 | 17.18 | 20.4 % | ACCEPTABLE |
| 880 | -5.81 | 5.14 | 17.96 | 8.7 % | ACCEPTABLE |
| 881 | -5.47 | 4.78 | 17.53 | 8.3 % | ACCEPTABLE |
| 882 | -5.60 | 4.61 | 17.61 | 14.8 % | ACCEPTABLE |
| 883 | -5.10 | 3.62 | 16.88 | 73.8 % | ACCEPTABLE |
| 884 | -4.92 | 3.45 | 16.68 | 74.6 % | ACCEPTABLE |
| 885 | -5.47 | 4.28 | 17.39 | 31.9 % | ACCEPTABLE |
| 886 | -5.12 | 3.94 | 16.98 | 69.4 % | ACCEPTABLE |
| 887 | -5.27 | 3.80 | 17.09 | 73.7 % | ACCEPTABLE |
| 888 | -5.53 | 4.45 | 17.50 | 20.2 % | ACCEPTABLE |
| 889 | -5.19 | 4.10 | 17.08 | 20.4 % | ACCEPTABLE |
| 890 | -5.43 | 5.14 | 18.15 | 31.5 % | ACCEPTABLE |
| 891 | -5.08 | 4.77 | 17.71 | 69.3 % | ACCEPTABLE |
| 892 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 893 | -5.20 | 4.82 | 17.75 | 69.5 % | ACCEPTABLE |
| 894 | -5.37 | 4.61 | 17.48 | 14.9 % | ACCEPTABLE |
| 895 | -5.58 | 5.44 | 18.29 | 13.8 % | ACCEPTABLE |
| 896 | -5.31 | 5.08 | 17.92 | 20.5 % | ACCEPTABLE |
| 897 | -5.43 | 5.07 | 18.04 | 29.9 % | ACCEPTABLE |
| 898 | -4.97 | 4.26 | 17.38 | 68.2 % | ACCEPTABLE |
| 899 | -5.35 | 4.85 | 17.90 | 74.4 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 900 | -5.12 | 4.61 | 17.61 | 69.6 % | ACCEPTABLE |
| 901 | -5.21 | 4.50 | 17.67 | 74.7 % | ACCEPTABLE |
| 902 | -5.27 | 4.37 | 17.32 | 19.0 % | ACCEPTABLE |
| 903 | -5.65 | 4.96 | 17.84 | 11.5 % | ACCEPTABLE |
| 904 | -5.42 | 4.72 | 17.56 | 14.8 % | ACCEPTABLE |
| 905 | -5.50 | 4.61 | 17.61 | 20.3 % | ACCEPTABLE |
| 906 | -5.16 | 3.94 | 17.12 | 74.1 % | ACCEPTABLE |
| 907 | -5.05 | 3.83 | 16.98 | 75.2 % | ACCEPTABLE |
| 908 | -5.41 | 4.39 | 17.47 | 33.8 % | ACCEPTABLE |
| 909 | -5.19 | 4.16 | 17.19 | 74.9 % | ACCEPTABLE |
| 910 | -5.28 | 4.06 | 17.26 | 74.1 % | ACCEPTABLE |
| 911 | -5.46 | 4.50 | 17.54 | 33.6 % | ACCEPTABLE |
| 912 | -5.23 | 4.27 | 17.26 | 34.4 % | ACCEPTABLE |
| 913 | -5.39 | 4.96 | 17.97 | 76.7 % | ACCEPTABLE |
| 914 | -5.16 | 4.72 | 17.68 | 69.3 % | ACCEPTABLE |
| 915 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 916 | -5.24 | 4.75 | 17.70 | 69.5 % | ACCEPTABLE |
| 917 | -5.35 | 4.61 | 17.52 | 18.9 % | ACCEPTABLE |
| 918 | -5.49 | 5.16 | 18.06 | 20.2 % | ACCEPTABLE |
| 919 | -5.31 | 4.92 | 17.81 | 29.8 % | ACCEPTABLE |
| 920 | -5.39 | 4.91 | 17.90 | 31.2 % | ACCEPTABLE |
| 921 | -5.09 | 4.38 | 17.46 | 68.7 % | ACCEPTABLE |
| 922 | -5.33 | 4.77 | 17.80 | 69.5 % | ACCEPTABLE |
| 923 | -5.18 | 4.61 | 17.61 | 69.6 % | ACCEPTABLE |
| 924 | -5.24 | 4.54 | 17.65 | 68.9 % | ACCEPTABLE |
| 925 | -5.28 | 4.45 | 17.42 | 31.6 % | ACCEPTABLE |
| 926 | -5.53 | 4.84 | 17.76 | 20.1 % | ACCEPTABLE |
| 927 | -5.38 | 4.69 | 17.57 | 14.9 % | ACCEPTABLE |
| 928 | -5.44 | 4.61 | 17.61 | 32.0 % | ACCEPTABLE |
| 929 | -5.21 | 4.16 | 17.28 | 74.5 % | ACCEPTABLE |
| 930 | -5.13 | 4.08 | 17.18 | 68.9 % | ACCEPTABLE |
| 931 | -5.38 | 4.46 | 17.52 | 74.5 % | ACCEPTABLE |
| 932 | -5.23 | 4.31 | 17.33 | 76.3 % | ACCEPTABLE |
| 933 | -5.29 | 4.24 | 17.37 | 74.4 % | ACCEPTABLE |
| 934 | -5.41 | 4.54 | 17.56 | 31.9 % | ACCEPTABLE |
| 935 | -5.26 | 4.38 | 17.37 | 33.2 % | ACCEPTABLE |
| 936 | -5.36 | 4.84 | 17.85 | 69.8 % | ACCEPTABLE |
| 937 | -5.21 | 4.68 | 17.66 | 69.5 % | ACCEPTABLE |
| 938 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 939 | -5.26 | 4.70 | 17.67 | 31.6 % | ACCEPTABLE |
| 940 | -5.34 | 4.61 | 17.55 | 21.1 % | ACCEPTABLE |
| 941 | -5.43 | 4.97 | 17.91 | 31.2 % | ACCEPTABLE |
| 942 | -5.31 | 4.82 | 17.75 | 29.9 % | ACCEPTABLE |
| 943 | -5.37 | 4.81 | 17.80 | 75.2 % | ACCEPTABLE |
| 944 | -5.16 | 4.45 | 17.51 | 68.6 % | ACCEPTABLE |
| 945 | -5.33 | 4.72 | 17.74 | 76.0 % | ACCEPTABLE |
| 946 | -5.22 | 4.61 | 17.61 | 69.6 % | ACCEPTABLE |
| 947 | -5.26 | 4.56 | 17.64 | 69.1 % | ACCEPTABLE |
| 948 | -5.29 | 4.50 | 17.48 | 31.6 % | ACCEPTABLE |
| 949 | -5.46 | 4.77 | 17.71 | 20.2 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 950 | -5.36 | 4.66 | 17.59 | 20.3 % | ACCEPTABLE |
| 951 | -5.40 | 4.61 | 17.61 | 32.0 % | ACCEPTABLE |
| 952 | -5.24 | 4.31 | 17.39 | 74.6 % | ACCEPTABLE |
| 953 | -5.19 | 4.26 | 17.32 | 69.2 % | ACCEPTABLE |
| 954 | -5.36 | 4.51 | 17.55 | 32.0 % | ACCEPTABLE |
| 955 | -5.25 | 4.41 | 17.42 | 30.0 % | ACCEPTABLE |
| 956 | -5.30 | 4.36 | 17.45 | 74.6 % | ACCEPTABLE |
| 957 | -5.38 | 4.56 | 17.58 | 31.9 % | ACCEPTABLE |
| 958 | -5.27 | 4.46 | 17.45 | 30.0 % | ACCEPTABLE |
| 959 | -5.35 | 4.76 | 17.77 | 75.2 % | ACCEPTABLE |
| 960 | -5.24 | 4.66 | 17.64 | 30.1 % | ACCEPTABLE |
| 961 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 962 | -5.28 | 4.67 | 17.65 | 70.0 % | ACCEPTABLE |
| 963 | -5.33 | 4.61 | 17.57 | 19.7 % | ACCEPTABLE |
| 964 | -5.39 | 4.85 | 17.81 | 31.3 % | ACCEPTABLE |
| 965 | -5.31 | 4.75 | 17.70 | 31.6 % | ACCEPTABLE |
| 966 | -5.35 | 4.74 | 17.74 | 75.3 % | ACCEPTABLE |
| 967 | -5.21 | 4.51 | 17.54 | 69.7 % | ACCEPTABLE |
| 968 | -5.32 | 4.68 | 17.69 | 69.7 % | ACCEPTABLE |
| 969 | -5.25 | 4.61 | 17.61 | 70.0 % | ACCEPTABLE |
| 970 | -5.28 | 4.58 | 17.63 | 76.4 % | ACCEPTABLE |
| 971 | -5.30 | 4.54 | 17.53 | 31.4 % | ACCEPTABLE |
| 972 | -5.41 | 4.71 | 17.68 | 20.3 % | ACCEPTABLE |
| 973 | -5.34 | 4.64 | 17.59 | 19.0 % | ACCEPTABLE |
| 974 | -5.37 | 4.61 | 17.61 | 32.1 % | ACCEPTABLE |
| 975 | -5.27 | 4.41 | 17.46 | 74.7 % | ACCEPTABLE |
| 976 | -5.23 | 4.37 | 17.42 | 75.6 % | ACCEPTABLE |
| 977 | -5.34 | 4.55 | 17.57 | 33.8 % | ACCEPTABLE |
| 978 | -5.27 | 4.48 | 17.48 | 69.9 % | ACCEPTABLE |
| 979 | -5.30 | 4.44 | 17.50 | 74.5 % | ACCEPTABLE |
| 980 | -5.35 | 4.58 | 17.59 | 33.8 % | ACCEPTABLE |
| 981 | -5.29 | 4.51 | 17.50 | 32.6 % | ACCEPTABLE |
| 982 | -5.33 | 4.71 | 17.72 | 76.7 % | ACCEPTABLE |
| 983 | -5.27 | 4.64 | 17.63 | 69.9 % | ACCEPTABLE |
| 984 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |
| 985 | -5.29 | 4.65 | 17.64 | 69.9 % | ACCEPTABLE |
| 986 | -5.32 | 4.61 | 17.58 | 30.0 % | ACCEPTABLE |
| 987 | -5.36 | 4.77 | 17.74 | 31.5 % | ACCEPTABLE |
| 988 | -5.31 | 4.70 | 17.67 | 29.9 % | ACCEPTABLE |
| 989 | -5.33 | 4.70 | 17.69 | 69.9 % | ACCEPTABLE |
| 990 | -5.24 | 4.54 | 17.56 | 69.7 % | ACCEPTABLE |
| 991 | -5.32 | 4.66 | 17.67 | 33.1 % | ACCEPTABLE |
| 992 | -5.27 | 4.61 | 17.61 | 70.0 % | ACCEPTABLE |
| 993 | -5.29 | 4.59 | 17.62 | 31.6 % | ACCEPTABLE |
| 994 | -5.30 | 4.56 | 17.55 | 70.0 % | ACCEPTABLE |
| 995 | -5.38 | 4.68 | 17.66 | 33.8 % | ACCEPTABLE |
| 996 | -5.33 | 4.63 | 17.60 | 31.3 % | ACCEPTABLE |
| 997 | -5.35 | 4.61 | 17.61 | 32.1 % | ACCEPTABLE |
| 998 | -5.28 | 4.48 | 17.51 | 32.1 % | ACCEPTABLE |
| 999 | -5.26 | 4.45 | 17.48 | 31.5 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1000 | -5.33 | 4.57 | 17.58 | 32.1 % | ACCEPTABLE |
| 1001 | -5.29 | 4.52 | 17.53 | 33.9 % | ACCEPTABLE |
| 1002 | -5.30 | 4.50 | 17.54 | 74.8 % | ACCEPTABLE |
| 1003 | -5.34 | 4.59 | 17.60 | 32.1 % | ACCEPTABLE |
| 1004 | -5.29 | 4.54 | 17.54 | 69.9 % | ACCEPTABLE |
| 1005 | -5.33 | 4.68 | 17.68 | 76.4 % | ACCEPTABLE |
| 1006 | -5.28 | 4.63 | 17.62 | 69.9 % | ACCEPTABLE |
| 1007 | -6.14 | 17.05 | 33.65 | 50.2 % | ACCEPTABLE |
| 1008 | -2.81 | 23.20 | 40.60 | 37.2 % | ACCEPTABLE |
| 1009 | -2.28 | 20.41 | 38.63 | 36.2 % | ACCEPTABLE |
| 1010 | 3.97 | 12.49 | 29.34 | 30.2 % | ACCEPTABLE |
| 1011 | 1.22 | 1.82 | 29.35 | 23.5 % | ACCEPTABLE |
| 1012 | -10.19 | 6.44 | 22.80 | 56.8 % | ACCEPTABLE |
| 1013 | 0.99 | 6.44 | 22.80 | 36.1 % | ACCEPTABLE |
| 1014 | -6.50 | 18.69 | 34.81 | 51.2 % | ACCEPTABLE |
| 1015 | 1.93 | 3.14 | 21.17 | 31.8 % | ACCEPTABLE |
| 1016 | -10.19 | 6.44 | 22.80 | 56.8 % | ACCEPTABLE |
| 1017 | -7.09 | 11.45 | 28.62 | 51.7 % | ACCEPTABLE |
| 1018 | -2.73 | 6.44 | 22.80 | 49.7 % | ACCEPTABLE |
| 1019 | -2.64 | 6.10 | 22.61 | 49.2 % | ACCEPTABLE |
| 1020 | -10.19 | 6.44 | 22.80 | 56.8 % | ACCEPTABLE |
| 1021 | -4.64 | 4.40 | 21.74 | 52.3 % | ACCEPTABLE |
| 1022 | -10.05 | 23.42 | 35.51 | 1.5 % | ACCEPTABLE |
| 1023 | -8.51 | 11.25 | 27.57 | 58.0 % | ACCEPTABLE |
| 1024 | -3.29 | 10.25 | 26.94 | 50.3 % | ACCEPTABLE |
| 1025 | -9.42 | 10.12 | 23.41 | 1.9 % | ACCEPTABLE |
| 1026 | -8.89 | 32.60 | 44.66 | 14.7 % | ACCEPTABLE |
| 1027 | -1.12 | 1.60 | 22.81 | 37.7 % | ACCEPTABLE |
| 1028 | -3.54 | 11.25 | 27.57 | 51.3 % | ACCEPTABLE |
| 1029 | -4.31 | 5.55 | 26.53 | 41.7 % | ACCEPTABLE |
| 1030 | -7.00 | 2.73 | 18.88 | 57.3 % | ACCEPTABLE |
| 1031 | -9.07 | 2.54 | 20.92 | 49.1 % | ACCEPTABLE |
| 1032 | -6.30 | 0.62 | 18.00 | 51.0 % | ACCEPTABLE |
| 1033 | -9.96 | 5.66 | 22.38 | 55.7 % | ACCEPTABLE |
| 1034 | -6.97 | 2.66 | 18.85 | 57.1 % | ACCEPTABLE |
| 1035 | -3.76 | 12.12 | 28.13 | 52.1 % | ACCEPTABLE |
| 1036 | -8.51 | 11.25 | 27.57 | 58.0 % | ACCEPTABLE |
| 1037 | -5.35 | 11.85 | 27.96 | 53.0 % | ACCEPTABLE |
| 1038 | -9.24 | 11.11 | 25.18 | 65.4 % | ACCEPTABLE |
| 1039 | -6.41 | 12.73 | 26.36 | 64.4 % | ACCEPTABLE |
| 1040 | -10.88 | 20.75 | 34.49 | 63.9 % | ACCEPTABLE |
| 1041 | -3.79 | 3.91 | 20.83 | 50.4 % | ACCEPTABLE |
| 1042 | -9.70 | 16.03 | 30.86 | 63.1 % | ACCEPTABLE |
| 1043 | -5.93 | 11.11 | 25.18 | 62.6 % | ACCEPTABLE |
| 1044 | -7.97 | 9.11 | 26.27 | 55.0 % | ACCEPTABLE |
| 1045 | -8.36 | 5.64 | 19.25 | 3.9 % | ACCEPTABLE |
| 1046 | -12.55 | 11.10 | 25.17 | 1.3 % | ACCEPTABLE |
| 1047 | -8.02 | 0.80 | 18.08 | 52.1 % | ACCEPTABLE |
| 1048 | -10.98 | 5.84 | 21.82 | 10.9 % | ACCEPTABLE |
| 1049 | -7.35 | 2.87 | 17.62 | 67.8 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1050 | -3.92 | 2.54 | 17.45 | 57.0 % | ACCEPTABLE |
| 1051 | -7.26 | 11.67 | 23.68 | 1.5 % | ACCEPTABLE |
| 1052 | -8.81 | 9.64 | 24.16 | 63.8 % | ACCEPTABLE |
| 1053 | -7.95 | 6.76 | 22.35 | 60.4 % | ACCEPTABLE |
| 1054 | -4.04 | 2.87 | 17.62 | 58.1 % | ACCEPTABLE |
| 1055 | -6.56 | 2.09 | 20.02 | 50.0 % | ACCEPTABLE |
| 1056 | -10.66 | 2.87 | 17.62 | 1.2 % | ACCEPTABLE |
| 1057 | -10.13 | 1.40 | 16.90 | 1.7 % | ACCEPTABLE |
| 1058 | -8.51 | 8.64 | 23.50 | 62.8 % | ACCEPTABLE |
| 1059 | -4.24 | 3.42 | 17.91 | 59.6 % | ACCEPTABLE |
| 1060 | -7.35 | 2.87 | 17.62 | 67.8 % | ACCEPTABLE |
| 1061 | -5.30 | 3.32 | 17.86 | 62.3 % | ACCEPTABLE |
| 1062 | -7.69 | 2.41 | 15.70 | 1.1 % | ACCEPTABLE |
| 1063 | -10.13 | 12.87 | 25.81 | 1.5 % | ACCEPTABLE |
| 1064 | -7.01 | 7.99 | 20.85 | 5.6 % | ACCEPTABLE |
| 1065 | -8.35 | 7.27 | 21.84 | 64.2 % | ACCEPTABLE |
| 1066 | -7.79 | 5.50 | 20.77 | 61.5 % | ACCEPTABLE |
| 1067 | -5.14 | 2.87 | 17.62 | 61.1 % | ACCEPTABLE |
| 1068 | -6.77 | 2.30 | 19.16 | 54.1 % | ACCEPTABLE |
| 1069 | -9.56 | 2.87 | 17.62 | 1.9 % | ACCEPTABLE |
| 1070 | -8.79 | 0.76 | 16.63 | 7.8 % | ACCEPTABLE |
| 1071 | -9.23 | 1.97 | 17.17 | 2.8 % | ACCEPTABLE |
| 1072 | -8.13 | 6.58 | 21.41 | 63.0 % | ACCEPTABLE |
| 1073 | -5.32 | 3.36 | 17.88 | 62.3 % | ACCEPTABLE |
| 1074 | -7.35 | 2.87 | 17.62 | 67.8 % | ACCEPTABLE |
| 1075 | -6.08 | 3.41 | 17.91 | 67.9 % | ACCEPTABLE |
| 1076 | -4.84 | 4.05 | 18.27 | 66.9 % | ACCEPTABLE |
| 1077 | -6.36 | 3.22 | 16.71 | 9.9 % | ACCEPTABLE |
| 1078 | -7.88 | 9.72 | 23.01 | 10.6 % | ACCEPTABLE |
| 1079 | -5.82 | 6.74 | 19.97 | 72.7 % | ACCEPTABLE |
| 1080 | -4.84 | 8.09 | 20.92 | 70.7 % | ACCEPTABLE |
| 1081 | -6.27 | 6.62 | 18.97 | 2.5 % | ACCEPTABLE |
| 1082 | -8.17 | 15.06 | 27.18 | 1.7 % | ACCEPTABLE |
| 1083 | -6.03 | 11.34 | 23.41 | 5.4 % | ACCEPTABLE |
| 1084 | -6.70 | 10.62 | 23.67 | 71.3 % | ACCEPTABLE |
| 1085 | -3.29 | 3.84 | 18.15 | 61.6 % | ACCEPTABLE |
| 1086 | -6.05 | 8.67 | 22.26 | 70.3 % | ACCEPTABLE |
| 1087 | -4.35 | 6.74 | 19.97 | 70.7 % | ACCEPTABLE |
| 1088 | -5.13 | 5.90 | 20.46 | 64.7 % | ACCEPTABLE |
| 1089 | -5.49 | 4.70 | 17.63 | 20.2 % | ACCEPTABLE |
| 1090 | -8.42 | 9.81 | 22.20 | 1.6 % | ACCEPTABLE |
| 1091 | -6.83 | 7.99 | 20.00 | 1.7 % | ACCEPTABLE |
| 1092 | -7.29 | 6.74 | 19.97 | 6.5 % | ACCEPTABLE |
| 1093 | -4.96 | 1.99 | 16.59 | 60.9 % | ACCEPTABLE |
| 1094 | -4.05 | 1.16 | 15.59 | 64.4 % | ACCEPTABLE |
| 1095 | -6.55 | 4.72 | 18.66 | 71.4 % | ACCEPTABLE |
| 1096 | -4.89 | 3.22 | 16.70 | 71.7 % | ACCEPTABLE |
| 1097 | -5.85 | 2.80 | 17.58 | 66.5 % | ACCEPTABLE |
| 1098 | -6.95 | 5.80 | 19.34 | 19.5 % | ACCEPTABLE |
| 1099 | -5.22 | 4.05 | 17.21 | 74.2 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1100 | -4.19 | 5.14 | 17.93 | 66.9 % | ACCEPTABLE |
| 1101 | -5.59 | 3.79 | 16.08 | 2.9 % | ACCEPTABLE |
| 1102 | -7.50 | 11.35 | 23.42 | 2.4 % | ACCEPTABLE |
| 1103 | -5.36 | 7.99 | 20.00 | 4.6 % | ACCEPTABLE |
| 1104 | -6.10 | 7.52 | 20.51 | 33.1 % | ACCEPTABLE |
| 1105 | -2.71 | 1.50 | 15.76 | 55.6 % | ACCEPTABLE |
| 1106 | -5.47 | 5.80 | 19.34 | 71.1 % | ACCEPTABLE |
| 1107 | -3.75 | 4.05 | 17.21 | 64.8 % | ACCEPTABLE |
| 1108 | -4.60 | 3.41 | 17.91 | 65.1 % | ACCEPTABLE |
| 1109 | -4.85 | 2.18 | 15.04 | 9.1 % | ACCEPTABLE |
| 1110 | -7.74 | 6.62 | 18.97 | 1.2 % | ACCEPTABLE |
| 1111 | -6.14 | 5.00 | 16.93 | 1.5 % | ACCEPTABLE |
| 1112 | -6.69 | 4.05 | 17.21 | 4.7 % | ACCEPTABLE |
| 1113 | -5.96 | 2.26 | 16.15 | 71.9 % | ACCEPTABLE |
| 1114 | -4.28 | 0.94 | 14.34 | 71.5 % | ACCEPTABLE |
| 1115 | -5.30 | 0.64 | 15.35 | 65.6 % | ACCEPTABLE |
| 1116 | -6.36 | 3.22 | 16.70 | 9.1 % | ACCEPTABLE |
| 1117 | -4.60 | 1.64 | 14.73 | 34.6 % | ACCEPTABLE |
| 1118 | -5.82 | 6.75 | 19.97 | 72.8 % | ACCEPTABLE |
| 1119 | -4.02 | 4.71 | 17.63 | 66.9 % | ACCEPTABLE |
| 1120 | -5.22 | 4.05 | 17.21 | 74.2 % | ACCEPTABLE |
| 1121 | -4.58 | 4.88 | 17.75 | 72.6 % | ACCEPTABLE |
| 1122 | -5.49 | 3.94 | 16.49 | 4.7 % | ACCEPTABLE |
| 1123 | -6.66 | 8.55 | 20.97 | 2.3 % | ACCEPTABLE |
| 1124 | -5.24 | 6.52 | 18.89 | 8.8 % | ACCEPTABLE |
| 1125 | -5.81 | 6.33 | 19.37 | 74.0 % | ACCEPTABLE |
| 1126 | -3.54 | 2.35 | 16.20 | 65.2 % | ACCEPTABLE |
| 1127 | -5.40 | 5.23 | 18.63 | 72.6 % | ACCEPTABLE |
| 1128 | -4.24 | 4.05 | 17.21 | 71.6 % | ACCEPTABLE |
| 1129 | -4.78 | 3.60 | 17.64 | 67.9 % | ACCEPTABLE |
| 1130 | -4.99 | 2.82 | 15.77 | 15.2 % | ACCEPTABLE |
| 1131 | -6.90 | 5.76 | 18.35 | 1.9 % | ACCEPTABLE |
| 1132 | -5.79 | 4.63 | 16.96 | 3.4 % | ACCEPTABLE |
| 1133 | -6.20 | 4.05 | 17.21 | 7.0 % | ACCEPTABLE |
| 1134 | -4.62 | 1.13 | 15.19 | 67.4 % | ACCEPTABLE |
| 1135 | -4.01 | 0.60 | 14.55 | 66.7 % | ACCEPTABLE |
| 1136 | -5.74 | 2.91 | 16.52 | 66.6 % | ACCEPTABLE |
| 1137 | -4.60 | 1.93 | 15.25 | 73.2 % | ACCEPTABLE |
| 1138 | -5.23 | 1.66 | 15.84 | 62.6 % | ACCEPTABLE |
| 1139 | -5.98 | 3.51 | 16.88 | 14.2 % | ACCEPTABLE |
| 1140 | -4.81 | 2.41 | 15.52 | 34.4 % | ACCEPTABLE |
| 1141 | -5.62 | 5.81 | 19.02 | 72.9 % | ACCEPTABLE |
| 1142 | -4.43 | 4.51 | 17.51 | 72.6 % | ACCEPTABLE |
| 1143 | -5.22 | 4.05 | 17.21 | 74.2 % | ACCEPTABLE |
| 1144 | -4.81 | 4.64 | 17.59 | 68.8 % | ACCEPTABLE |
| 1145 | -5.40 | 4.01 | 16.74 | 7.1 % | ACCEPTABLE |
| 1146 | -6.14 | 6.91 | 19.57 | 6.8 % | ACCEPTABLE |
| 1147 | -5.21 | 5.63 | 18.26 | 15.1 % | ACCEPTABLE |
| 1148 | -5.62 | 5.55 | 18.63 | 73.9 % | ACCEPTABLE |
| 1149 | -4.10 | 2.91 | 16.52 | 62.9 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1150 | -5.34 | 4.84 | 18.16 | 73.0 % | ACCEPTABLE |
| 1151 | -4.57 | 4.05 | 17.21 | 67.1 % | ACCEPTABLE |
| 1152 | -4.92 | 3.74 | 17.48 | 69.4 % | ACCEPTABLE |
| 1153 | -5.07 | 3.24 | 16.25 | 22.1 % | ACCEPTABLE |
| 1154 | -6.34 | 5.19 | 17.96 | 4.0 % | ACCEPTABLE |
| 1155 | -5.58 | 4.42 | 17.02 | 5.1 % | ACCEPTABLE |
| 1156 | -5.87 | 4.05 | 17.21 | 11.6 % | ACCEPTABLE |
| 1157 | -4.80 | 2.03 | 15.78 | 69.3 % | ACCEPTABLE |
| 1158 | -4.39 | 1.65 | 15.34 | 69.0 % | ACCEPTABLE |
| 1159 | -5.58 | 3.32 | 16.76 | 67.9 % | ACCEPTABLE |
| 1160 | -4.81 | 2.62 | 15.88 | 73.5 % | ACCEPTABLE |
| 1161 | -5.20 | 2.39 | 16.23 | 64.1 % | ACCEPTABLE |
| 1162 | -5.73 | 3.70 | 16.99 | 29.9 % | ACCEPTABLE |
| 1163 | -4.95 | 2.95 | 16.07 | 74.6 % | ACCEPTABLE |
| 1164 | -4.53 | 3.50 | 16.41 | 68.6 % | ACCEPTABLE |
| 1165 | -5.12 | 2.89 | 15.58 | 6.3 % | ACCEPTABLE |
| 1166 | -5.87 | 5.64 | 18.26 | 6.2 % | ACCEPTABLE |
| 1167 | -4.93 | 4.43 | 17.02 | 11.1 % | ACCEPTABLE |
| 1168 | -5.35 | 4.37 | 17.41 | 75.0 % | ACCEPTABLE |
| 1169 | -4.95 | 5.00 | 17.83 | 68.8 % | ACCEPTABLE |
| 1170 | -5.54 | 4.33 | 16.95 | 5.6 % | ACCEPTABLE |
| 1171 | -6.30 | 7.30 | 19.85 | 5.2 % | ACCEPTABLE |
| 1172 | -5.36 | 6.00 | 18.52 | 9.0 % | ACCEPTABLE |
| 1173 | -5.76 | 5.91 | 18.87 | 33.2 % | ACCEPTABLE |
| 1174 | -4.22 | 3.21 | 16.69 | 63.8 % | ACCEPTABLE |
| 1175 | -5.47 | 5.16 | 18.37 | 73.4 % | ACCEPTABLE |
| 1176 | -4.70 | 4.37 | 17.41 | 68.1 % | ACCEPTABLE |
| 1177 | -5.03 | 4.04 | 17.66 | 70.3 % | ACCEPTABLE |
| 1178 | -5.21 | 3.55 | 16.45 | 11.8 % | ACCEPTABLE |
| 1179 | -6.48 | 5.54 | 18.19 | 3.4 % | ACCEPTABLE |
| 1180 | -5.73 | 4.77 | 17.25 | 4.3 % | ACCEPTABLE |
| 1181 | -6.00 | 4.37 | 17.41 | 8.7 % | ACCEPTABLE |
| 1182 | -4.91 | 2.29 | 15.92 | 70.4 % | ACCEPTABLE |
| 1183 | -4.51 | 1.92 | 15.47 | 70.2 % | ACCEPTABLE |
| 1184 | -5.69 | 3.61 | 16.93 | 29.9 % | ACCEPTABLE |
| 1185 | -4.93 | 2.90 | 16.04 | 74.5 % | ACCEPTABLE |
| 1186 | -5.31 | 2.66 | 16.37 | 65.0 % | ACCEPTABLE |
| 1187 | -5.85 | 4.00 | 17.18 | 13.7 % | ACCEPTABLE |
| 1188 | -5.08 | 3.24 | 16.25 | 22.1 % | ACCEPTABLE |
| 1189 | -5.62 | 5.55 | 18.63 | 73.9 % | ACCEPTABLE |
| 1190 | -4.83 | 4.70 | 17.63 | 68.9 % | ACCEPTABLE |
| 1191 | -5.35 | 4.37 | 17.41 | 75.0 % | ACCEPTABLE |
| 1192 | -5.09 | 4.81 | 17.70 | 69.4 % | ACCEPTABLE |
| 1193 | -5.48 | 4.35 | 17.11 | 8.9 % | ACCEPTABLE |
| 1194 | -5.97 | 6.26 | 18.97 | 7.6 % | ACCEPTABLE |
| 1195 | -5.35 | 5.43 | 18.12 | 11.0 % | ACCEPTABLE |
| 1196 | -5.62 | 5.39 | 18.37 | 31.7 % | ACCEPTABLE |
| 1197 | -4.60 | 3.59 | 16.92 | 65.7 % | ACCEPTABLE |
| 1198 | -5.43 | 4.90 | 18.05 | 73.9 % | ACCEPTABLE |
| 1199 | -4.91 | 4.37 | 17.41 | 68.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1200 | -5.13 | 4.14 | 17.57 | 72.2 % | ACCEPTABLE |
| 1201 | -5.26 | 3.83 | 16.77 | 15.0 % | ACCEPTABLE |
| 1202 | -6.10 | 5.15 | 17.93 | 5.9 % | ACCEPTABLE |
| 1203 | -5.60 | 4.63 | 17.29 | 6.3 % | ACCEPTABLE |
| 1204 | -5.79 | 4.37 | 17.41 | 10.4 % | ACCEPTABLE |
| 1205 | -5.04 | 2.94 | 16.38 | 72.3 % | ACCEPTABLE |
| 1206 | -4.78 | 2.69 | 16.07 | 72.9 % | ACCEPTABLE |
| 1207 | -5.58 | 3.87 | 17.09 | 33.7 % | ACCEPTABLE |
| 1208 | -5.07 | 3.38 | 16.49 | 74.8 % | ACCEPTABLE |
| 1209 | -5.31 | 3.20 | 16.68 | 72.6 % | ACCEPTABLE |
| 1210 | -5.69 | 4.13 | 17.26 | 12.6 % | ACCEPTABLE |
| 1211 | -5.17 | 3.61 | 16.63 | 20.6 % | ACCEPTABLE |
| 1212 | -5.53 | 5.15 | 18.21 | 74.3 % | ACCEPTABLE |
| 1213 | -5.01 | 4.60 | 17.56 | 69.4 % | ACCEPTABLE |
| 1214 | -5.35 | 4.37 | 17.41 | 75.0 % | ACCEPTABLE |
| 1215 | -5.18 | 4.67 | 17.61 | 69.6 % | ACCEPTABLE |
| 1216 | -5.44 | 4.36 | 17.21 | 10.4 % | ACCEPTABLE |
| 1217 | -5.76 | 5.61 | 18.42 | 10.0 % | ACCEPTABLE |
| 1218 | -5.34 | 5.07 | 17.87 | 19.7 % | ACCEPTABLE |
| 1219 | -5.53 | 5.05 | 18.05 | 31.8 % | ACCEPTABLE |
| 1220 | -4.85 | 3.85 | 17.08 | 67.3 % | ACCEPTABLE |
| 1221 | -5.41 | 4.73 | 17.84 | 74.3 % | ACCEPTABLE |
| 1222 | -5.06 | 4.37 | 17.41 | 69.0 % | ACCEPTABLE |
| 1223 | -5.20 | 4.22 | 17.51 | 73.2 % | ACCEPTABLE |
| 1224 | -5.29 | 4.01 | 16.98 | 20.4 % | ACCEPTABLE |
| 1225 | -5.85 | 4.89 | 17.75 | 8.7 % | ACCEPTABLE |
| 1226 | -5.51 | 4.54 | 17.33 | 9.6 % | ACCEPTABLE |
| 1227 | -5.64 | 4.37 | 17.41 | 15.9 % | ACCEPTABLE |
| 1228 | -5.14 | 3.40 | 16.70 | 73.7 % | ACCEPTABLE |
| 1229 | -4.96 | 3.23 | 16.49 | 73.6 % | ACCEPTABLE |
| 1230 | -5.51 | 4.04 | 17.20 | 33.7 % | ACCEPTABLE |
| 1231 | -5.16 | 3.71 | 16.79 | 34.0 % | ACCEPTABLE |
| 1232 | -5.32 | 3.57 | 16.91 | 73.6 % | ACCEPTABLE |
| 1233 | -5.58 | 4.21 | 17.31 | 20.2 % | ACCEPTABLE |
| 1234 | -5.23 | 3.86 | 16.89 | 32.2 % | ACCEPTABLE |
| 1235 | -5.47 | 4.89 | 17.94 | 31.8 % | ACCEPTABLE |
| 1236 | -5.12 | 4.52 | 17.51 | 69.7 % | ACCEPTABLE |
| 1237 | -5.35 | 4.37 | 17.41 | 75.0 % | ACCEPTABLE |
| 1238 | -5.24 | 4.57 | 17.54 | 69.5 % | ACCEPTABLE |
| 1239 | -5.41 | 4.37 | 17.28 | 14.8 % | ACCEPTABLE |
| 1240 | -5.62 | 5.18 | 18.07 | 14.7 % | ACCEPTABLE |
| 1241 | -5.34 | 4.83 | 17.71 | 20.3 % | ACCEPTABLE |
| 1242 | -5.47 | 4.82 | 17.83 | 31.9 % | ACCEPTABLE |
| 1243 | -5.02 | 4.03 | 17.19 | 68.1 % | ACCEPTABLE |
| 1244 | -5.39 | 4.61 | 17.69 | 74.4 % | ACCEPTABLE |
| 1245 | -5.16 | 4.37 | 17.41 | 69.0 % | ACCEPTABLE |
| 1246 | -5.25 | 4.27 | 17.48 | 73.7 % | ACCEPTABLE |
| 1247 | -5.31 | 4.13 | 17.13 | 20.4 % | ACCEPTABLE |
| 1248 | -5.68 | 4.72 | 17.64 | 12.5 % | ACCEPTABLE |
| 1249 | -5.46 | 4.48 | 17.35 | 11.6 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1250 | -5.54 | 4.37 | 17.41 | 21.6 % | ACCEPTABLE |
| 1251 | -5.21 | 3.72 | 16.93 | 74.1 % | ACCEPTABLE |
| 1252 | -5.09 | 3.60 | 16.79 | 74.0 % | ACCEPTABLE |
| 1253 | -5.46 | 4.16 | 17.27 | 32.0 % | ACCEPTABLE |
| 1254 | -5.23 | 3.93 | 16.99 | 32.1 % | ACCEPTABLE |
| 1255 | -5.32 | 3.83 | 17.07 | 74.0 % | ACCEPTABLE |
| 1256 | -5.50 | 4.26 | 17.34 | 20.3 % | ACCEPTABLE |
| 1257 | -5.27 | 4.03 | 17.06 | 21.8 % | ACCEPTABLE |
| 1258 | -5.43 | 4.71 | 17.76 | 31.9 % | ACCEPTABLE |
| 1259 | -5.20 | 4.47 | 17.48 | 69.5 % | ACCEPTABLE |
| 1260 | -5.35 | 4.37 | 17.41 | 75.0 % | ACCEPTABLE |
| 1261 | -5.28 | 4.51 | 17.50 | 70.0 % | ACCEPTABLE |
| 1262 | -5.39 | 4.37 | 17.32 | 14.9 % | ACCEPTABLE |
| 1263 | -5.53 | 4.91 | 17.85 | 21.5 % | ACCEPTABLE |
| 1264 | -5.34 | 4.67 | 17.61 | 29.9 % | ACCEPTABLE |
| 1265 | -5.43 | 4.67 | 17.69 | 31.9 % | ACCEPTABLE |
| 1266 | -5.13 | 4.14 | 17.26 | 68.7 % | ACCEPTABLE |
| 1267 | -5.37 | 4.53 | 17.60 | 74.6 % | ACCEPTABLE |
| 1268 | -5.22 | 4.37 | 17.41 | 69.3 % | ACCEPTABLE |
| 1269 | -5.28 | 4.30 | 17.45 | 74.2 % | ACCEPTABLE |
| 1270 | -5.32 | 4.21 | 17.22 | 20.4 % | ACCEPTABLE |
| 1271 | -5.57 | 4.60 | 17.56 | 14.7 % | ACCEPTABLE |
| 1272 | -5.42 | 4.44 | 17.37 | 14.8 % | ACCEPTABLE |
| 1273 | -5.48 | 4.37 | 17.41 | 31.9 % | ACCEPTABLE |
| 1274 | -5.25 | 3.93 | 17.09 | 74.2 % | ACCEPTABLE |
| 1275 | -5.18 | 3.85 | 16.99 | 74.2 % | ACCEPTABLE |
| 1276 | -5.42 | 4.23 | 17.32 | 31.9 % | ACCEPTABLE |
| 1277 | -5.27 | 4.07 | 17.13 | 32.1 % | ACCEPTABLE |
| 1278 | -5.33 | 4.01 | 17.18 | 74.4 % | ACCEPTABLE |
| 1279 | -5.45 | 4.30 | 17.36 | 32.0 % | ACCEPTABLE |
| 1280 | -5.30 | 4.14 | 17.18 | 33.8 % | ACCEPTABLE |
| 1281 | -5.40 | 4.60 | 17.65 | 31.9 % | ACCEPTABLE |
| 1282 | -5.25 | 4.44 | 17.45 | 30.0 % | ACCEPTABLE |
| 1283 | -5.35 | 4.37 | 17.41 | 75.0 % | ACCEPTABLE |
| 1284 | -5.30 | 4.46 | 17.47 | 33.9 % | ACCEPTABLE |
| 1285 | -5.38 | 4.37 | 17.35 | 21.7 % | ACCEPTABLE |
| 1286 | -5.47 | 4.73 | 17.70 | 21.6 % | ACCEPTABLE |
| 1287 | -5.35 | 4.57 | 17.54 | 33.8 % | ACCEPTABLE |
| 1288 | -5.40 | 4.57 | 17.60 | 31.9 % | ACCEPTABLE |
| 1289 | -5.20 | 4.22 | 17.31 | 74.5 % | ACCEPTABLE |
| 1290 | -5.37 | 4.48 | 17.54 | 74.6 % | ACCEPTABLE |
| 1291 | -5.26 | 4.37 | 17.41 | 74.7 % | ACCEPTABLE |
| 1292 | -5.30 | 4.32 | 17.44 | 74.5 % | ACCEPTABLE |
| 1293 | -5.33 | 4.26 | 17.28 | 32.1 % | ACCEPTABLE |
| 1294 | -5.50 | 4.52 | 17.51 | 20.2 % | ACCEPTABLE |
| 1295 | -5.40 | 4.42 | 17.38 | 20.2 % | ACCEPTABLE |
| 1296 | -5.44 | 4.37 | 17.41 | 21.7 % | ACCEPTABLE |
| 1297 | -5.29 | 4.07 | 17.19 | 74.5 % | ACCEPTABLE |
| 1298 | -5.23 | 4.02 | 17.13 | 74.7 % | ACCEPTABLE |
| 1299 | -5.40 | 4.28 | 17.35 | 21.7 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1300 | -5.30 | 4.17 | 17.22 | 32.1 % | ACCEPTABLE |
| 1301 | -5.34 | 4.13 | 17.25 | 74.6 % | ACCEPTABLE |
| 1302 | -5.42 | 4.32 | 17.38 | 31.9 % | ACCEPTABLE |
| 1303 | -5.31 | 4.22 | 17.25 | 32.1 % | ACCEPTABLE |
| 1304 | -5.39 | 4.52 | 17.57 | 74.7 % | ACCEPTABLE |
| 1305 | -5.28 | 4.42 | 17.44 | 32.2 % | ACCEPTABLE |
| 1306 | -5.35 | 4.37 | 17.41 | 75.0 % | ACCEPTABLE |
| 1307 | -5.32 | 4.43 | 17.45 | 75.1 % | ACCEPTABLE |
| 1308 | -5.29 | 4.49 | 17.49 | 32.1 % | ACCEPTABLE |
| 1309 | -5.34 | 4.43 | 17.41 | 21.7 % | ACCEPTABLE |
| 1310 | -5.40 | 4.67 | 17.64 | 20.3 % | ACCEPTABLE |
| 1311 | -5.32 | 4.56 | 17.54 | 32.1 % | ACCEPTABLE |
| 1312 | -5.36 | 4.56 | 17.58 | 31.9 % | ACCEPTABLE |
| 1313 | -5.22 | 4.33 | 17.38 | 75.6 % | ACCEPTABLE |
| 1314 | -5.19 | 4.39 | 17.42 | 69.6 % | ACCEPTABLE |
| 1315 | -5.24 | 4.33 | 17.34 | 31.6 % | ACCEPTABLE |
| 1316 | -5.30 | 4.57 | 17.57 | 34.4 % | ACCEPTABLE |
| 1317 | -5.22 | 4.46 | 17.47 | 69.8 % | ACCEPTABLE |
| 1318 | -5.26 | 4.46 | 17.50 | 74.9 % | ACCEPTABLE |
| 1319 | -5.12 | 4.23 | 17.31 | 68.9 % | ACCEPTABLE |
| 1320 | -5.23 | 4.40 | 17.46 | 69.0 % | ACCEPTABLE |
| 1321 | -5.16 | 4.33 | 17.38 | 69.0 % | ACCEPTABLE |
| 1322 | -5.19 | 4.30 | 17.40 | 75.2 % | ACCEPTABLE |
| 1323 | -5.21 | 4.26 | 17.30 | 74.9 % | ACCEPTABLE |
| 1324 | -5.32 | 4.43 | 17.45 | 75.1 % | ACCEPTABLE |
| 1325 | -5.25 | 4.36 | 17.36 | 33.2 % | ACCEPTABLE |
| 1326 | -5.28 | 4.33 | 17.38 | 74.5 % | ACCEPTABLE |
| 1327 | -5.18 | 4.13 | 17.23 | 74.2 % | ACCEPTABLE |
| 1328 | -5.14 | 4.10 | 17.19 | 68.8 % | ACCEPTABLE |
| 1329 | -5.25 | 4.27 | 17.34 | 74.8 % | ACCEPTABLE |
| 1330 | -5.18 | 4.20 | 17.26 | 69.2 % | ACCEPTABLE |
| 1331 | -5.21 | 4.17 | 17.28 | 74.5 % | ACCEPTABLE |
| 1332 | -5.26 | 4.30 | 17.36 | 74.8 % | ACCEPTABLE |
| 1333 | -5.20 | 4.23 | 17.28 | 74.6 % | ACCEPTABLE |
| 1334 | -5.24 | 4.43 | 17.48 | 69.1 % | ACCEPTABLE |
| 1335 | -5.18 | 4.36 | 17.40 | 69.2 % | ACCEPTABLE |
| 1336 | -5.22 | 4.33 | 17.38 | 75.6 % | ACCEPTABLE |
| 1337 | -5.20 | 4.37 | 17.41 | 69.3 % | ACCEPTABLE |
| 1338 | -5.23 | 4.33 | 17.35 | 69.7 % | ACCEPTABLE |
| 1339 | -5.27 | 4.49 | 17.51 | 69.7 % | ACCEPTABLE |
| 1340 | -5.22 | 4.42 | 17.44 | 69.8 % | ACCEPTABLE |
| 1341 | -5.24 | 4.42 | 17.46 | 69.3 % | ACCEPTABLE |
| 1342 | -5.15 | 4.26 | 17.34 | 68.9 % | ACCEPTABLE |
| 1343 | -5.23 | 4.38 | 17.44 | 75.4 % | ACCEPTABLE |
| 1344 | -5.18 | 4.33 | 17.38 | 69.1 % | ACCEPTABLE |
| 1345 | -5.20 | 4.31 | 17.39 | 76.2 % | ACCEPTABLE |
| 1346 | -5.18 | 4.35 | 17.42 | 69.1 % | ACCEPTABLE |
| 1347 | -5.21 | 4.31 | 17.36 | 69.1 % | ACCEPTABLE |
| 1348 | -5.25 | 4.47 | 17.52 | 69.2 % | ACCEPTABLE |
| 1349 | -5.20 | 4.40 | 17.45 | 69.0 % | ACCEPTABLE |

| No. | Center | | Radius | Utilization | Verification |
|---|---|---|---|---|---|
| | x [m] | z [m] | R [m] | | |
| 1350 | -5.22 | 4.40 | 17.47 | 69.1 % | ACCEPTABLE |
| 1351 | -5.13 | 4.24 | 17.35 | 68.8 % | ACCEPTABLE |
| 1352 | -5.21 | 4.36 | 17.45 | 75.3 % | ACCEPTABLE |
| 1353 | -5.16 | 4.31 | 17.39 | 69.0 % | ACCEPTABLE |
| 1354 | -5.18 | 4.29 | 17.40 | 68.7 % | ACCEPTABLE |
| 1355 | -5.19 | 4.26 | 17.33 | 69.2 % | ACCEPTABLE |
| 1356 | -5.27 | 4.38 | 17.43 | 74.7 % | ACCEPTABLE |
| 1357 | -5.22 | 4.33 | 17.38 | 75.6 % | ACCEPTABLE |
| 1358 | -5.24 | 4.31 | 17.39 | 74.6 % | ACCEPTABLE |
| 1359 | -5.17 | 4.18 | 17.29 | 74.4 % | ACCEPTABLE |
| 1360 | -5.15 | 4.16 | 17.27 | 75.4 % | ACCEPTABLE |
| 1361 | -5.22 | 4.27 | 17.36 | 74.3 % | ACCEPTABLE |
| 1362 | -5.18 | 4.22 | 17.31 | 74.5 % | ACCEPTABLE |
| 1363 | -5.19 | 4.20 | 17.32 | 74.3 % | ACCEPTABLE |
| 1364 | -5.23 | 4.29 | 17.38 | 74.5 % | ACCEPTABLE |
| 1365 | -5.18 | 4.24 | 17.32 | 69.1 % | ACCEPTABLE |
| 1366 | -5.22 | 4.38 | 17.46 | 75.4 % | ACCEPTABLE |
| 1367 | -5.17 | 4.33 | 17.40 | 69.1 % | ACCEPTABLE |
| 1368 | -5.31 | 4.61 | 17.61 | 76.9 % | ACCEPTABLE |

| PRDW Consulting Port and Coastal Engineers | PORT OF PORT ELIZABETH OLD TUG JETTY SHEETPILE REFURBISHMENT (FEL 2 STUDY) | TRANSNET national ports authority |
|---|---|---|
| | DECK ON PILE | |
| | DESIGN CHECKS | |

CALCULATION SHEET REGISTER

| |
|---|
| S2001-109-CS-ST-101 – BERTHING LOAD |
| S2001-109-CS-ST-102 – REINFORCED CONCRETE DESIGN OF COPE PANELS |
| S2001-109-CS-ST-103 – REINFORCED CONCRETE DESIGN OF SLABS |
| S2001-109-CS-ST-104 – REINFORCED CONCRETE DESIGN OF BEAMS |
| S2001-109-CS-ST-105 – REINFORCED CONCRETE DESIGN OF PILES |
| S2001-109-CS-GT-201 – PILE END BEARING ASSESSMENT |

REVIEW REGISTER

| **Author** | **Reviewed** | **Approved** |
|---|---|---|
| YH | PES | PES |
| Signature | Signature | Signature |

DOCUMENT CHANGE RECORD

| **Rev** | **Date** | **Description of Revision** | **Status** |
|---|---|---|---|
| 0 | 25/01/2019 | Rev 0 | For Approval |
| | | | |

TOTAL NUMBER OF PAGES: [33]

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## Calculation Summary

**PRDW STANDARD CALCULATION DESIGN SHEET** **Wednesday, January 23, 2019**

**Project No. & Title** **S2001-109 Port of Port Elizabeth Old Tug Jetty SheetPile Refurbishment**

| APPROVALS | INITIAL | DATE | SECTION | Berthing Energy Calculations | |
|---|---|---|---|---|---|
| DESIGN | YH | 1/23/2019 | REFERENCE | BS 6349-4:2014 | |
| CHECKED | YH | 1/23/2019 | CALCULATION | S2001-109-CS-ST-101 | |
| APPROVED | PES | 1/23/2019 | REVISION | R0 | 01 of 02 |
| CALCULATION FILE REFERENCE | *S2042 Saldanha Jetty Easy berthing 100% Trawler Krotoa Md1399Te Vb384 VC 2016-10-24 Rev03.pdf* | | | | |

**PROJECT INFORMATION**

| | |
|---|---|
| Calculation No. | **S2001-109-CS-ST-101** |
| Prepared By | **YH** |
| Project Reference | **Berthing for Fishing Vessel *Krotoa*** |
| Comment | **Jetty Difficult berthing exposed BS6349-4 Vb384mm/s FS1.5 VC Trawler 1111grt Md1399Te D100%** |
| **Displacement Calculation according to ROM3.1** | Jetty structure, side berthing, 1/4 point berthing at 0.25 LBP, berthing angle 6 deg<br>Berthing conditions according to BS 6349-4:2014. Berthing velocity increased x 1.20. Berthing factor 1.50 (FS).<br>$M_D = C_B \times L_{BP} \times B \times D_L \times \rho sw$ [ Note spreadsheet formula does not include x ρsw ] TF to Trelleborg, Fenderteam 2015 |

**SHIP DATA**

| | | | |
|---|---|---|---|
| Ship Category | | Passenger Ship | |
| Select Dimensions By | | dwt (or grt) | |
| Deadweight | dwt | 1111 | t* |
| Displacement | $M_D$ | 1399 | t* |
| Overall Length | $L_{OA}$ | 47.50 | m* |
| Length Between Perpendiculars | $L_{BP}$ | 42.00 | m* |
| Beam | B | 11.90 | m* |
| Laden Draught | D | 5.70 | m* |
| Freeboard | F | 1.60 | m* |
| Block Coefficient | $C_B$ | 0.491 | |
| Design deadweight (% Laden) | dwt % | 100 | |
| Design Deadweight | dwt' | 1111 | t* |
| Design Displacement | $M_D'$ | 1399 | t* |

**BERTHING DATA**

| | | | |
|---|---|---|---|
| Berthing Mode | | Side Berthing | |
| Structure Type | | Open Structure | |
| Eccentricity Calculation Method | | Full Calculation | |
| Under Keel Clearance | $K_D$ | 0.30 | m |
| Impact from Bow | x | 25.00 | % $L_{BP}$ |
| | | 10.50 | m |
| Radius of Gyration | K | 8.54 | m |
| Impact to Centre of Mass | R | 12.07 | m |
| Berthing Angle | a | 6.00 | deg |
| Velocity Vector Angle | F | 54.46 | deg |
| Added Mass Coefficient | $C_M$ | **1.958** | |
| Eccentricity Coefficient | $C_E$ | 0.559 | |
| Berth Configuration Coefficient | $C_C$ | 1.000 | * |
| Softness Coefficient | $C_S$ | 1.000 | * |

<u>Berthing energy calculations</u> performed based on :
1. **Berthing Energy Calculation Sheet (V2h)** - Trelleborg Marine Systems. Revised Spreadsheet calculates : <u>Characteristic</u> and <u>Design berthing energies</u> (*normal* and *abnormal* berthing) in accordance with **<u>BS6349-Part 4:2014 (Revised edition) Section 5</u>** and **<u>PIANC WG33 Guidelines for the Design of Fender Systems:2002.</u>** <u>Added Mass Coefficient $C_M$</u> in accordance with default method **<u>Vasco Costa Method (1964)</u>**. <u>Berthing factor</u>[FS]in accordance with **<u>BS 6349-4:2014 Clause 5.1</u>**. <u>Berthing velocity</u> in accordance with **<u>BS 6349-4:2014 Figure 10</u>**. <u>Corrected Energy</u> calculation includes Correction factors and Manufacturing tolerances, based on recommendations of **<u>BS6349-Part 4:2014 Section 6</u>**, **<u>PIANC WG33:2002</u>** and **Manufacturers Rated Performance Data (RPD*)**.

**<u>Independent berthing energy calculations</u>** performed using :
2. **FenderCalc V0.95b DB V0.9** - FenderTeam.
3. **Berthing Energy Calculator** - Maritime International.

**Added Mass Coefficient $C_M$** — **Vasco Costa Method (1964)**

| Override $C_M$ | Vasco Costa 1964 | Shigeru Ueda 1981 | PIANC 2002 |
|---|---|---|---|
| 0.000 | 1.958 | 2.532 | 1.800 |

**BERTHING ENERGY**

| | | | |
|---|---|---|---|
| Berthing Velocity | $V_B$ | **384** | mm/s* |
| *Characteristic berthing energy* | E | **113** | kNm |
| | | 11.5 | t-m |
| *Berthing Factor to BS 6349-4:2014, 5.1* | Fs | **1.50** | * |
| *Design berthing energy (calculated)* | $E_D$ | **169.3** | kNm |
| | | 17.3 | t-m |
| *Design Berthing Energy* (at design $V_B$) | $E_V$ | **169.3** | **kNm** |

**BERTHING ENERGY kNm**

| | Selected Method | Vasco Costa 1964 | Shigeru Ueda 1981 | PIANC 2002 |
|---|---|---|---|---|
| Characteristic berthing energy | 112.9 | 112.9 | 146.0 | 103.8 |
| Design berthing energy (calculated) | 169.3 | 169.3 | 219.0 | 155.7 |

from Energy Calculation Sheet

| Correction factors | | | Trelleborg | FenderTeam | |
|---|---|---|---|---|---|
| | VF | **1.00** | 1.000 | 1.000 | |
| | berthing angle AF | **6.00** deg | 1.046 | 1.000 | from Rated Performance Data |
| | TF (Tmin) | **10.0** °C | 1.030 | 1.034 | from Performance Factor Sheet |
| | TF (Tmax) | **45.0** °C | 0.932 | 0.938 | |
| Manufacturing tolerance ±10% | | -10% on Energy, | 0.90 | 0.90 | according to PIANC 2002 |
| | | +10% on Reaction | 1.10 | 1.10 | |
| Corrected Design Energy | $E_{DC}$ | **193.0** kNm | | | for Performance Factors and Manufacturing Tolerance |

$E_{DC}$ = Design energy $E_D$ / [manufacturing tolerance x berthing angle factor x velocity factor x temperature factor]
$E = E_D$ / [ 0.90 x AF berthing x VFE (Vmin) x TF (Tmax) ] ; $E = E_D$ / [ 0.90 x AF berthing x VFE (Vmin) x TF (Tmin) ]

**Selection of Fender Size - to PIANC Appendix D** **Manufacturer's Rated Performance Data**

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| ***Energy per metre length of vertical fender*** | | 96.5 | kNm/m | for Trelleborg AF 6 deg | | | |
| ***Length of arch fender unit*** | | 2.0 | m | | | | |
| Fender manufacturer | | Trelleborg | | Trelleborg | FenderTeam | Trelleborg | FenderTeam |
| Select fender for Revised rated energy | ER' | 179.8 | **kNm** | AN 600-E2.0 | SX 600-G1.2 | 89.9 | 90.0 |
| Revised rated reaction | RR' | 872.4 | **kN** | AN 600-E2.0 | SX 600-G1.2 | 385.0 | 357.0 |
| | | FenderTeam | | | | | |
| | ER' | 180.0 | | | | | |
| | RR' | 809.0 | | | | | |

## BERTHING ENERGY - DETERMINATION OF FENDER REACTION FORCE

According to TNPA Port Engineering Handbook (2015)

| S2001_109 | Port of Port Elizabeth Old Tug Jetty SheetPile Refurbishment | | | | Saturday, January 19, 2019 | 02 of 02 |
|---|---|---|---|---|---|---|
| APPROVALS | INITIAL | DATE | | SECTION | Berthing Energy Calculations | |
| DESIGN | YH | 19/01/2019 | | REFERENCE ITEMS | S2001-109-CS-ST-102 | |
| CHECKED | PES | 23/01/2019 | | CALCULATION No. | S2001-109-CS-ST-101 | |
| APPROVED | PES | 23/01/2020 | | REVISION | R 0 | |

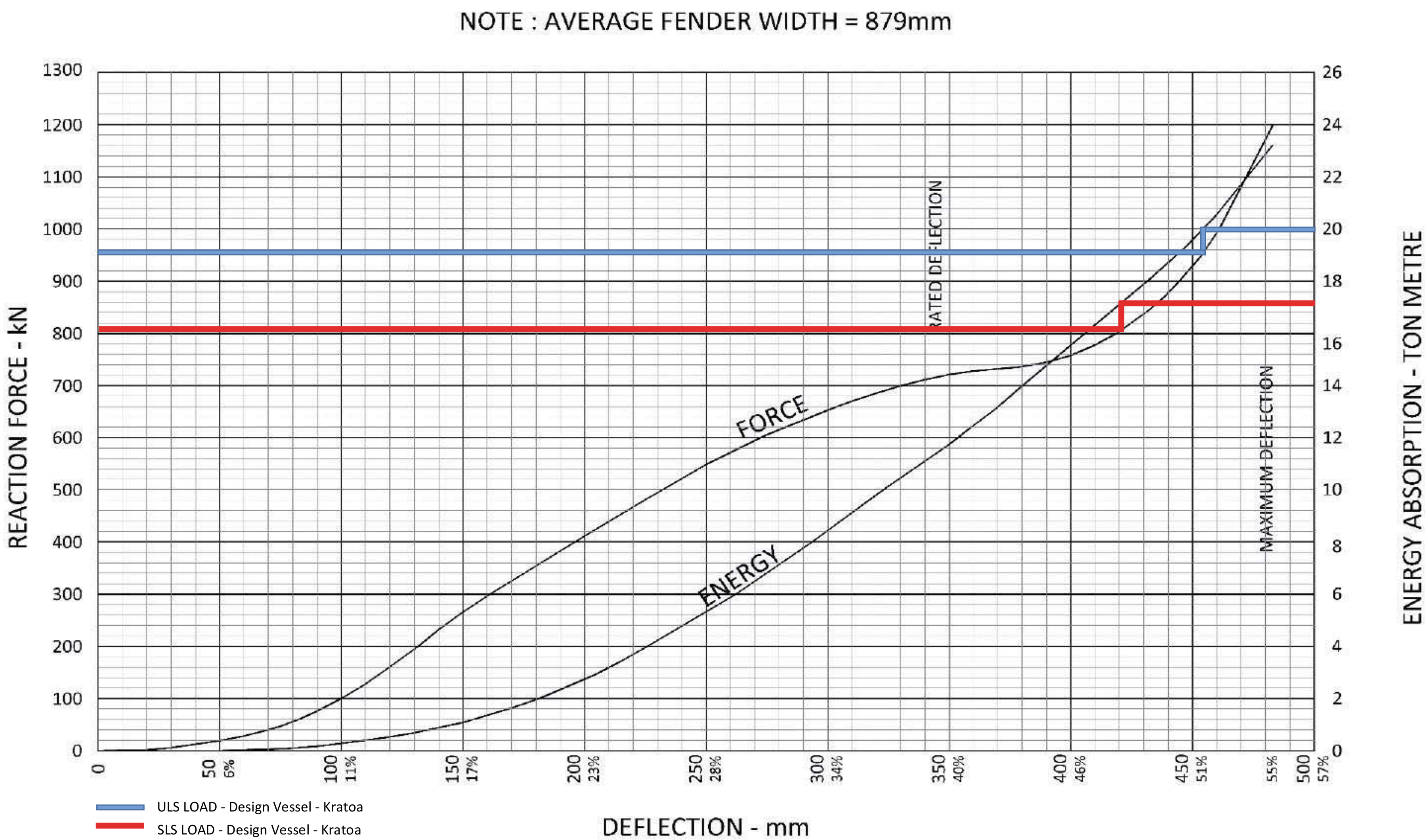


***Figure 6-9:*** *Single tyre fender energy and reaction curves*

# COPE PANEL - ULS REINFORCED CONCRETE DESIGN

According to BS EN 1992-1-1:2004

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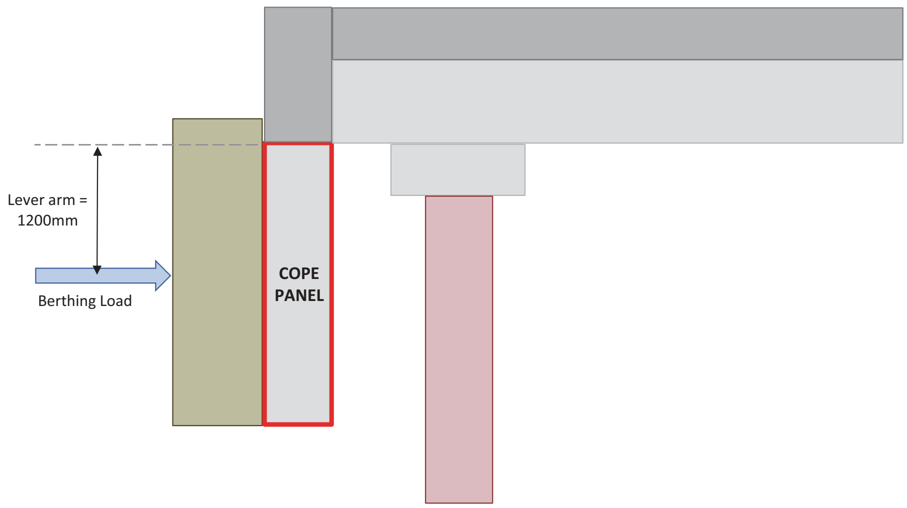
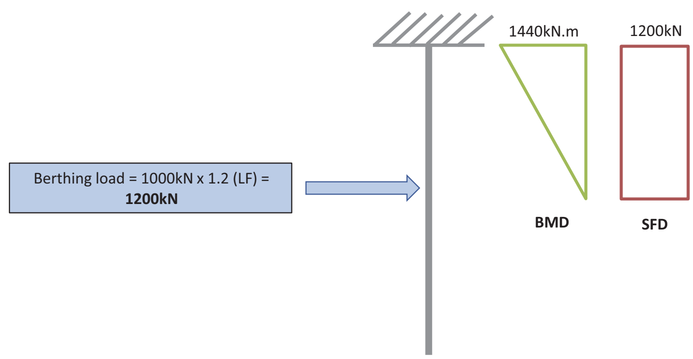
| S2001_109 | Port of Port Elizabeth Old Tug Jetty sheet pile refurbishment | | Tuesday, January 22, 2019 | 01 of 02 |
|---|---|---|---|---|
| APPROVALS | INITIAL | DATE | SECTION | Deck-on-pile |
| DESIGN | YH | 19/01/2019 | REFERENCE ITEMS | Berthing Load Calc Sheet: S2001-109-CS-ST-101 |
| CHECKED | PES | 23/01/2019 | CALCULATION No. | S2001-109-CS-ST-102 |
| APPROVED | PES | 23/01/2020 | REVISION | R 0 |

**CALCULATION DESCRIPTION**

**Description: Reinforced concrete design of cope panel subjected to berthing loads for ULS**




STRUCTURAL DESCRIPTION




IDEALISED STRUCTURAL REPRESENTATION WITH BMD AND SFD

**CELL NOTATION**

| Input | Calculation | Note |
|---|---|---|

**INPUT**

| | | | | |
|---|---|---|---|---|
| Beam width | = | 2700 | mm | |
| Beam height | = | 700 | mm | |
| Beam effective depth | = | 596.5 | mm | |
| Density of reinforced concrete | = | 25 | $kN/m^3$ | |
| Density of sea water | = | 10.2 | $kN/m^3$ | |
| $f_{ck}$ | = | 40 | MPa | |
| $f_{ctm}$ | = | 4 | MPa | |
| Fyk (rebar) | = | 450 | MPa | |
| Fykz (stirrups) | = | 450 | MPa | |
| Berthing load factor | = | 1.2 | | |
| Lever arm | = | 1.2 | m | |
| ULS berthing load | = | 1000 | kN | Source: Calc sheet S2001-109-CS-ST-201 |
| Cover | = | 75 | mm | |
| Design moment | = | 1440 | kNm | |
| Design shear | = | 1200 | kN | |

$$K = M/bd^2 f_{ck} \leq K_{bal}$$

where

$$K_{bal} = 0.167 \text{ for } f_{ck} \leq C50$$

Reinforced Concrete Design To EC 2, pg179

k = 0.037

*therefore k is less than 0.167 and beam can therefore be singly reinforced*

$$V_{Rd,max} = 0.18 b_w d(1 - f_{ck}/250) f_{ck}$$

Reinforced Concrete Design To EC 2, pg179

Shear strength before crushing occurs

| | | | | |
|---|---|---|---|---|
| Max shear resistance ($V_{RD,max}$) | = | 9741 | kN | Using smallest Effective Depth |
| Factored applied shear ($V_{ED}$) | = | 1200 | kN | |

*Therefore there is sufficient shear capacity*

To avoid reinforcement congestion $V_{RD,max}$ should be 2 times greater than the Applied Shear

**Output: Longitudinal reinforcement**

$$z = d\left[0.5 + \sqrt{(0.25 - K/1.134)}\right]$$

Reinforced Concrete Design To EC 2, pg182

| | | | | |
|---|---|---|---|---|
| Section lever arm (Z) | = | 576 | mm | |

$$A_s = \frac{M}{0.87 f_{yk} z}$$

Reinforced Concrete Design To EC 2, pg182

| | | | | |
|---|---|---|---|---|
| Calculated minimum required rebar area ($A_s$) | = | 6385 | $mm^2$ | |
| Calculated minimum steel required ($A_s$) | = | 0.40 | % | |
| Code recommended minimum steel content ($A_{s,min}$) | = | 0.13 | % | Reinforced Concrete Design To EC 2, pg182 |
| Code recommended minimum steel content ($A_{s,min}$) | = | 0.20 | % | |
| Therefore design steel content is ($A_{s,Design}$) | = | 0.40 | % | |

**Provided longitudinal reinforcement**

| | | | | |
|---|---|---|---|---|
| Therefore design steel content is ($A_{s,Design}$) | = | 6385 | $mm^2$ | |
| Minimum space between rebar layers | = | 0 | mm | |
| How many layers of tension reinforcement (1/2) | = | 1 | | |
| Layer 1 provided Y | = | 25 | mm | |
| How many bars | = | 20 | | |
| Layer 2 provided Y | = | 0 | mm | |
| How many bars | = | 0 | | |
| Provided reinforcement ($A_{s,provided}$) | = | 9817 | $mm^2$ | $A_{s\ provided}$ 0.61 % |
| Actual moment resistance with specified rebar ($M_{min}$) | = | 2214 | kNm | |
| Applied moment ($M_{ED}$) | = | 1440 | kNm | |
| Design utilization | = | 0.65 | **Design satisfactory** | |

**For simplicity provide the same quantum of reinforcement on both the top and bottom sides**

**Output: Shear reinforcement**

$$V_{Rd,\,max} = 0.124 b_w d(1 - f_{ck}/250) f_{ck}$$

Reinforced Concrete Design To EC 2, pg195

| | | | | |
|---|---|---|---|---|
| Design shear resistance ($V_{RD,max}$) | = | 6710 | kN | |
| Applied shear force ($V_{ED}$) | = | 1200 | kN | |

Therefore Since VRD,max > VED, Simple Shear Analysis is Sufficient

| | | | | |
|---|---|---|---|---|
| Assumed stirrup spacing (S) | = | 300 | mm | 600 mm maximum allowable stirrup spacing |

$$\frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 d f_{yk} \cot\theta}$$

Reinforced Concrete Design To EC 2, pg195

where cotΘ = 2.5

| | | | | |
|---|---|---|---|---|
| Minimum required shear reinforcement ($A_{sw}$) | = | 688 | $mm^2$ | |

$$\frac{A_{sw,\,min}}{s} = \frac{0.08 f_{ck}^{0.5} b_w}{f_{yk}}$$

Reinforced Concrete Design To EC 2, pg195

| | | | | |
|---|---|---|---|---|
| Code recommended minimum shear reinforcement ($A_{sw,min}$) | = | 911 | $mm^2$ | |
| Design minimum shear reinforcement ($A_{sw,\ Design}$) | = | 911 | $mm^2$ | |

**Provided steel**

| | | | | |
|---|---|---|---|---|
| Diameter of bars Y | = | 16 | | |
| Number of bars | = | 8 | | |
| Provided shear reinforcement ($A_{sw,provided}$) | = | 1608 | $mm^2$ | |

$$V_{min} = \frac{A_{sw}}{s} \times 0.78 d f_{yk} \cot\theta$$

Reinforced Concrete Design To EC 2, pg196

where cotΘ = 2.5

| | | | | |
|---|---|---|---|---|
| Actual shear resistance with specified stirrups ($V_{min}$) | = | 2806 | kN | |
| Applied shear force ($V_{ED}$) | = | 1200 | kN | |
| Design utilization | = | 0.43 | **Design satisfactory** | |
| Tensile force caused by shear | = | 1500 | kN | |

# SLAB - ULS REINFORCED CONCRETE DESIGN

According to BS EN 1992-1-1:2004

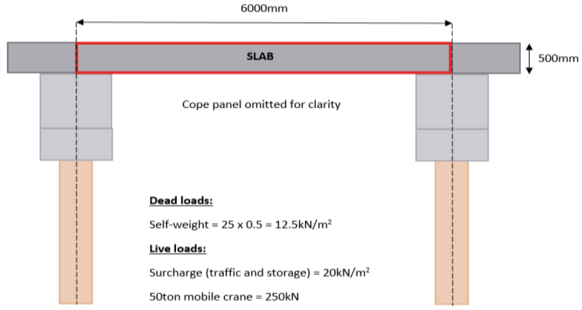
PRDW Consulting Port and Coastal Engineers

| S2001_109 | Port of Port Elizabeth Old Tug Jetty sheet pile refurbishment | | | Monday, January 21, 2019 | 01 of 02 |
|---|---|---|---|---|---|
| APPROVALS | INITIAL | DATE | SECTION | Deck-on-pile | |
| DESIGN | JPR | 23/01/2019 | REFERENCE ITEMS | | |
| CHECKED | YH | 23/01/2019 | CALCULATION No. | S2001-109-CS-ST-103 | |
| APPROVED | PES | 23/01/2019 | REVISION | R 0 | |

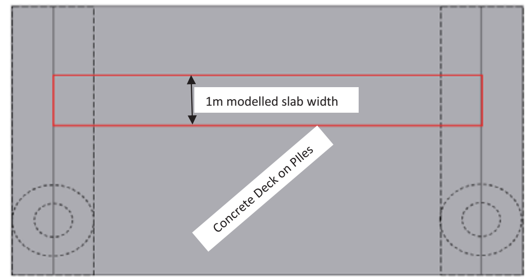
**CALCULATION DESCRIPTION**

**Description: Reinforced concrete design of slab subjected to traffic and crane loads for ULS**

FRONT VIEW

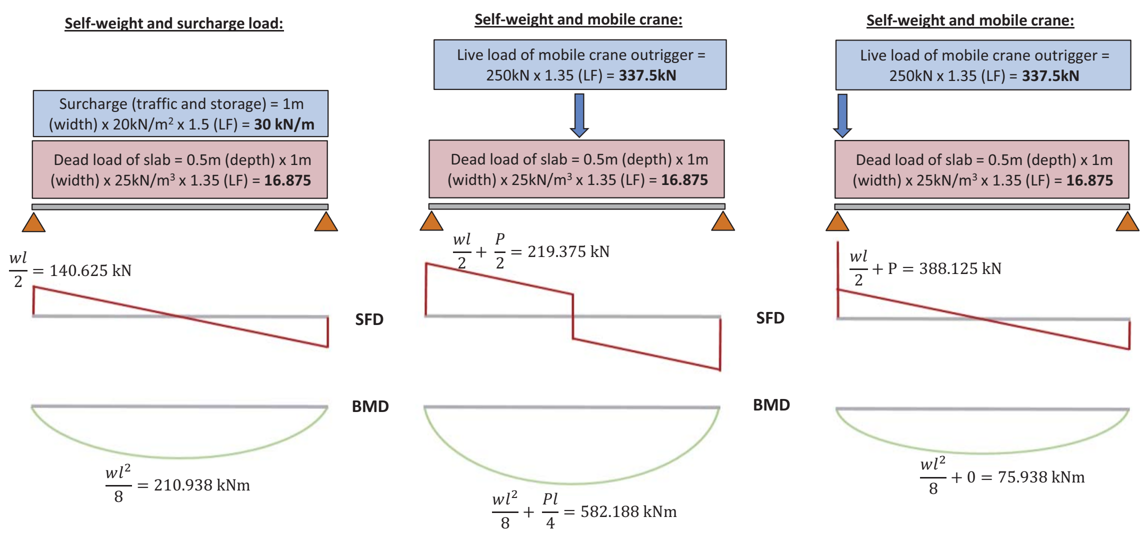



Plan VIEW




***Note:***

*It is assumed that surcharge and crane*




IDEALISED STRUCTURAL REPRESENTATION WITH BMD AND SFD

| **CELL NOTATION** | Input | Calculation | Note |
|---|---|---|---|

**INPUT**

| | | | | |
|---|---|---|---|---|
| Beam width | = | 1000 | mm | |
| Beam height | = | 500 | mm | |
| Beam effective depth | = | 396.5 | mm | |
| Density of reinforced concrete | = | 25 | $kN/m^3$ | |
| Density of sea water | = | 10.2 | $kN/m^3$ | |
| $f_{ck}$ | = | 40 | MPa | |
| $f_{ctm}$ | = | 4 | MPa | |
| $F_{yk}$ (rebar) | = | 450 | MPa | |
| $F_{ykz}$ (stirrups) | = | 450 | MPa | |
| Variable persistent action load factor | = | As above | | |
| Beam length | = | 6 | m | |
| ULS distributed load | = | As above | kPa | Source: Calc sheet S2001-109-CS-ST-201 |
| Cover | = | 75 | mm | |
| Design moment | = | 582.188 | kNm | Critical Load Case - Mobile Crane |
| Design shear | = | 388.125 | kN | |

$$K = M/bd^2 f_{ck} \leq K_{bal}$$

where

$$K_{bal} = 0.167 \text{ for } f_{ck} \leq C50$$

Reinforced Concrete Design To EC 2, pg179

K = 0.093

*Therefore K is less than 0.167 and beam can therefore be singly reinforced*

$$V_{Rd,max} = 0.18 b_w d(1 - f_{ck}/250) f_{ck}$$

Reinforced Concrete Design To EC 2, pg179

Shear strength before crushing occurs

| | | | | |
|---|---|---|---|---|
| Max shear resistance ($V_{RD,max}$) | = | 2398 | kN | Using smallest Effective Depth |
| Factored applied shear ($V_{ED}$) | = | 388 | kN | |

*Therefore there is sufficient shear capacity*

To avoid reinforcement congestion $V_{RD,\,max}$ should be 2 times greater than the Applied Shear

**Output: Longitudinal reinforcement**

$$z = d\left[0.5 + \sqrt{(0.25 - K/1.134)}\right]$$

Reinforced Concrete Design To EC 2, pg182

| | | | | |
|---|---|---|---|---|
| Section lever arm (Z) | = | 361 | mm | |

$$A_s = \frac{M}{0.87 f_{yk} z}$$

Reinforced Concrete Design To EC 2, pg182

| | | | | |
|---|---|---|---|---|
| Calculated minimum required rebar area ($A_s$) | = | 4120 | $mm^2$ | |
| Calculated minimum steel required ($A_s$) | = | 1.04 | % | |
| Code recommended minimum steel content ($A_{s,min}$) | = | 0.13 | % | Reinforced Concrete Design To EC 2, pg182 |
| Code recommended minimum steel content ($A_{s,min}$) | = | 0.20 | % | |
| Therefore design steel content is ($A_{s,design}$) | = | 1.04 | % | |

**Provided longitudinal reinforcement**

| | | | | |
|---|---|---|---|---|
| Therefore design steel content is ($A_{s,design}$) | = | 4120 | $mm^2$ | |
| Minimum space between rebar layers | = | 0 | mm | |
| How many layers of tension reinforcement (1/2) | = | 1 | | |
| Layer 1 provided Y | = | 25 | mm | |
| How many bars | = | 10 | | |
| Layer 2 provided Y | = | 0 | mm | |
| How many bars | = | 0 | | At least 1 bar in the second row (refer to rebar layout below) |
| Provided reinforcement ($A_{s,provided}$) | = | 4909 | $mm^2$ | $A_{s\ provided}$ 1.24 % |
| Actual moment resistance with specified rebar ($M_{min}$) | = | 694 | kNm | |
| Applied moment ($M_{ED}$) | = | 582.2 | kNm | |
| Design utilization | = | 0.84 | **Design satisfactory** | |

**For simplicity provide the same quantum of reinforcement on both the top and bottom sides**

**Output: Shear reinforcement**

$$V_{Rd,\,max} = 0.124 b_w d(1 - f_{ck}/250) f_{ck}$$

Reinforced Concrete Design To EC 2, pg195

| | | | | |
|---|---|---|---|---|
| Design shear resistance ($V_{Rd,max}$) | = | 1652 | kN | |
| Applied shear force ($V_{ED}$) | = | 388 | kN | |

Therefore since VRD,max > VED, Simple shear analysis is sufficient

| | | | | |
|---|---|---|---|---|
| Assumed stirrup spacing (S) | = | 400 | mm | 600 mm maximum allowable stirrup spacing |

$$\frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 d f_{yk} \cot\theta}$$

Reinforced Concrete Design To EC 2, pg195

where cotϴ = 2.5

| | | | | |
|---|---|---|---|---|
| Minimum required shear reinforcement ($A_{sw}$) | = | 446 | $mm^2$ | |

$$\frac{A_{sw,\,min}}{s} = \frac{0.08 f_{ck}^{0.5} b_w}{f_{yk}}$$

Reinforced Concrete Design To EC 2, pg195

| | | | | |
|---|---|---|---|---|
| Code recommended minimum shear reinforcement ($A_{sw,min}$) | = | 450 | $mm^2$ | |
| Design minimum shear reinforcement ($A_{sw,\,design}$) | = | 450 | $mm^2$ | |

**Provided steel**

| | | | | |
|---|---|---|---|---|
| Diameter of bars Y | = | 16 | | |
| Number of bars | = | 4 | | |
| Provided shear reinforcement ($A_{sw,provided}$) | = | 804 | $mm^2$ | |

$$V_{min} = \frac{A_{sw}}{s} \times 0.78 d f_{yk} \cot\theta$$

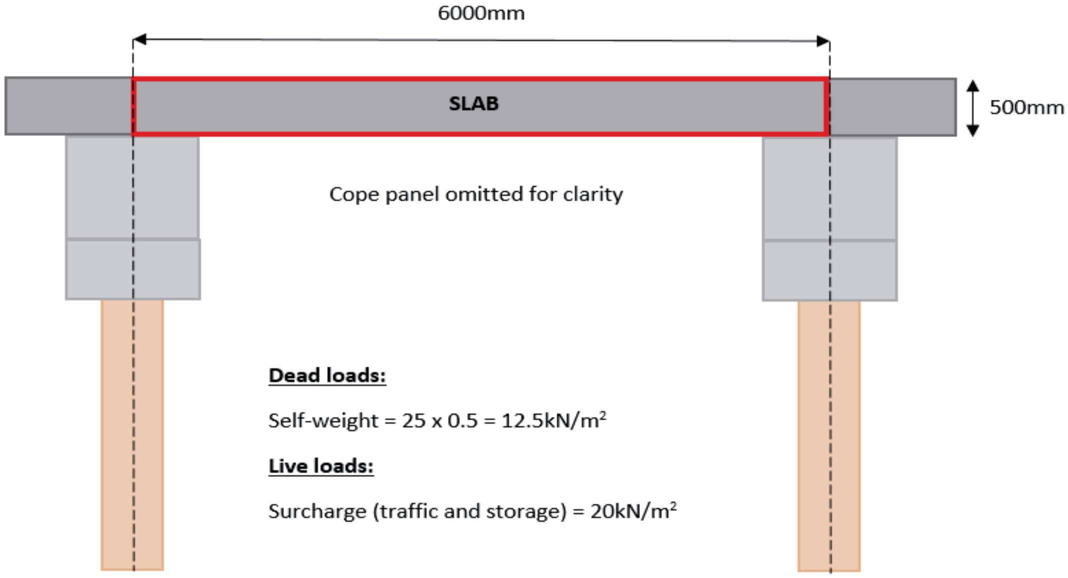
Reinforced Concrete Design To EC 2, pg196

where cotϴ = 2.5

| | | | | |
|---|---|---|---|---|
| Actual shear resistance with specified stirrups ($V_{min}$) | = | 700 | kN | |
| Applied shear force ($V_{ED}$) | = | 388 | kN | |
| Design utilization | = | 0.55 | **Design satisfactory** | |
| Tensile force caused by shear | = | 485 | kN | |

| S2001_109 | Port of Port Elizabeth Old Tug Jetty sheet pile refurbishment | | Saturday, January 19, 2019 | 02 of 02 |
|---|---|---|---|---|
| APPROVALS | INITIAL | DATE | SECTION | Deck-on-pile |
| DESIGN | JPR | 23/01/2019 | REFERENCE ITEMS | |
| CHECKED | YH | 23/01/2019 | CALCULATION No. | S2001-109-CS-ST-103 |
| APPROVED | PES | 23/01/2019 | REVISION | R 0 |

**Description: Flexural crack width check for reinforced concrete design of slab subjected to traffic loads for SLS**




**STRUCTURAL DESCRIPTION**

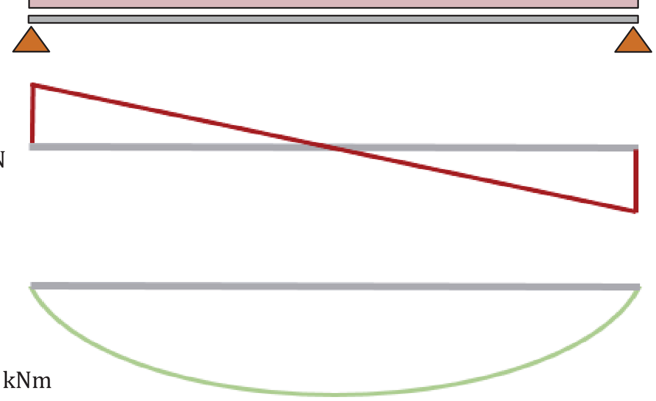
*__Note:__*
*Mobile crane load is omited due to its infrequent and short occurance.*

**Self-weight and surcharge load:**

Surcharge (traffic and storage) = 1m (width) x 20kN/m$^2$ x 0.5 (Frequent value) = **10 kN/m**

Dead load of slab = 0.5m (depth) x 1m (width) x 25kN/m$^3$ x 1 (LF) = **12.5 kN/m**

*__Note:__*
*Surcharge factored by 0.5 since it is assumed to be a frequent combination of actions at SLS.*

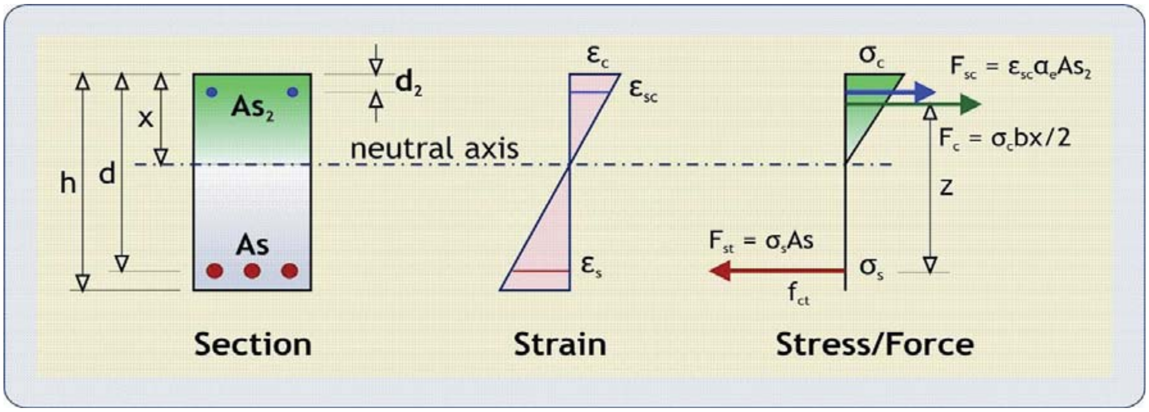


$$\frac{wl}{2} = 67.5 \text{ kN}$$

$$\frac{wl^2}{8} = 101.25 \text{ kNm}$$

**IDEALISED STRUCTURAL REPRESENTATION WITH BMD AND SFD**

## LEGEND




## INPUT

| | | | | | |
|---|---|---|---|---|---|
| $f_{ck}$ = | 35.00 | MPa | Area of tension steel, $A_s$ = | 4909 | mm² |
| $f_{yk}$ = | 450.00 | MPa | **d** = | 397 | mm |
| **b** = | 1000.00 | mm | Area of compression steel, $A_{s2}$ = | 0 | mm² |
| **h** = | 500.00 | mm | $d_2$ = | 0 | mm |
| QP moment, **M** = | 101.25 | KNm | Maxmum tension bar spacing, **S** = | 90 | mm |
| Age at cracking = | 28 | days | Max tension bar dia, $Ø_{eq}$ = | 25 | mm |
| Cement type = | N | (S, N, or R) | Short term or long term ? | L | (S or L) |
| Creep factor, **ϕ** = | 2.0 | | Cover to $A_s$, **c** = | 91 | mm |

## CALCULATIONS

| | | | |
|---|---|---|---|
| Modulus of Elasticity of concrete = $22[(fck+8)/10]^{0.3}$ | $E_{cm}$ = | 34.1 | GPa |
| Moduli of Elasticity of steel | $E_s$ = | 200.0 | GPa |
| Modular ratio | $\alpha_e$ = | 17.61 | |
| Mean concrete strength at cracking | $f_{cm,t}$ = | 43.00 | MPa |
| Mean concrete tensile strength | $f_{ct,eff}$ = | 3.21 | MPa |
| Uncracked neutral axis depth $[bh^2/2+(\alpha_e-1)(A_sd+A_{s2}d_2)]/[bh+(\alpha_e-1)(A_s+A_{s2})]$ | $x_u$ = | 270.54 | mm |
| uncracked 2nd moment of area $bh^3/12+bh(h/2-x)^2+(\alpha_e-1)[A_s(d-x)^2+A_{s2}(x-d_2)^2]$ | $I_u$ = | 11921 | mm⁴ 10⁶ |
| cracking moment = $f_{ct}I/(h-x)$ | $M_{cr}$ = | | kNm |
| < 101.25 kNm | → section is CRACKED | | |
| fully cracked neutral axis depth $(-A_s\alpha_e-A_{s2}(\alpha_e-1)+[\{A_s\alpha_e+A_{s2}(\alpha_e-1)\}^2-2b\{A_s\alpha_e d-A_{s2}d_2(\alpha_e-1)\}]^{½})/b$ | $x_c$ = | 189.27 | mm |
| concrete stress = $M/[bx(d-x/3)/2+(\alpha_e-1)A_{s2}(d-d_2)(x-d_2)/x]$ | $\sigma_c$ = | 3.209 | MPa |
| stress in tension steel = $\sigma c \cdot \alpha e(d-x)/x$ | $\sigma_s$ = | 61.9 | MPa |
| effective tension area = $\min[2.5(h-d), (h-x)/3, h/2]b - A_s$ | $A_{c,eff}$ = | 98669 | mm² |
| $A_s/A_{c,eff}$ | $\rho_{p,eff}$ = | 0.0497 | |
| max final crack spacing = $\min[1.3/(h-x),3.4c+0.17Ø/\rho_{p,eff})]$ | $s_{r,max}$ = | 394.8 | mm |
| average strain for crack width calculation | $\varepsilon_{sm}-\varepsilon_{cm}$ = | 185.6 | µstrain |
| **CALCULATED CRACK WIDTH** | $W_k$ = | **0.073** | mm |

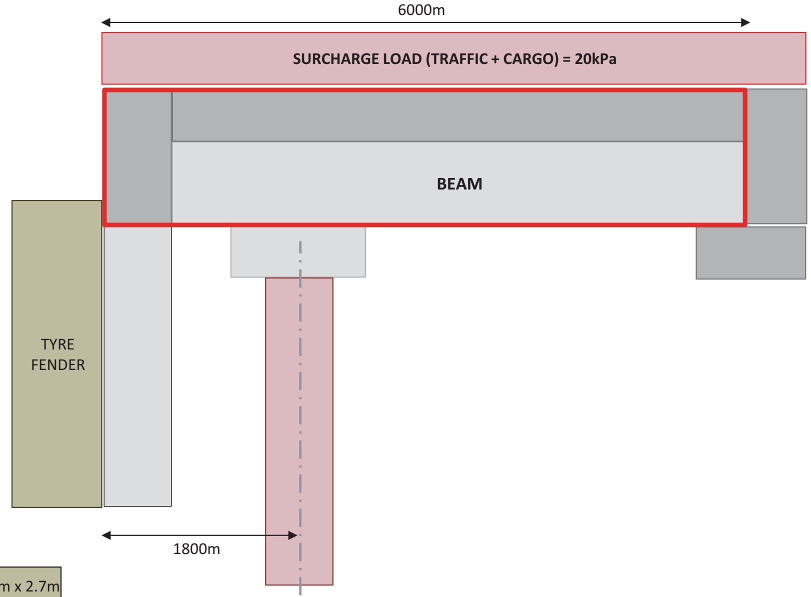
# BEAM - ULS REINFORCED CONCRETE DESIGN

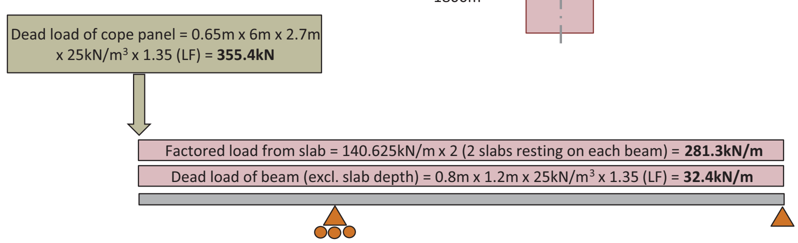
According to BS EN 1992-1-1:2004

| S2001_109 | Port of Port Elizabeth Old Tug Jetty sheet pile refurbishment | | | Tuesday, January 22, 2019 |  |
|---|---|---|---|---|---|
| APPROVALS | INITIAL | DATE | SECTION | Deck-on-pile | |
| DESIGN | YH | 23/01/2019 | REFERENCE ITEMS | S2001-109-CS-ST-103 | |
| CHECKED | PES | 23/01/2019 | CALCULATION No. | S2001-109-CS-ST-104 | |
| APPROVED | PES | 23/01/2019 | REVISION | R 0 | |

**Description: Reinforced concrete design of beam subjected to traffic and crane loads for ULS**

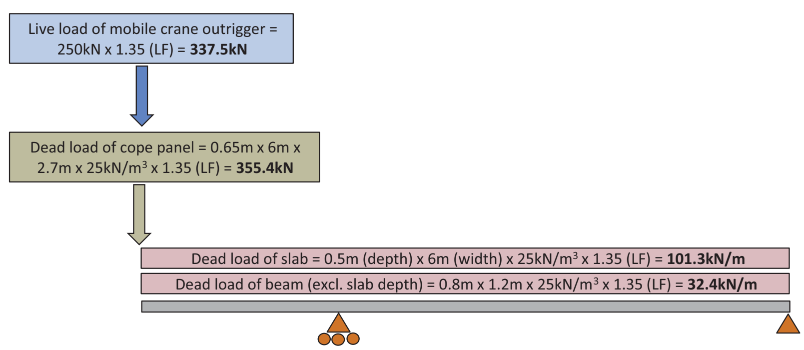
***Note:***
*It is assumed that surcharge and crane loads will never occur simultaneously.*



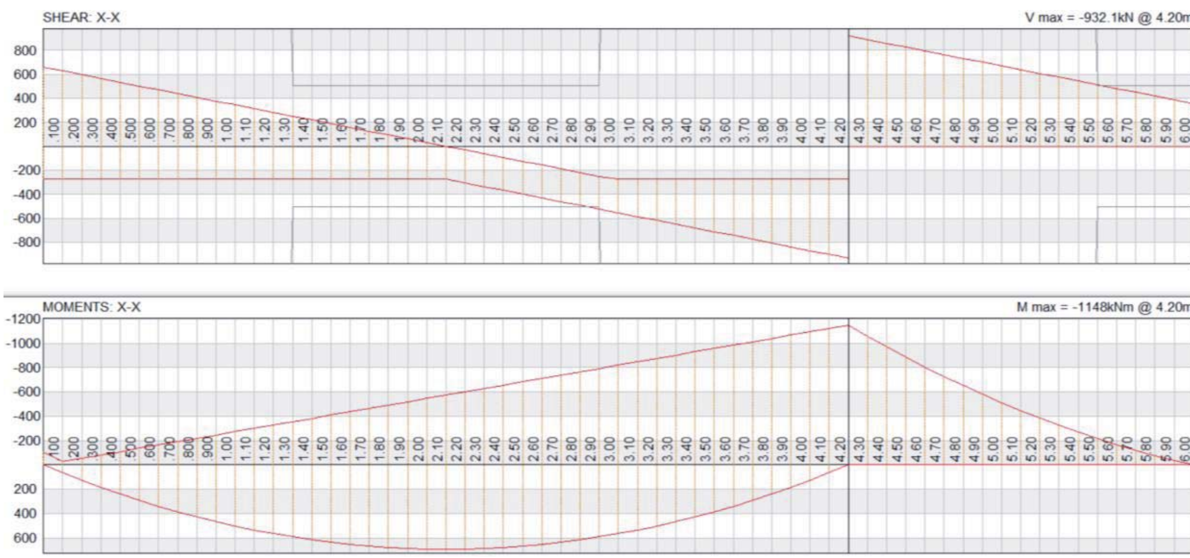

IDEALISED STRUCTURAL REPRESENTATION - SUBJECTED TO TRAFFIC LOAD

***Note:***
*Factored load from the slab includes:*
*- self-weight of slab*
*- surcharge (traffic and storage) load*

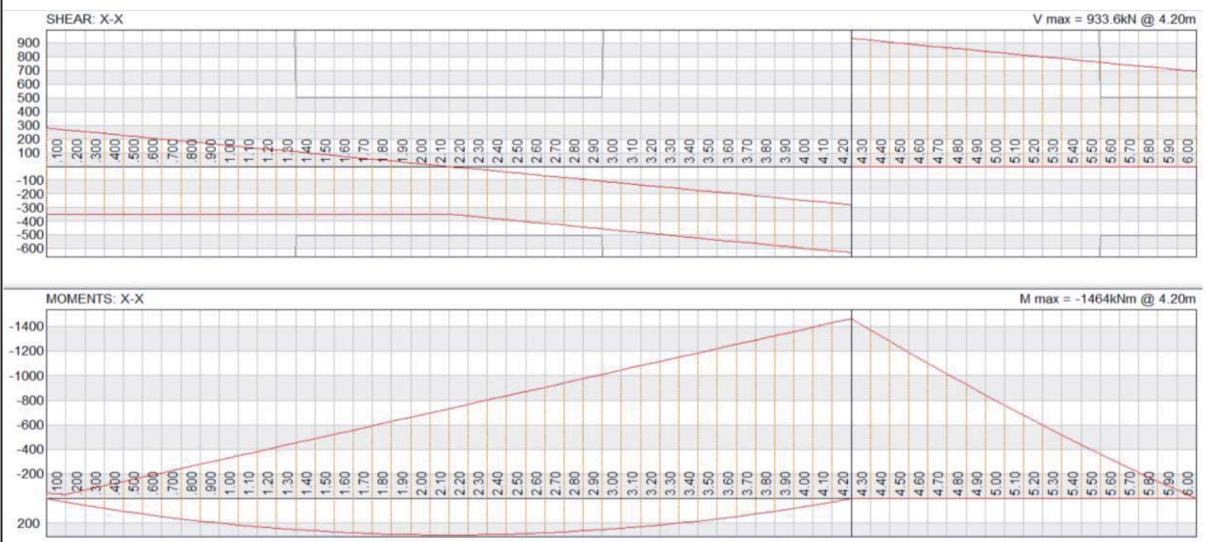



IDEALISED STRUCTURAL REPRESENTATION - SUBJECTED TO MOBILE CRANE LOAD

CALCULATION DESCRIPTION




BMD AND SFD - SUBJECTED TO TRAFFIC LOAD




BMD AND SFD - SUBJECTED TO MOBILE CRANE LOAD

| CELL NOTATION | Input | Calculation | Note |
|---|---|---|---|

| | | | |
|---|---|---|---|
| Beam width | = | 1200 | mm |
| Beam height | = | 1300 | mm |
| Beam effective depth | = | 1193 | mm |
| Density of reinforced concrete | = | 25 | $kN/m^3$ |
| Density of sea water | = | 10.2 | $kN/m^3$ |
| $f_{ck}$ | = | 35 | MPa |
| $f_{ctm}$ | = | 4 | MPa |
| $F_{yk}$ (rebar) | = | 450 | MPa |
| $F_{ykz}$ (stirrups) | = | 450 | MPa |
| Beam length | = | 6 | m |
| ULS distributed load | = | As above | kPa |
| Cover | = | 75 | mm |

**INPUT**

| | | | | |
|---|---|---|---|---|
| Design moment | = | 1464 | kNm | Crane Load Critical Load Case |
| Design shear | = | 933.6 | kN | Crane Load Critical Load Case |

$$K = M/bd^2 f_{ck} \leq K_{bal}$$
where
$$K_{bal} = 0.167 \text{ for } f_{ck} \leq C50$$

Reinforced Concrete Design To EC 2, pg179

| | | | |
|---|---|---|---|
| K | = | 0.024 | |

*Therefore K is less than 0.167 and beam can therefore be singly reinforced*

$$V_{Rd,max} = 0.18 b_w d(1 - f_{ck}/250) f_{ck}$$

Reinforced Concrete Design To EC 2, pg179
Shear strength before crushing occurs

| | | | | |
|---|---|---|---|---|
| Max shear resistance ($V_{RD,max}$) | = | 7756 | kN | Using smallest Effective Depth |
| Factored applied shear ($V_{ED}$) | = | 934 | kN | |

*Therefore there is sufficient shear capacity*

To avoid reinforcement congestion $V_{RD,\,max}$ should be 2 times greater than the Applied Shear

**Output: Longitudinal reinforcement**

$$z = d\left[0.5 + \sqrt{(0.25 - K/1.134)}\right]$$

Reinforced Concrete Design To EC 2, pg182

| | | | |
|---|---|---|---|
| Section lever arm (Z) | = | 1167 | mm |

$$A_s = \frac{M}{0.87 f_{yk} z}$$

Reinforced Concrete Design To EC 2, pg182

| | | | | |
|---|---|---|---|---|
| Calculated minimum required rebar area ($A_s$) | = | 3205 | $mm^2$ | |
| Calculated minimum steel required ($A_s$) | = | 0.22 | % | Reinforced Concrete Design To EC 2, pg182 |
| Code recommended minimum steel content ($A_{s,min}$) | = | 0.13 | % | |
| Code recommended minimum steel content ($A_{s,min}$) | = | 0.19 | % | |
| Therefore design steel content is ($A_{s,design}$) | = | 0.22 | % | |

**Provided longitudinal reinforcement**

| | | | | |
|---|---|---|---|---|
| Therefore design steel content is ($A_{s,design}$) | = | 3205 | $mm^2$ | |
| Minimum space between rebar layers | = | 0 | mm | |
| How many layers of tension reinforcement (1/2) | = | 1 | | |
| Layer 1 provided Y | = | 32 | mm | |
| How many bars | = | 8 | | |
| Layer 2 provided Y | = | 0 | mm | |
| How many bars | = | 0 | | At least 1 bar in the second row (refer to rebar layout below) |
| Provided reinforcement ($A_{s,provided}$) | = | 6434 | $mm^2$ | $A_{s\ provided}$ 0.45 % |
| Actual moment resistance with specified rebar ($M_{min}$) | = | 2939 | kNm | |
| Applied moment ($M_{ED}$) | = | 1464.0 | kNm | |
| Design utilization | = | 0.50 | **Design satisfactory** | |

**For simplicity provide the same quantum of reinforcement on both the top and bottom sides**

**Output: Shear reinforcement**

$$V_{Rd,\,max} = 0.124 b_w d(1 - f_{ck}/250) f_{ck}$$

Reinforced Concrete Design To EC 2, pg195

| | | | |
|---|---|---|---|
| Design shear resistance ($V_{Rd,max}$) | = | 5343 | kN |
| Applied shear force ($V_{ED}$) | = | 934 | kN |

Therefore since VRD,max > VED, Simple shear analysis is sufficient

| | | | | |
|---|---|---|---|---|
| Assumed stirrup spacing (S) | = | 450 | mm | 600 mm maximum allowable stirrup spacing |

$$\frac{A_{sw}}{s} = \frac{V_{Ed}}{0.78 d f_{yk} \cot\theta}$$

Reinforced Concrete Design To EC 2, pg195
where cotΘ = 2.5

| | | | |
|---|---|---|---|
| Minimum required shear reinforcement ($A_{sw}$) | = | 401 | $mm^2$ |

$$\frac{A_{sw,\,min}}{s} = \frac{0.08 f_{ck}^{0.5} b_w}{f_{yk}}$$

Reinforced Concrete Design To EC 2, pg195

| | | | |
|---|---|---|---|
| Code recommended minimum shear reinforcement ($A_{sw,min}$) | = | 568 | $mm^2$ |
| Design minimum shear reinforcement ($A_{sw,\,design}$) | = | 568 | $mm^2$ |

**Provided steel**

| | | | |
|---|---|---|---|
| Diameter of bars Y | = | 16 | |
| Number of bars | = | 4 | |
| Provided shear reinforcement ($A_{sw,provided}$) | = | 804 | $mm^2$ |

$$V_{min} = \frac{A_{sw}}{s} \times 0.78 d f_{yk} \cot\theta$$

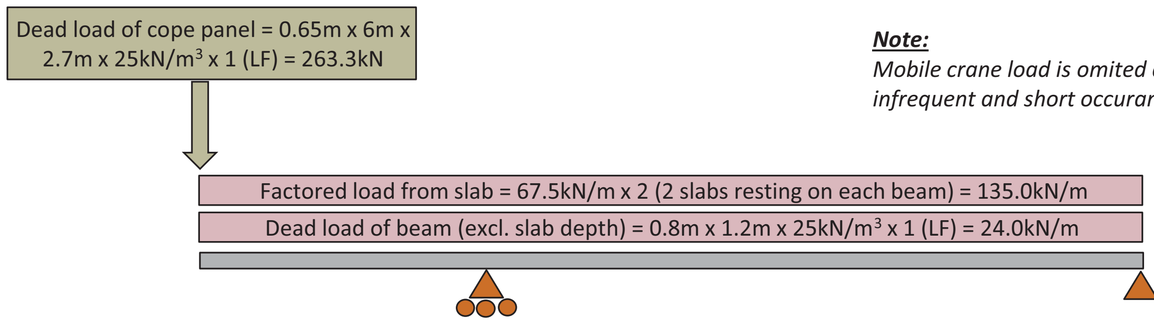
Reinforced Concrete Design To EC 2, pg196
where cotΘ = 2.5

| | | | |
|---|---|---|---|
| Actual shear resistance with specified stirrups ($V_{min}$) | = | 1871 | kN |
| Applied shear force ($V_{ED}$) | = | 934 | kN |
| Design utilization | = | 0.50 | **Design satisfactory** |
| Tensile force caused by shear | = | 1167 | kN |

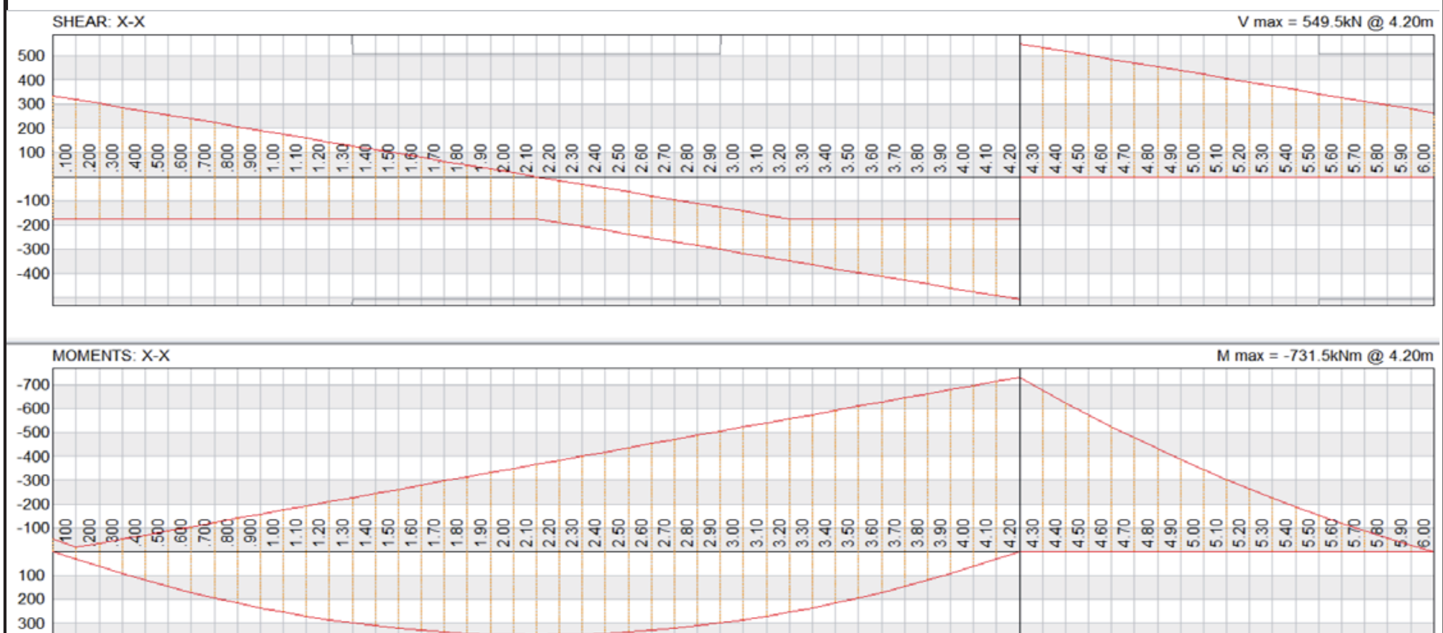
| S2001_109 | Port of Port Elizabeth Old Tug Jetty sheet pile refurbishment | | Thursday, January 24, 2019 | 02 of 02 |
|---|---|---|---|---|
| **APPROVALS** | **INITIAL** | **DATE** | **SECTION** | Deck-on-pile |
| **DESIGN** | YH | 23/01/2019 | **REFERENCE ITEMS** | S2001-109-CS-ST-103 |
| **CHECKED** | PES | 23/01/2020 | **CALCULATION No.** | S2001-109-CS-ST-104 |
| **APPROVED** | PES | 23/01/2021 | **REVISION** | R 0 |

**Description: Flexural crack width check for reinforced concrete design of beam subjected to traffic loads for SLS**

***Note:***
*Mobile crane load is omited due to its infrequent and short occurance.*

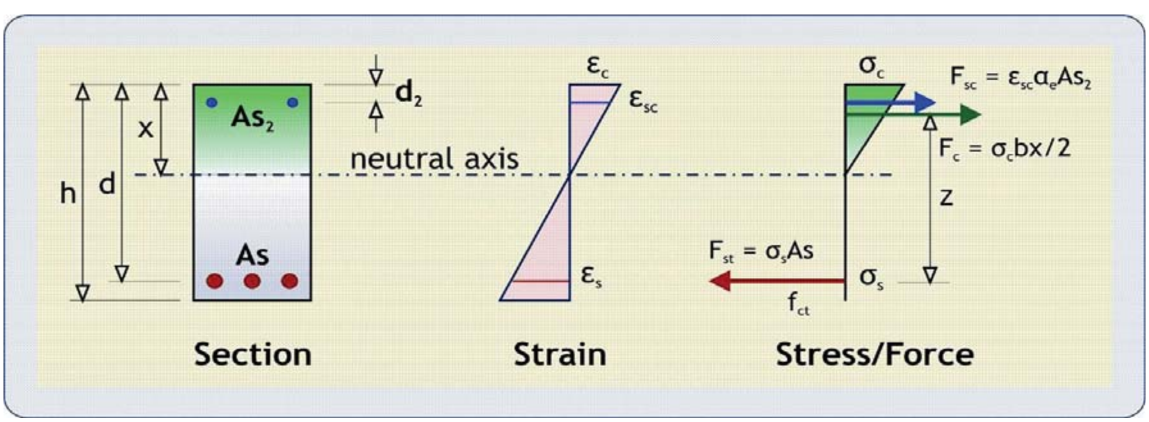



**IDEALISED STRUCTURAL REPRESENTATION - SUBJECTED TO TRAFFIC LOAD**




**BMD AND SFD - SUBJECTED TO TRAFFIC LOAD**

**LEGEND**




**INPUT**

| | | | | | |
|---|---|---|---|---|---|
| $f_{ck}$ = | 35.00 | MPa | Area of tension steel, $A_s$ = | 6434 | $mm^2$ |
| $f_{yk}$ = | 450.00 | MPa | $d$ = | 1193 | mm |
| $b$ = | 1200.00 | mm | Area of compression steel, $A_{s2}$ = | 0 | $mm^2$ |
| $h$ = | 1300.00 | mm | $d_2$ = | 0 | mm |
| QP moment, $M$ = | 731.50 | KNm | Maxmum tension bar spacing, $S$ = | 100 | mm |
| Age at cracking = | 28 | days | Max tension bar dia, $Ø_{eq}$ = | 32 | mm |
| Cement type = | N | (S, N, or R) | Short term or long term ? | L | (S or L) |
| Creep factor, $\phi$ = | 2.0 | | Cover to $A_s$, $c$ = | 91 | mm |

**CALCULATIONS**

| | | | |
|---|---|---|---|
| Modulus of Elasticity of concrete = $22[(f_{ck}+8)/10]^{0.3}$ | $E_{cm}$ = | 34.1 | GPa |
| Moduli of Elasticity of steel | $E_s$ = | 200.0 | GPa |
| Modular ratio | $\alpha_e$ = | 17.61 | |
| Mean concrete strength at cracking | $f_{cm,t}$ = | 43.00 | MPa |
| Mean concrete tensile strength | $f_{ct,eff}$ = | 3.21 | MPa |
| Uncracked neutral axis depth | | | |
| $[bh^2/2+(\alpha_e-1)(A_sd+A_{s2}d_2)]/[bh+(\alpha_e-1)(A_s+A_{s2})]$ | $x_u$ = | 684.81 | mm |
| uncracked 2nd moment of area | | | |
| $bh^3/12+bh(h/2-x)^2+(\alpha_e-1)[A_s(d-x)^2+A_{s2}(x-d_2)^2]$ | $I_u$ = | 249185 | $mm^4$ $10^6$ |
| cracking moment = $f_{ct}I/(h-x)$ | $M_{cr}$ = | | kNm |
| < 731.5 kNm | → section is | CRACKED | |
| fully cracked neutral axis depth | | | |
| $(-A_s\alpha_e-A_{s2}(\alpha_e-1)+[\{A_s\alpha_e+A_{s2}(\alpha_e-1)\}^2-2b\{A_s\alpha_e d-A_{s2}d_2(\alpha_e-1)\}]^{½})/b$ | $x_c$ = | 389.50 | mm |
| concrete stress = $M/[bx(d-x/3)/2+(\alpha_e-1)A_{s2}(d-d_2)(x-d_2)/x]$ | $\sigma_c$ = | 2.944 | MPa |
| stress in tension steel = $\sigma c \cdot \alpha e(d-x)/x$ | $\sigma_s$ = | 106.9 | MPa |
| effective tension area = $\min[2.5(h-d), (h-x)/3, h/2]b - A_s$ | $A_{c,eff}$ = | 314566 | $mm^2$ |
| $A_s/A_{c,eff}$ | $\rho_{p,eff}$ = | 0.0205 | |
| max final crack spacing = $\min[1.3/(h-x), 3.4c+0.17Ø/\rho_{p,eff})]$ | $s_{r,max}$ = | 575.4 | mm |
| average strain for crack width calculation | $\varepsilon_{sm}-\varepsilon_{cm}$ = | 320.8 | µstrain |
| **CALCULATED CRACK WIDTH** | $W_k$ = | **0.185** | mm |

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# PILE REINFORCED CONCRETE DESIGN

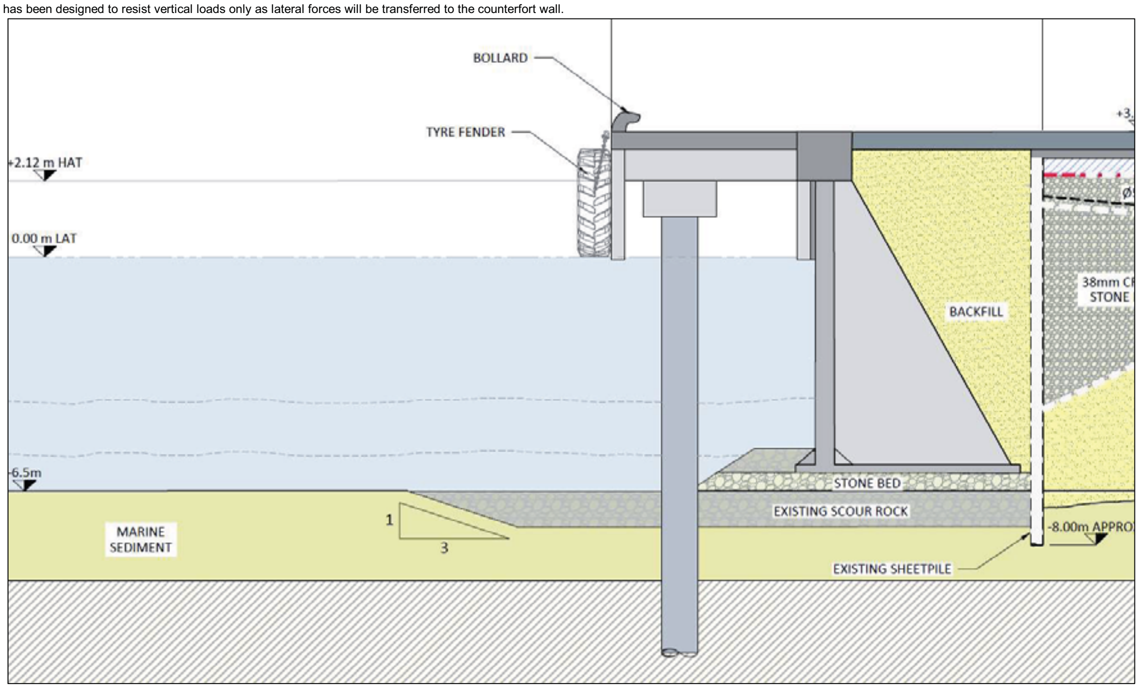
According to BS EN 1992-1-1:2004

| S2001_109 | Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment | | Friday, January 25, 2019 | 01 of 01 |
|---|---|---|---|---|
| APPROVALS | INITIAL | DATE | SECTION | Deck-on-pile |
| DESIGN | YH | 25/01/2019 | REFERENCE ITEMS | S2001-109-CS-ST-104 |
| CHECKED | PES | 25/01/2019 | CALCULATION No. | S2001-109-CS-ST-105 |
| APPROVED | PES | 25/01/2019 | REVISION | R 0 |

**CALCULATION DESCRIPTION**

**Description: Pile Reinforced concrete design for Maximum Pile Axial Compression subjected to operational loads for ULS.**

The pile has been designed to resist vertical loads only as lateral forces will be transferred to the counterfort wall.




**Typical Cross Sectional**

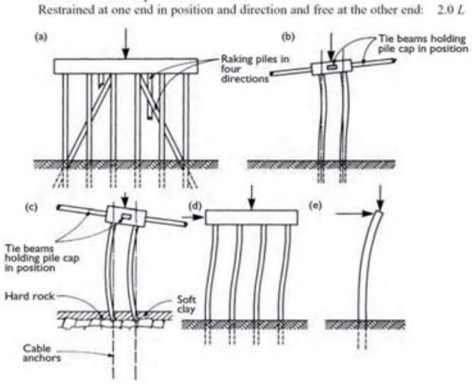
**CELL NOTATION**

| Input | Calculation | Note |
|---|---|---|

**MODEL INPUTS**

| | | | |
|---|---|---|---|
| Pile Diameter (d) | = | 0.6 | m |
| Depth to Fixity | = | 5 | d |
| Modelled Pile Head Level | = | 2.2 | mCD |
| Modelled Pile Toe Level | = | -9 | mCD |
| Modelled Pile Length | = | 14.2 | m |
| Water Density | = | 10.025 | kN/m$^3$ |
| Concrete Density | = | 25 | kN/m$^3$ |
| Concrete Compression Strength $f_{ck}$ | = | 35 | MPa |
| Rebar Yield Strength $f_y$ | = | 450 | MPa |
| Rebar Elastic Modulus $E_s$ | = | 200 | GPa |
| Dead Load Factor | = | 1.35 | |
| Pile Rebar Diameter | = | 25 | mm |
| No. of Pile Rebar | = | 6 | |
| Total Pile Rebar | = | 2945.2 | mm$^2$ |

| | |
|---|---|
| Restrained at both ends in position and direction: | 0.5 $L$ |
| Restrained at both ends in position and one end in direction: | 0.7 $L$ |
| Restrained at both ends in position but not in direction: | 1.0 $L$ |
| Restrained at one end in position and direction and at the other end in direction but not in position: | 1.0 $L$ |
| Restrained at one end in position and direction and free at the other end: | 2.0 $L$ |




**4.7.1.3 Braced and unbraced columns**

A column may be considered braced in a given plane if lateral stability to the structure as a whole is provided by walls, bracing or buttressing designed to resist all lateral forces in that plane. It should otherwise be considered unbraced. If the degree of lateral restraint is in doubt, the stiffness of the bracing system should be evaluated from the ratio $S_b/S_u$. If the ratio exceeds 5, the frame can be considered fully braced.

$S_b$ lateral stiffness of braced structure

$S_u$ sway stiffness of unbraced structure

SABS 0100-1:2000, pg 72

*Figure 7.4* Conditions of restraint for vertical piles (a) Restrained at top and bottom in position and direction (b) Restrained at bottom in position and direction; restrained at top in position but not in direction (c) Restrained at top and bottom in position but not in direction (d) Restrained at bottom in position and direction; restrained at top in direction but not in position (e) Restrained at bottom in position and direction; unrestrained at top in position or direction.

Pile Design and Construction Practice, 5th Edition, pg 384

Pile assumed to be pinned at the bottom and top. In addition, the pile is braced by the slab and counterfort wall. Therefore, the effective length factor = 1

**COLUMN DESIGN OUTPUTS**

**Pile Applied Loads**

| | | | | |
|---|---|---|---|---|
| Pile Self Weight (factored) | = | 135.5 | kN | |
| Applied load from deck (factored) | = | 933.6 | kN | Extracted from Calc S2001-109-CS-ST-104 |
| Total Applied Load | = | 1069.1 | kN | |

**Design Based on Prokon Output**

| Design results for load case | 1: (Max Compressic | | |
|---|---|---|---|
| | Top | Middle | Bottom |
| N (kN) | 1069.1 | 1069.1 | 1069.1 |
| Mxadd (kNm) | 0.0 | 184.1 | 0.0 |
| Myadd (kNm) | 0.0 | 184.1 | 0.0 |
| Mx (kNm) | 0.0 | 184.1 | 0.0 |
| My (kNm) | 0.0 | 184.1 | 0.0 |
| M-imperf (kNm) | 38.0 | 38.0 | 38.0 |
| M-design (kNm) | 0.0 | 298.4 | 0.0 |
| Design axis | X-X | X-X | X-X |
| Asc ($mm^2$) | 1131 | 1131 | 1131 |
| Asc/Ac (%) | 0.40 | 0.40 | 0.40 |
| Critical load casi | Case 1 (Max Compression load) | | |

| Software Consultants (Pty) Ltd<br>Internet: http://www.prokon.com<br>E-Mail : mail@prokon.com | Job Number | S2001-109-CS-ST-105 | | | Sheet | 1 |
|---|---|---|---|---|---|---|
| | Job Title | Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment | | | | |
| | Client | TNPA | | | | |
| | Calcs by | YH | Checked by | PES | Date | 24/01/2019 |

**l**

C12

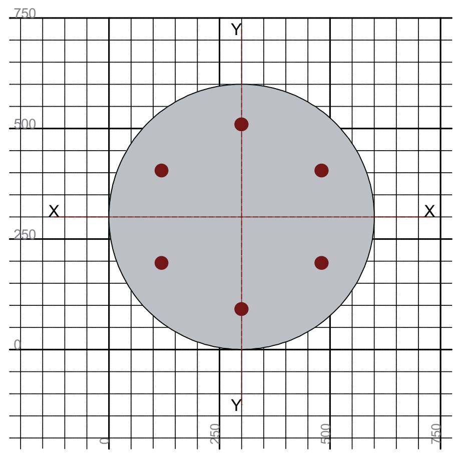
Circular column design by *PROKON*. (CirCol Ver W3.0.11 - 26 Jun 2018)

Design code : Eurocode 2 - 2004

## General design parameters:

Given:

d = 600 mm
d' = 91 mm
l = 14.200 m
fck = 35 MPa
fy = 450 MPa




Therefore:

$$A_c = \frac{\pi\ d^2}{4}$$

$$= \frac{\pi \times 600^2}{4}$$

$$= 282.7 \times 10^3 \text{ mm}^2$$

$$d_{iax'} = d_{ia} - d'$$

$$= 600 - 91$$

$$= 509.000 \text{ mm}$$

$$d_{iay'} = d_{ia} - d'$$

$$= 600 - 91$$

$$= 509.000 \text{ mm}$$

Assumptions:

(1) The general conditions of clauses 5.8.8.3, 5.8.4, and 5.8.8 are applicable.
(2) The section is symmetrically reinforced.
(3) The specified design axial loads include the self-weight of the column.
(4) The design axial loads are taken constant over the height of the column.

## Design approach:

The column is designed using an iterative procedure:

(1) The column design charts are constructed.
(2) An area steel is chosen.
(3) The corresponding slenderness moments are calculated.
(4) The design axis and design ultimate moment is determined .
(5) The steel required for the design axial force and moment is read from the relevant design chart.
(6) The procedure is repeated until the convergence of the area steel about the design axis.
(7) The area steel perpendicular to the design axis is read from the relevant design chart.

## Check column slenderness:

End fixity and bracing for bending about the X-X axis:
The column is braced.
Designer specified ßx = 1.00

End fixity and bracing for bending about the Y-Y axis:
The column is braced.
Designer specified ßy = 1.00

Effective column height:

$$l_{ox} = \beta_x \cdot l$$
$$= 1 \times 14.2$$
$$= 14.200 \text{ m}$$

$$l_{oy} = \beta_y \cdot l$$
$$= 1 \times 14.2$$
$$= 14.200 \text{ m}$$

Column slenderness about both axes:

$$\lambda_x = \frac{l_{ox}}{r_x}$$
$$= \frac{14.2}{.17321}$$
$$= 81.981$$

$$\lambda_y = \frac{l_{oy}}{r_y}$$
$$= \frac{14.2}{.17321}$$
$$= 81.981$$

## Minimum Moments for Design:

Check for mininum eccentricity:

For bi-axial bending, it is only necessary to ensure that the eccentricity exceeds the minimum about one axis at a time.

For the worst effect, apply the minimum eccentricity about the minor axis:

5.2(7)

$$e_{min} = \frac{\theta \cdot l_0}{2}$$
$$= \frac{.005 \times 14.2}{2}$$
$$= 0.0355 \text{ m}$$

But emin must be at least 20mm or the value below:

6.4

$$e_{min} = 0.03 \cdot d$$
$$= 0.03 \times .6$$
$$= 0.0180 \text{ m}$$

$$M_{min} = e_{min} \cdot N$$
$$= .0355 \times 1\,069.1$$
$$= 37.953 \text{ kNm}$$

Check if the column is slender: *5.8.3.1*

$$N_{ed} = 1069.1 \text{ kN}$$

$$f_{cd} = \frac{a_{cc} \cdot f_{ck}}{1.5}$$
$$= \frac{1 \times 35}{1.5}$$
$$= 23.333 \text{ MPa}$$

5.5.3.1 (1)

$$n = \frac{N_{ed}}{A_c \cdot f_{cd}}$$
$$= \frac{1\,069.1}{.28274 \times 23333}$$
$$= 0.1621$$

Check slenderness about X-X — 5.8.3.1 (1)

$A$ = 0.7

5.8.3.1 (1)

$B$ = 1.1

Larger end moment about X-X axis

$M_{02}$ = 0.0 kNm

Smaller end moment about X-X axis

$M_{01}$ = 0.0 kNm

Since M02=0: — 5.8.3.1 (1)

$r_m$ = 0.0

5.8.3.1 (1)

$$C = 1.7 - r_m$$
$$= 1.7 - 0$$
$$= 1.700$$

5.8.3.1 (1)

$$\lambda_{limx} = \frac{20 \cdot A \cdot B \cdot C}{\sqrt{n}}$$
$$= \frac{20 \times .7 \times 1.1 \times 1.7}{\sqrt{.16205}}$$
$$= 65.035$$

$\lambda_x = 94.67 > 65.03$

Check slenderness about Y-Y 5.8.3.1 (1)

$A = 0.7$

5.8.3.1 (1)

$B = 1.1$

Larger end moment about Y-Y axis

$M_{02} = 0.0$ kNm

Smaller end moment about Y-Y axis

$M_{01} = 0.0$ kNm

Since M02 = 0: 5.8.3.1 (1)

$r_m = 0.0$

5.8.3.1 (1)

$$C = 1.7 - r_m$$
$$= 1.7 - 0$$
$$= 1.700$$

5.8.3.1 (1)

$$\lambda_{limy} = \frac{20 \cdot A \cdot B \cdot C}{\sqrt{n}}$$
$$= \frac{20 \times .7 \times 1.1 \times 1.7}{\sqrt{.16205}}$$
$$= 65.035$$

$\lambda_y = 94.67 > 65.03$

∴ The column is slender.

## Initial moments:

The initial end moments about the X-X axis:
M1 = Smaller initial end moment = 0.0 kNm
M2 = Larger initial end moment = 0.0 kNm

The initial moment near mid-height of the column : *5.8.8.2*

$$M_i = -0.4 \cdot M_1 + 0.6 \cdot M_2$$
$$= -0.4\times0 + 0.6\times0$$
$$= 0.0000\times10^0 \text{ kNm}$$

$$M_{i2} = 0.4 \cdot M_2$$
$$= 0.4\times0$$
$$= 0.0000\times10^0 \text{ kNm}$$

$\therefore$ Mi $\geq$ 0.4M2 = 0.0 kNm

The initial end moments about the Y-Y axis:
M1 = Smaller initial end moment = 0.0 kNm
M2 = Larger initial end moment = 0.0 kNm

The initial moment near mid-height of the column : *5.8.8.2*

$$M_i = -0.4 \cdot M_1 + 0.6 \cdot M_2$$
$$= -0.4\times0 + 0.6\times0$$
$$= 0.0000\times10^0 \text{ kNm}$$

$$M_{i2} = 0.4 \cdot M_2$$
$$= 0.4\times0$$
$$= 0.0000\times10^0 \text{ kNm}$$

$\therefore$ Mi $\geq$ 0.4M2 = 0.0 kNm

## Deflection induced moments:

*5.8.8.2*

$$f_{cd} = \frac{a_{cc} \cdot f_{ck}}{1.5\times10^6}$$
$$= \frac{1\times3500\times10^4}{1.5\times10^6}$$
$$= 23.333 \text{ MPa}$$

5.8.8.3 (3)

$$n = \frac{N_{ed}}{A_c \cdot f_{cd}}$$
$$= \frac{1069\times10^3}{.28274\times2333\times10^4}$$
$$= 0.1621$$

5.8.8.3 (3)

$$\omega = \frac{A_s \cdot f_{yd}}{A_c \cdot f_{cd}}$$
$$= \frac{.00113\times3913\times10^5}{.28274\times2333\times10^4}$$
$$= 0.0670$$

5.8.8.3 (3)

$$n_u = 1 + \omega$$
$$= 1 + .06708$$
$$= 1.067$$

***For bending about the X-X axis:***

5.8.8.3 (3)

$$n_{bal} = \frac{N_{bal}}{A_c \cdot f_{cd}}$$
$$= \frac{1422\times10^3}{.28274\times2333\times10^4}$$
$$= 0.2156$$

5.8.8.3 (3)

$$K_r = \frac{n_u - n}{n_u - n_{bal}}$$
$$= \frac{1.0671 - .16205}{1.0671 - .21556}$$
$$= 1.063$$

With the proviso that

$$K_r <= 1$$

Allowable tensile strain in steel 5.8.8.3 (1)

$$\varepsilon_{yd} = \frac{f_{yd}}{E_s}$$
$$= \frac{3913\times10^5}{2000\times10^8}$$
$$= 0.0020$$

5.8.8.3 (4)

$$\beta = \left[0.35 + \frac{f_{ck}}{200}\right] - \frac{\lambda}{150}$$
$$= \left[0.35 + \frac{35}{200}\right] - \frac{94.667}{150}$$
$$= -0.1061$$

5.8.8.3 (4)

$$K_\phi = 1 + \beta \cdot \phi_{ef}$$
$$= 1 + -.10611\times0$$
$$= 1.0000$$

Kϕ is limited to >= 1

5.8.8.3 (1)

$$curvature = \frac{K_r \cdot K_\phi \cdot \varepsilon_{yd}}{0.45 \cdot d}$$
$$= \frac{1\times1\times.00196}{0.45\times.509}$$
$$= 0.0086$$

5.8.8.2 (3)

$$e_2 = \frac{c_{urvature} \cdot l_o^2}{c}$$
$$= \frac{.00854 \times 14.2^2}{10}$$
$$= 0.1722$$

5.8.8.2 (3)

$$M_{add} = N_{ed} \cdot e_2$$
$$= 1\ 069.1 \times .17224$$
$$= 184.142\ \text{kNm}$$

***For bending about the Y-Y axis:***

5.8.8.3 (3)

$$n_{bal} = \frac{N_{bal}}{A_c \cdot f_{cd}}$$
$$= \frac{1422 \times 10^3}{.28274 \times 2333 \times 10^4}$$
$$= 0.2156$$

5.8.8.3 (3)

$$K_r = \frac{n_u - n}{n_u - n_{bal}}$$
$$= \frac{1.0671 - .16205}{1.0671 - .21556}$$
$$= 1.063$$

With the proviso that

$$K_r <= 1$$

Allowable tensile strain in steel 5.8.8.3 (1)

$$\varepsilon_{yd} = \frac{f_{yd}}{E_s}$$
$$= \frac{3913 \times 10^5}{2000 \times 10^8}$$
$$= 0.0020$$

5.8.8.3 (4)

$$\beta = \left[0.35 + \frac{f_{ck}}{200}\right] - \frac{\lambda}{150}$$
$$= \left[0.35 + \frac{35}{200}\right] - \frac{94.667}{150}$$
$$= -0.1061$$

5.8.8.3 (4)

$$K_\phi = 1 + \beta \cdot \phi_{ef}$$
$$= 1 + -.10611 \times 0$$
$$= 1.0000$$

Kϕ is limited to >= 1

5.8.8.3 (1)

$$c_{urvature} = \frac{K_r \cdot K_\phi \cdot \varepsilon_{yd}}{0.45 \cdot d}$$
$$= \frac{1 \times 1 \times .00196}{0.45 \times .509}$$
$$= 0.0086$$

5.8.8.2 (3)

$$e_2 = \frac{c_{urvature} \cdot l_o^2}{c}$$
$$= \frac{.00854 \times 14.2^2}{10}$$
$$= 0.1722$$

5.8.8.2 (3)

$$M_{add} = N_{ed} \cdot e_2$$
$$= 1\,069.1 \times .17224$$
$$= 184.142 \text{ kNm}$$

**Design ultimate load and moment:**

Design axial load:
N = 1069.1 kN

For bending about the X-X axis, the maximum design moment is the greatest of: *5.8.8.2*

(a) 5.8.8.2

$M_2 = 0.0$ kNm

(b) 5.8.8.2

$M = M_i + M_{add}$
$= 0 + 184.14$
$= 184.140$ kNm

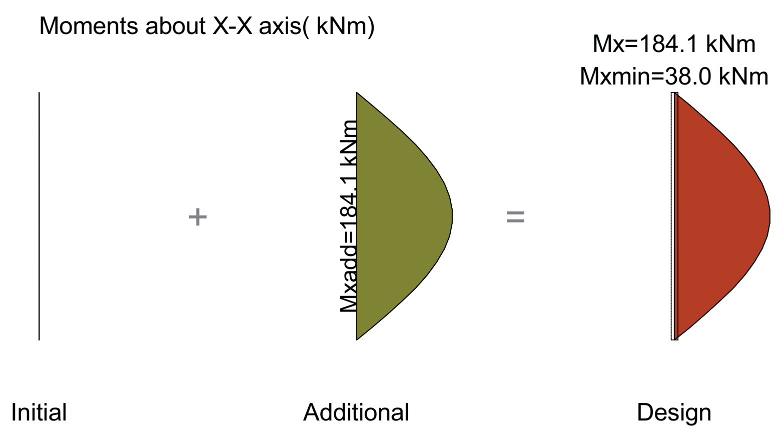
(c) 5.8.8.2

$M = M_1 + \frac{M_{add}}{2}$
$= 0 + \frac{184.14}{2}$
$= 92.070$ kNm

Thus 5.8.8.2

$M = 184.1$ kNm

Moment distribution along the height of the column for bending about the X-X:
At the top, Mx = 0.0 kNm
Near mid-height, Mx = 184.1 kNm
At the bottom, Mx = 0.0 kNm



For bending about the Y-Y axis, the maximum design moment is the greatest of: *5.8.8.2*

(a) 5.8.8.2

$M_2$ = 0.0 kNm

(b) 5.8.8.2

$M = M_i + M_{add}$

$= 0 + 184.14$

$= 184.140$ kNm

(c) 5.8.8.2

$M = M_I + \frac{M_{add}}{2}$

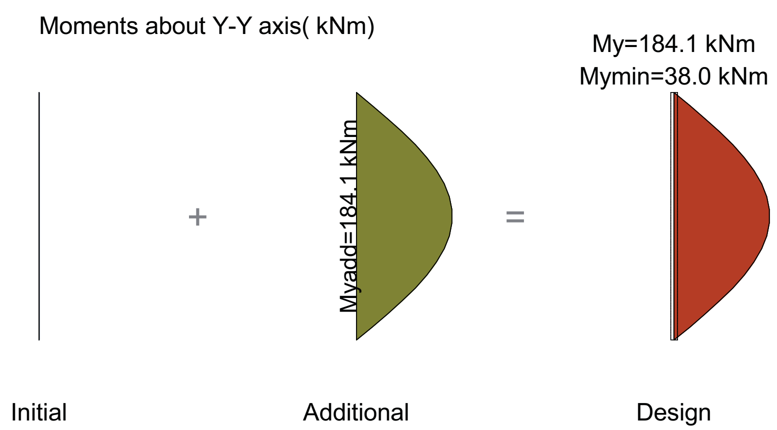
$= 0 + \frac{184.14}{2}$

$= 92.070$ kNm

Thus 5.8.8.2

$M$ = 184.1 kNm

Moment distribution along the height of the column for bending about the Y-Y:
At the top, My = 0.0 kNm
Near mid-height, My = 184.1 kNm
At the bottom, My = 0.0 kNm




## Design of column section for ULS:

Through inspection:
The critical section lies near mid-height of the column.

The column is bi-axially bent: Therefore: *5.8.9 (4)*

From 5.8.9 (4): fac = $(M_{Edz}/M_{Rdz})^{\alpha} + (M_{Edy}/M_{Rdy})^{\alpha}$ <= 1

Now for a circular column, $\alpha$ = 2

Since the column is circular and symmetrically reinforced,
it follows that $M_{Rdz} = M_{Rdy} = M_r$ - the design resistance of the column

For our notation $M_{Edz}$ becomes $M_x$ and $M_{Edy}$ becomes $M_y$, our design moments.
The formula then becomes:

fac = $(M_x/Mr)^2 + (M_y/M_r)^2 \quad <= 1$

thus fac = $M_x^2/Mr^2 + M_y^2/M_r^2 \quad <= 1$

thus fac = $(M_x^2 + M_y^2)/M_r^2 \quad <= 1$

Taking square roots above and below we can write fac = $M_{des}/M_r \quad <= 1$
where the total design moment $M_{des} = (M_x^2 + M_y^2)^{½}$

This deduction is used to complete the design calculation in a simplified way below:

The column is bi-axially bent: the moments are therefore added vectorially
to obtain the final design moment:

$$M_{des'} = \sqrt{M_x^2 + M_y^2}$$
$$= \sqrt{184.14^2 + 184.14^2}$$
$$= 260.413$$

The moment due to imperfections is added to this:

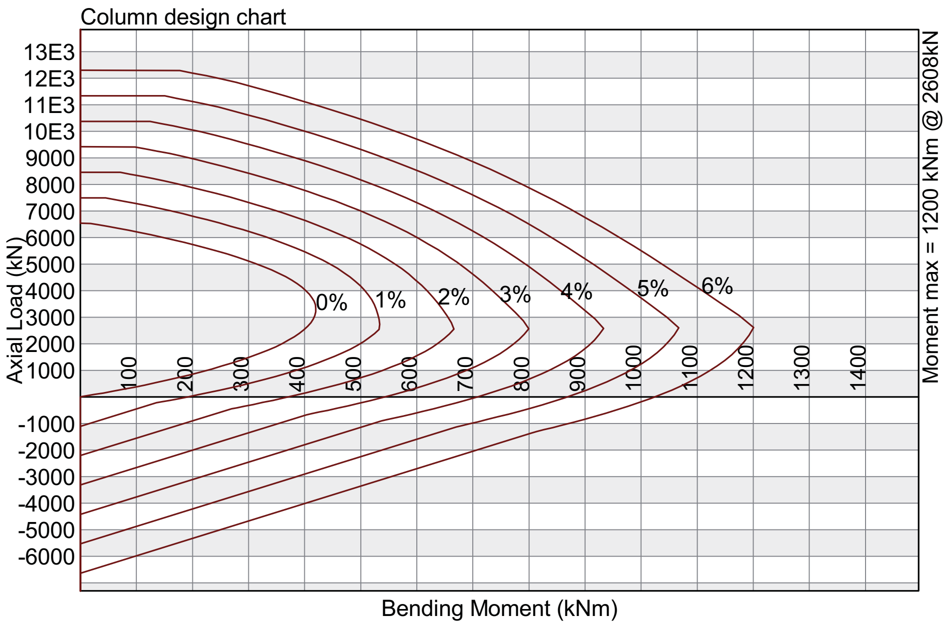
$$M_{des'} = M_{des} + M\_imperf$$
$$= 260.41 + 37.953$$
$$= 298.363$$

Design axial load:

$$N = 1069.1$$

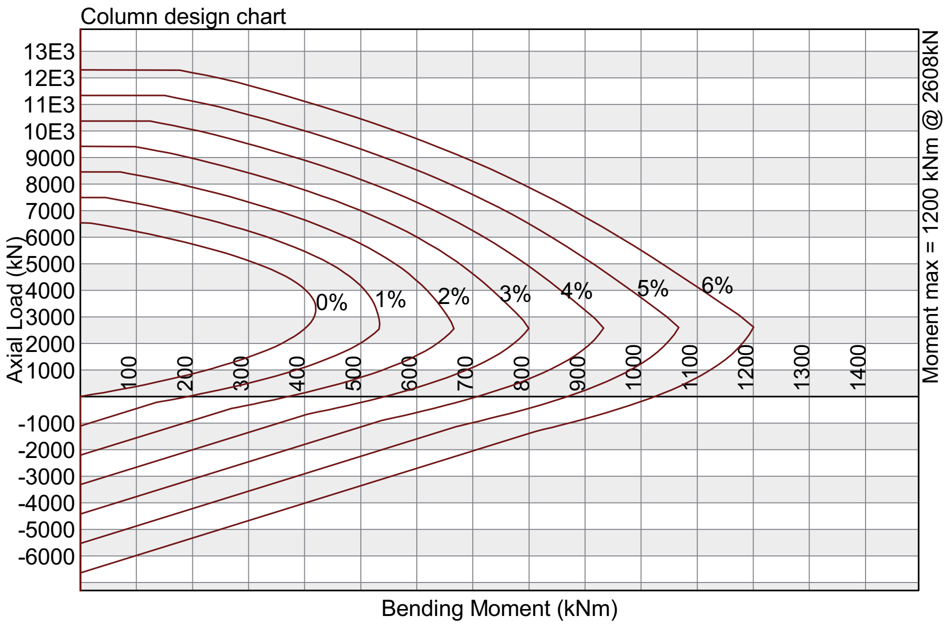
| PROKON<br>Software Consultants (Pty) Ltd<br>Internet: http://www.prokon.com<br>E-Mail : mail@prokon.com | Job Number: S2001-109-CS-ST-105 | | Sheet: 14 |
|---|---|---|---|
| | Job Title: Port of Port Elizabeth Old Tug Jetty Sheetpile Refurbishment | | |
| | Client: TNPA | | |
| | Calcs by: YH | Checked by: PES | Date: 24/01/2019 |

For bending about the design axis:




From the design chart, Asc = 1131 = 0.40%

Design chart for bending about any axis:



# Summary of design calculations:

Design results for all load cases:

| Load case | Axis | N (kN) | M1 (kNm) | M2 (kNm) | Mi (kNm) | Madd (kNm) | Design | M (kNm) | M-design (kNm) | Asc (mm²) |
|---|---|---|---|---|---|---|---|---|---|---|
| 1 | X-X<br>Y-Y | 1069.1 | 0.0<br>0.0 | 0.0<br>0.0 | 0.0<br>0.0 | 184.1<br>184.1 | X-X<br>Middle | 184.1<br>184.1 | 298.4 | 1131 (0.40%) |

# PILE END BEARING DESIGN

According to Pile Design and Construction Practice, 5th Edition (Tomlinson)

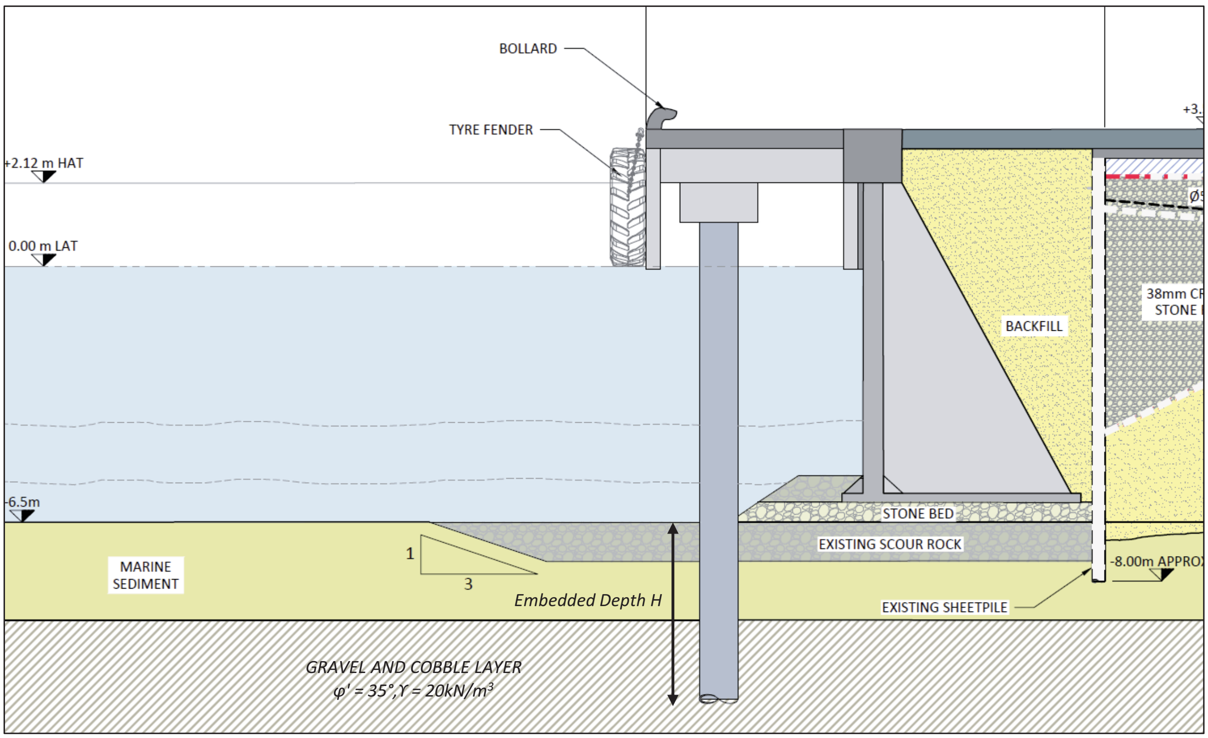
| S2001_109 | Port of Port Elizabeth Old Tug Jetty sheet pile refurbishment | | Friday, January 25, 2019 | 01 of 01 |
|---|---|---|---|---|
| **APPROVALS** | **INITIAL** | **DATE** | **SECTION** | Deck-on-pile |
| **DESIGN** | YH | 25/01/2019 | **REFERENCE ITEMS** | S2001-109-CS-ST-105 |
| **CHECKED** | PES | 25/01/2019 | **CALCULATION No.** | S2001-109-CS-GT-201 |
| **APPROVED** | PES | 25/01/2019 | **REVISION** | R 0 |

## CALCULATION DESCRIPTION

**Description: Pile end bearing design check - Subjected to maximum axial compression load as a result of mobile crane operations.**

Note: Piles founded in gravel and cobble layer.

The following pile end bearing checks have been undertaken in accordance with Tomlinson, section 4.3.1:




## CALCULATION INPUT

| | | | | |
|---|---|---|---|---|
| Factored max compression load (extracted from Robot Model) | = | 1069.1 | kN | Source: Calc S2001-109-CS-ST-105 |
| *Factored Axial load defactored by 1.35 since Tomlinson end bearing check is based on Factor of Safety approach* | | | | |
| Unfactored max axial compression load | = | 792 | kN | |
| Rebar yield strength | = | 300 | $N/mm^2$ | |
| Density of seawater | = | 10.025 | $kN/m^3$ | |
| Density of gravel and cobble layer | = | 20 | $kN/m^3$ | ASSUMMED |
| Internal friction angle of gravel and cobble layer | = | 35 | ° | ASSUMMED |
| Pile embedment depth (H) | = | 8.5 | m | Assumed 6m embedment into gravel cobble layer |
| Pile diameter (d) | = | 0.6 | m | |

BEARING CAPACITY CHECK

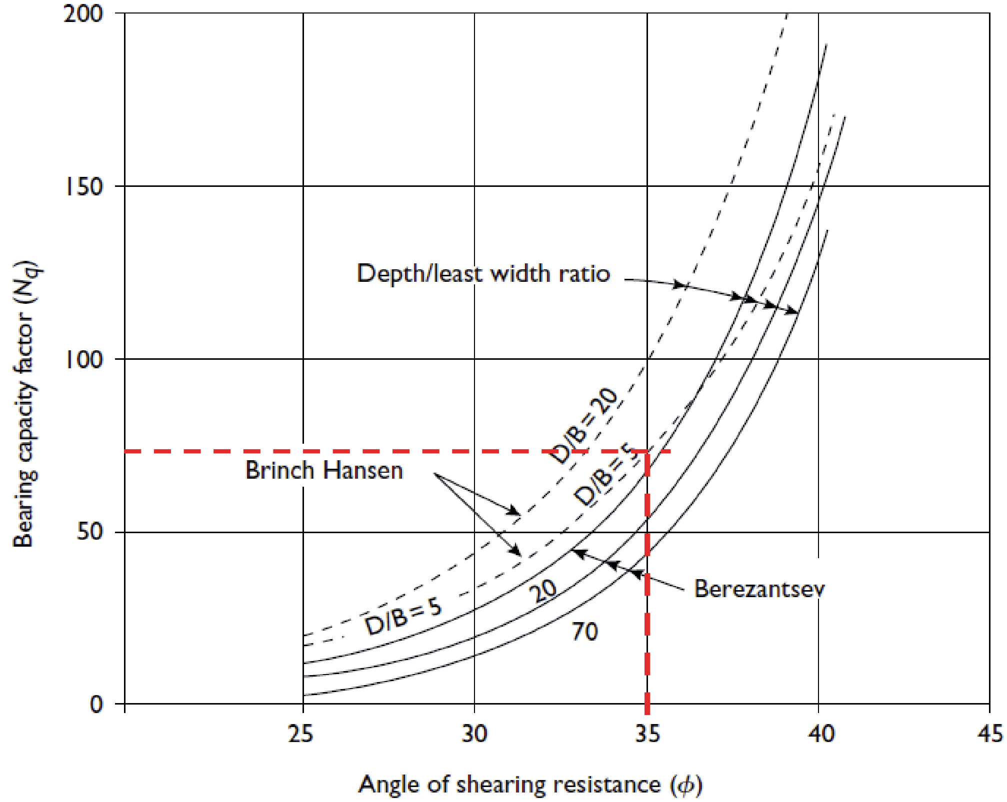



*Figure 4.13* Bearing capacity factors of Berezantsev *et al.*[4.21] and Brinch Hansen[5.4].

$$Q_p = \underbrace{\boxed{N_q \sigma'_{vo} A_b}}_{\text{End Bearing}} + \underbrace{\boxed{\frac{1}{2} K_s \sigma'_{vo} \tan \delta A_s}}_{\text{Shaft Friction = 0}}$$

*(Assuming piles may be bored therefore, shaft friction assumed to be zero)*

| | | | |
|---|---|---|---|
| Depth/width D/B | = | 14.17 | |
| Effective overburded $\sigma'_{vo}$ | = | 84.79 | kN/m$^2$ |
| Pile cross sectional area $A_b$ | = | 0.28 | m$^2$ |
| Bearing capacity factor $N_q$ | = | 75.00 | |
| Bearing capacity $Q_p$ | = | 1798 | kN |
| FOS > 2 | = | 2.3 | SAFE — Source: BS 8004:1986, Cl 7.3.8b |
| Pile end bearng pressure | = | 2.80 | MPa |