Ref: PG19-090/541 Rev00

Date: 19 February 2020

# MAMPA & SWAZI MNYAMANE ACCESS BRIDGES

## GEOTECHNICAL INVESTIGATION REPORT

PREPARED FOR: **ILIFA AFRICA ENGINEERS (PTY) LTD**

**Peregrine Geoconsultants (Pty) Ltd**

PO Box 39842, Moreleta Park, 0044, South Africa
Louis du Plessis **+27 72 284 1826** | Vian van der Westhuizen **+27 72 761 3231**
**info@peregrinegeo.co.za** | **www.peregrinegeo.co.za**
REG 2017/135870/07

## Table of Contents

## Table of Figures

## Table of Tables

## Appendices

## List of Acronyms

| Acronym | Description |
|---|---|
| c | Cohesion (kPa) |
| COLTO | Commission of Land Transport Officials |
| E | Young’s modulus (MPa) |
| FOS | Factor of Safety |
| kPa | Kilo Pascal |
| m.a.s.l. | Meters above sea level |
| MPa | Mega Pascal |
| NGL | Natural Ground Level |
| $q_a$ | Allowable bearing capacity (kPa) |
| TP | Test pit |
| UCS | Uniaxial Compressive Strength (MPa) |
| $\phi$ | Internal degree of friction (°) |
| $\gamma$ | Unit weight (kN/m$^3$) |

# 1. INTRODUCTION

Peregrine Geoconsultants was appointed in November 2019 by Ilifa Africa Engineers (Pty) Ltd to carry out geotechnical foundation investigations for the proposed upgrades to two existing stream crossing structures (Mampa and Swazi Mnyamane Access Bridges) near Burgersfort in Limpopo Province. The scope of work and associated terms and conditions of the engagement for the two bridges were detailed in the proposal letter referenced PG19-090/371 Rev00, dated 7 June 2019.

This report presents the findings of the investigations, which were aimed at providing information for each structure in terms of:

- Geological profile underlying the site areas, including identification of any problematic soil if encountered,
- Assessment of the suitability of the underlying soils for use during construction,
- Excavatability of material on site,
- Identification of groundwater level,
- Optimal founding recommendations for the structures.

The two bridges are approximately 7km apart (see Figure 1-1 below) and the geological conditions were found to be markedly different. As such, each bridge will be discussed separately in the report. The details and results of the work undertaken for each bridge are given together with comments and recommendations on the issues listed above.

**Figure 1-1: Google Earth image indicating the two bridge locations in relation to the surrounding areas.**

# 2. MAMPA ACCESS BRIDGE

## 2.1 GENERAL

The Mampa Access Bridge, from this point onwards only referred to as Mampa, is situated next to the Ga-Mampa township just to the west of the R37 regional route. Figure 2-1 and Figure 2-2 show closer views of the crossing structure, while Figure 2-3 and Figure 2-4 show recent aerial photographs of the crossing. The current structure comprises a ground embankment crossing at an elevation of approximately 1m above the ephemeral stream's bed. There are no culverts allowing flow through the embankment.

It is furthermore clear from the surrounding areas that the ground conditions are prone to severe erosion problems, possibly due to dispersive soils combined with overgrazing.

The current design of the bridge upgrade works entails a culvert crossing, comprising numerous box culverts placed next to each other, together with a network of rock-filled gabions before and after the bridge. The latter is aimed to negate the erosion effects of the high flow energy during the seasonal flood events when the stream comes down.

**Figure 2-1: Closer view of two bridge locations.**

**Figure 2-2: Close-up aerial view of Mampa Access Bridge next to R37.**

**Figure 2-3: View of the existing stream crossing.**

**Figure 2-4: Sideways view of the existing stream crossing.**

## 2.2 SITE DESCRIPTION AND GEOLOGY

### 2.2.1 GEOLOGY

According to the 1:250 000 geological map sheet 2430 PILGRIM'S REST, the site is covered by alluvial soils. These transported materials are in turn underlain by pyroxenite, porphyritic pyroxenite, anorthosite, leuconorite, melanorite, chromitite layer, Merensky reef and platreef of the Critical zone formations of the Rustenburg Layered Suite of the Bushveld Igneous Complex.

From Viljoen and Schurmann (1998) the stable Kaapvaal Craton in Southern Africa is characterised by the presence of large mafic to ultramafic layered complexes, the best known and largest of which is the Bushveld Complex. This complex was intruded about 2,060 million years ago into rocks of the Transvaal Supergroup, largely along an unconformity between the Magaliesberg quartzite of the Pretoria Group and the overlying Rooiberg felsites. The total estimated extent of the Bushveld Complex is some 66,000 km$^2$ of which about 55% is covered by younger formations. The mafic rocks of the Bushveld Complex host layers rich in Platinum Group Metals (PGM), chromium and vanadium, and constitute the world's largest known resource of these metals.

The mafic rocks (collectively termed the Rustenburg Layered Suite) can be divided into five zones known as the Marginal, Lower, Critical, Main and Upper Zones from the base upwards.

The Mampa site area is situated on the boundary of the Lower and Critical Zones. The Lower Zone is dominated by orthopyroxenite with associated harzburgites and dunites. The Critical Zone is characterised by a regular layering of chromite within pyroxenites, olivine-rich rocks and plagioclase-rich rocks (norites, anorthosites).

### 2.2.2 WEATHERING

The type and rate of rock weathering are determined by the climate of an area. Weinert (1980) developed an N-value system, which is used to derive the type of weathering likely to occur in an area based on macro-climatic conditions (evaporation and rainfall). Mechanical weathering is likely to occur in locations where N>5, while chemical weathering occurs in regions where N<5.

An N-value ranging from 2-5 was determined for this site, using the diagram provided in Figure 2-5 (TRH4, 1996). This indicates that moderate climatic conditions occur on the site and that rock and soil are therefore expected to be subject to predominantly chemical weathering.

### 2.2.3 SEISMICITY

According to the Seismic Hazard Map of South Africa (Kijko et al., 2003), the peak ground acceleration is 0.12g for the site. The peak ground acceleration may be described as the maximum acceleration of the ground shaking during an earthquake, which has a 10% probability of being exceeded in a 50-year period.

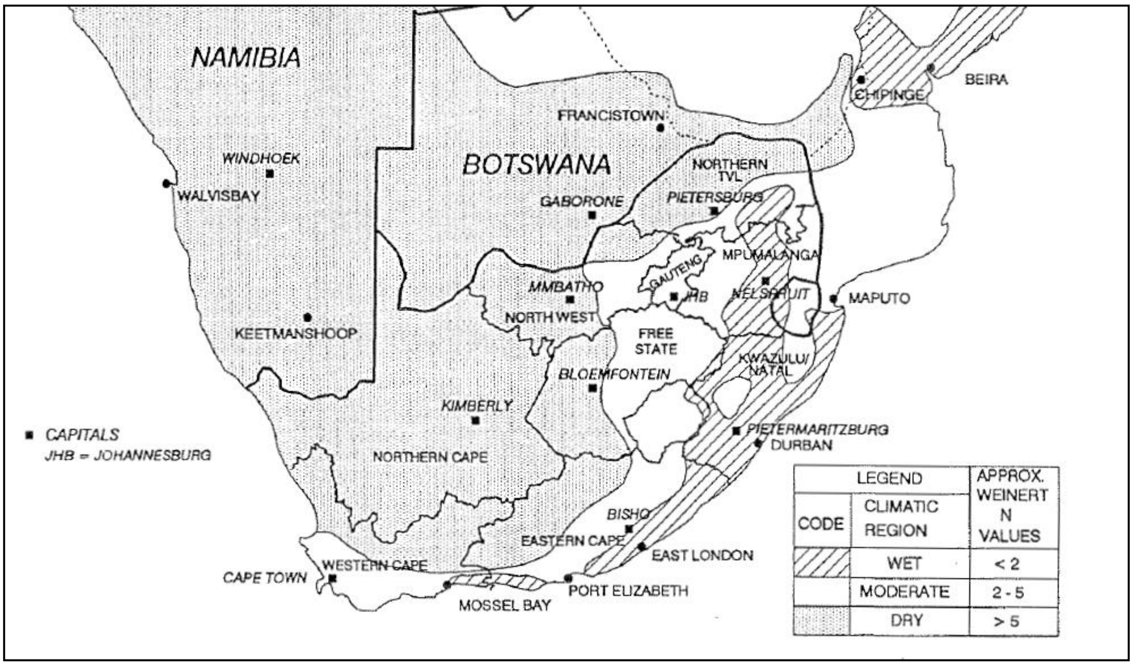


**Figure 2-5: Macro-climatic regions of Southern Africa (TRH4, 1996 adapted from Weinert, 1980).**

## 2.3 SITE INVESTIGATION

### 2.3.1 FIELD TESTING

The fieldwork for the Mampa geotechnical investigation comprised the excavation of four test pits and a DCP test next to each hole. The hole positions were chosen so that both sides of the crossing and of the road could be investigated - see Figure 2-6. The planned excavation depth was 3.0m, which typically is the maximum reach of a TLB, or until effective refusal conditions are encountered.

The investigation was conducted according to SAICE's Site Investigation Code of Practice (2010) and test pits were profiled by a geotechnical engineer in accordance with the current South

African standard procedures as per Brink and Bruin (2002). Detailed profiles and photographs are included in **Appendix A**. General site photographs are included in **Appendix D**.

The DCP tests were conducted according to the ASTM D6951/D6951M standard and interpreted using formulations from Paige-Green and Du Plessis (2009). The results are included in **Appendix B**.

**Figure 2-6: Layout of test pits on the Mampa site.**

### 2.3.2 LABORATORY TESTING

Four soil samples were taken from the test pits TP-MP01 and MP-3 and submitted for testing at Specialised Testing Laboratory, a SANAS accredited soil laboratory. Table 2-1 summarises the type and quantity of tests requested.

**Table 2-1: Laboratory test schedule summary - Mampa**

| Type of Test | Test Method | Quantity |
|---|---|---|
| Foundation Indicators | SANS 3001: GR1-3, GR10-13 | 3 |
| California Bearing Ratio | SANS 3001: GR30 | 1 |
| Moisture Density | SANS 3001: GR40 | 1 |
| pH & Conductivity | TMH1: A20, A21T | 3 |
| Chemical Dispersion | | 3 |
| Collapse Potential | BS 1377 Part 5 | 1 |

## 2.4 FIELD TEST RESULTS

### 2.4.1 TEST PITS

The test pits were excavated using a hired Tractor Loader Backhoe (TLB), with refusal conditions only encountered in TP-MP04 on buried concrete. The generalised sequence of subsurface strata encountered is summarised in Table 2-2 and can be defined as follows:

- **ALLUVIUM**

A dry to slightly moist alluvial horizon was found to cover the stream crossing site with a thickness up to 1.10m. This layer was typically described as orange-brown, intact sandy clay or fine sand with a soft/loose consistency. This is in line with the DCP results. Small grassroots were present in this layer.

- **TRANSPORTED**

A slightly moist to moist transported soil horizon was encountered at depths ranging from 0.1m to 1.1m across the site. This layer was typically described as red sandy clay or clayey sand, with a firm/medium dense to stiff/dense consistency. The structure of the material showed occasional evidence of pinhole-voided structures. Small grassroots were present in this layer at the top contact.

**Note:** Sidewall collapse was observed in the upper layer of two test pits. Refusal was only encountered in TP-MP04 at a depth of 1.70m on a large piece of concrete. It could not be determined whether this was an isolated piece of concrete, or whether it forms part of a larger buried structure.

**Table 2-2: Summary of profiles encountered on site - Mampa**

| TP No. | Sandy CLAY or SAND, Alluvium (m) | Silty CLAY or clayey SAND, Transported (m) | Excavation Depth (m) | Refusal (Y/N) | Water (m) |
|---|---|---|---|---|---|
| TP-MP01 | 0 – 0.60 | 0.60 – 3.50 | 3.50 | N | - |
| TP-MP02 | 0 – 0.30 | 0.30 – 3.70 | 3.70 | N | - |
| TP-MP03 | 0 – 1.10 | 1.10 – 3.50 | 3.50 | N | - |
| TP-MP04 | 0 – 0.10 | 0.10 – 1.70 | 1.70 | Y | - |

### 2.4.2 DCP RESULTS

Figure 2-7 summarises the DCP results in terms of DN values (mm/blow), which was translated to CBR values in Figure 2-8 using the formulations of Paige-Green and Du Plessis (2009). These CBR values can then be used to estimate stiffness values (Young’s Modulus, E’) using E’ = 0.7 x CBR, which is presented in Figure 2-9.

The results correlate well with the insitu consistency assessment of soft to stiff soils.

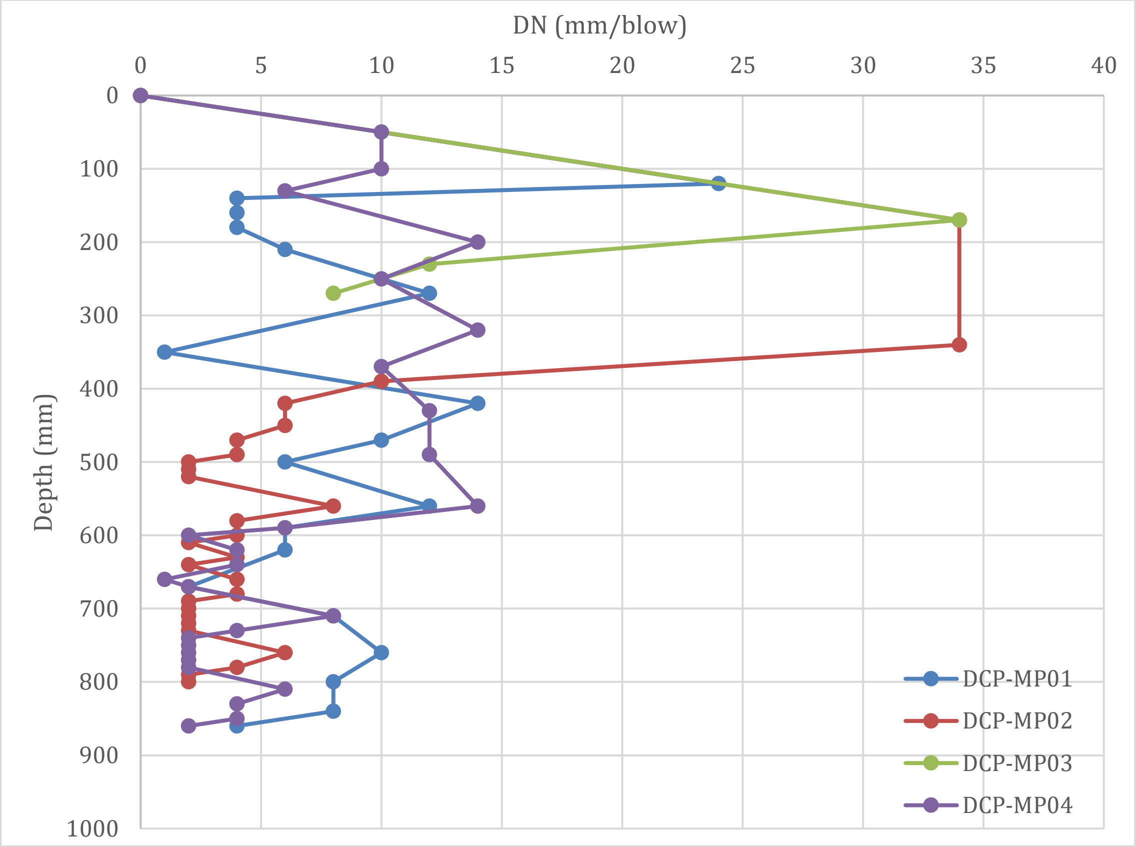


**Figure 2-7: Summary of DCP results – Mampa.**

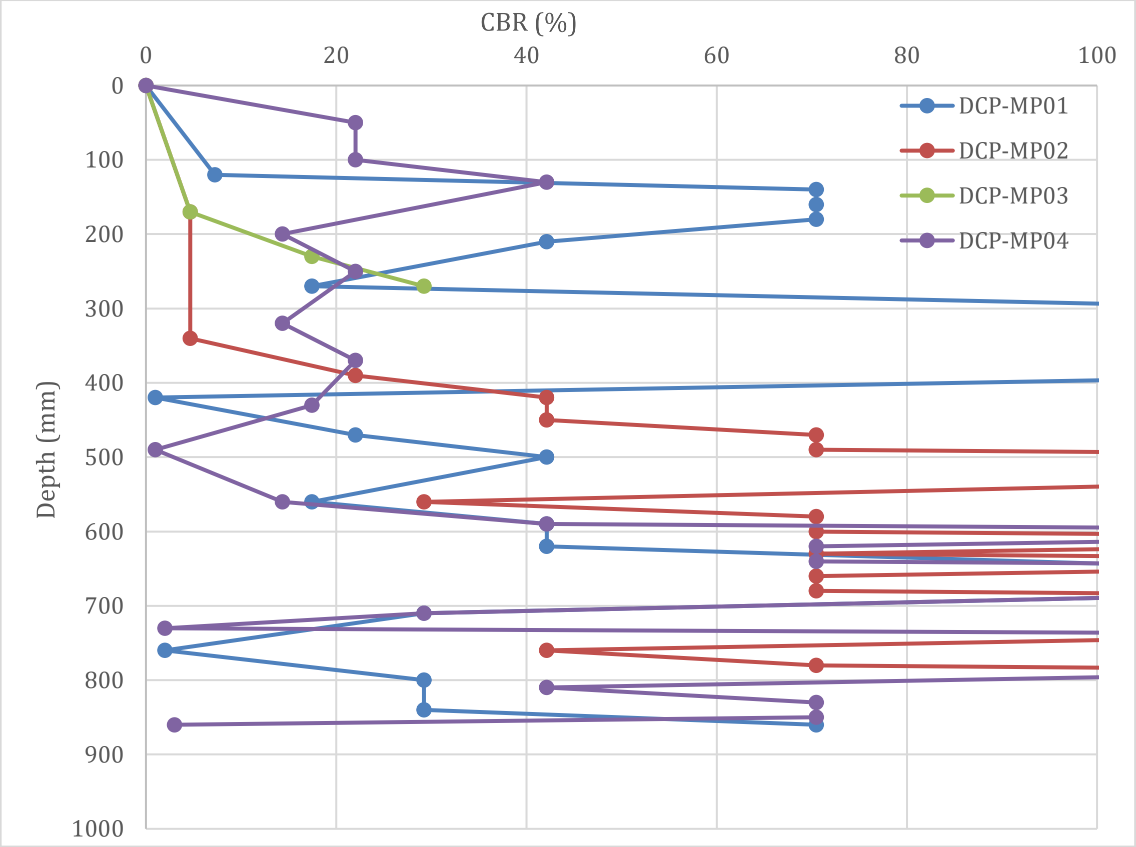


**Figure 2-8: DCP test results converted to CBR values – Mampa.**

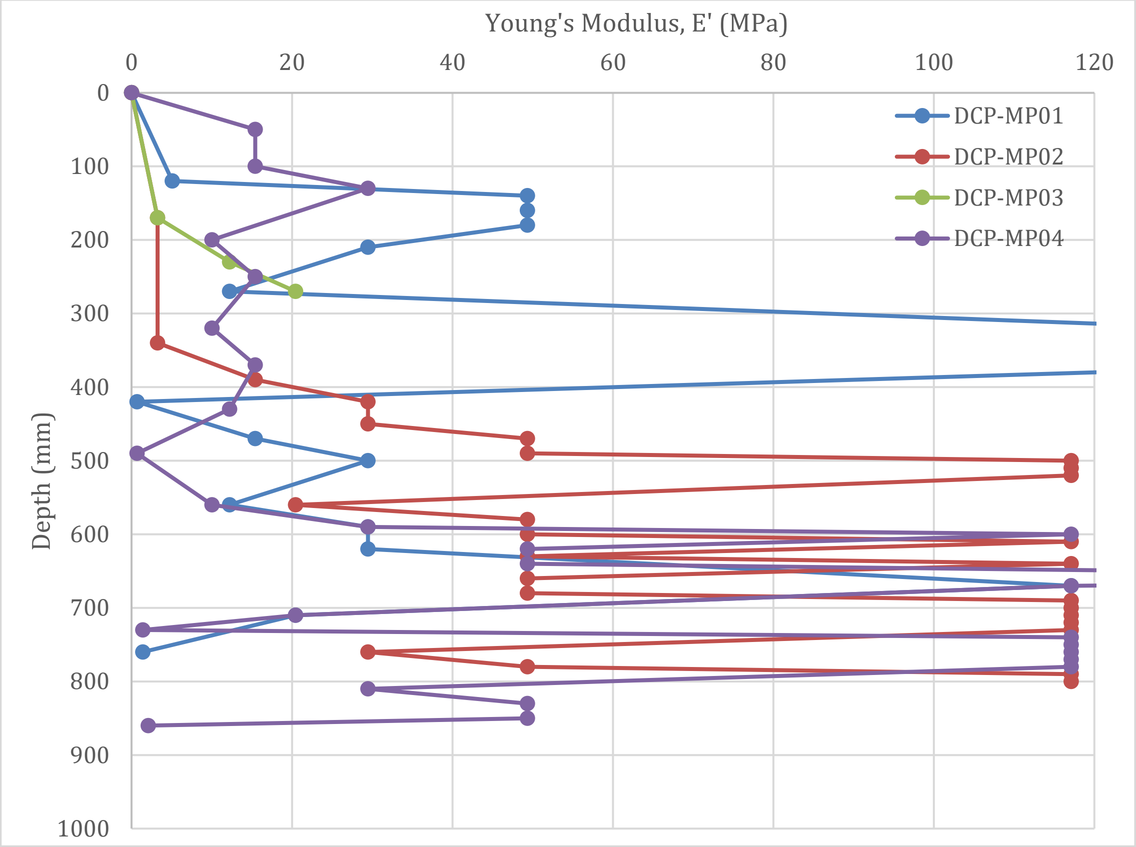


**Figure 2-9: DCP results converted to Young's Moduli – Mampa.**

## 2.5 LABORATORY TEST RESULTS

### 2.5.1 INDICATOR, STRENGTH AND CHEMICAL TESTS

Table 2-3 summarises the results of the laboratory tests conducted on disturbed samples taken from two of the test pits. The detailed results of all laboratory testing are included in **Appendix C**.

All three samples tested as sandy material with low PI values and all samples classifying with "low" expansiveness ratings according to Van Der Merwe (1964).

The moisture-density and compaction testing of the transported soil also returned favourable results, showing that it classifies as G6 quality according to COLTO guidelines. This means that it is suitable for use as subgrade and selected layers within the earthworks. It is believed that the alluvial soils will also test as G8 or better quality material.

**Table 2-3: Summary of test results conducted on disturbed samples - Mampa**

| TP No. | | TP-MP01 | TP-MP01 | TP-MP03 |
|---|---|---|---|---|
| **Depth (m)** | | **0 – 0.6** | **0.6 – 3.5** | **0 – 1.1** |
| **Description** | | **Alluvium** | **Transported** | **Alluvium** |
| Gravel (%) | | 4 | 44 | 4 |
| Sand (%) | | 78 | 45 | 95 |
| Silt (%) | | 11 | 10 | 0 |
| Clay (%) | | 7 | 1 | 1 |
| Liquid Limit | | 32 | 24 | - |
| Plasticity Index | | 12 | 4 | NP |
| Linear Shrinkage (%) | | 5.5 | 2.5 | 0.0 |
| Grading Modulus | | 1.13 | 1.91 | 1.78 |
| Expansiveness Rating | | Low | Low | Low |
| Maximum Dry Density (kg/m³) | | | 1 903 | |
| Optimum Moisture Content (%) | | | 12.5 | |
| CBR at % Mod AASHTO density | 100% | | 48 | |
| | 98% | | 43 | |
| | 97% | | 41 | |
| | 95% | | 36 | |
| | 93% | | 27 | |
| | 90% | | 18 | |
| Swell (%) | | | 0.2 | |
| COLTO Classification (1998) | | | G6 | |
| AASHTO Classification (1993) | | A-2-6 | A-1-b | A-1-b |
| Unified (ASTM D2487) | | SC | SM | SP |
| pH | | 7.7 | 7.8 | 7.2 |
| Electrical conductivity (S/m) | | 0.031 | 0.046 | 0.005 |
| Corrosivity rating (CSIR, 1997) | | Corrosive | Corrosive | Generally not |

### 2.5.2 DISPERSIVE SOILS

As noted, the severe erosion dongas in the general site area suggest evidence of dispersive soils and it was hence decided to evaluate the dispersivity of the insitu alluvial and transported soils. A flow diagram for the evaluation of dispersive soils was prepared by Gerber and Harmse (1987) and is presented in Figure 2-10. The laboratory test results are summarised in Table 2-4 below.

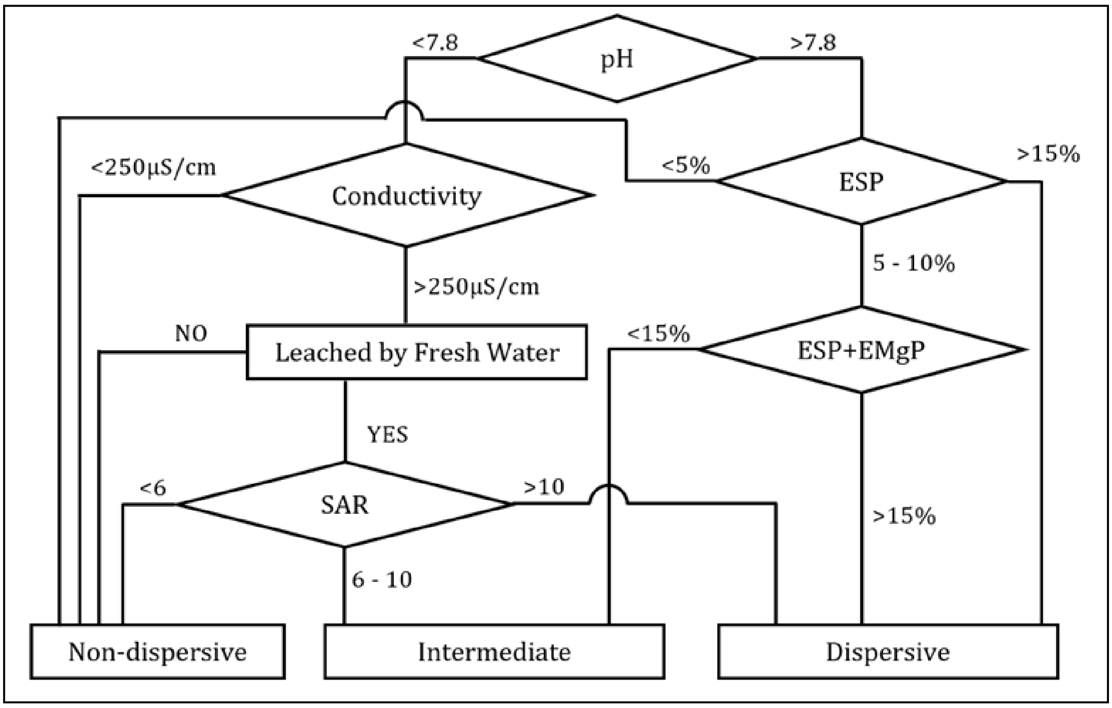


**Figure 2-10: Chemical dispersivity evaluation (Gerber and Harmse, 1987)**

**Table 2-4: Chemical analysis of soil – Mampa**

| **Parameter** | **TP-MP01** | **TP-MP01** | **TP-MP03** |
|---|---|---|---|
| **Depth (m)** | **0 – 0.6** | **0.6 – 3.3** | **0 – 1.1** |
| **Description** | **Alluvium** | **Transported** | **Alluvium** |
| pH | 8.59 | 8.54 | 9.03 |
| Conductivity (µS/cm) | 701.0 | 586.0 | 155.0 |
| Na (me/ℓ) | 3.9 | 4.6 | 1.5 |
| Ca (me/ℓ) | 62.4 | 59.4 | 36.8 |
| Mg (me/ℓ) | 23.4 | 23.4 | 19.1 |
| SAR | 0.59 | 0.72 | 0.28 |
| ESP | 2.91 | 3.09 | 3.02 |
| ESP + EMgP | 20.33 | 18.78 | 41.45 |
| **Dispersiveness rating** | **Non-dispersive** | **Non-dispersive** | **Non-dispersive** |

In accordance with Gerber and Harmse's flow diagram and test results detailed above, all tested materials are non-dispersive.

### 2.5.3 COLLAPSE POTENTIAL

The transported soils exhibited a pinhole voided structure, which is indicative of a collapsible grain structure. It was hence decided to take an undisturbed sample to test the collapse potential of the soil.

Soils which exhibit an open grain texture are prone to compression when exposed to moisture and loading. This is termed "collapse potential". Generally silty or sandy soil with a high void ratio exhibits a relatively high shear strength at low moisture content due to colloidal coating around individual grains. This is common in many transported soils and in areas where quartz-rich rock has undergone chemical weathering.

For the laboratory test, an undisturbed sample is incrementally loaded up to 200kPa after which it is inundated and loaded further to 400kPa. A plot of void ratio versus stress shows the sudden reduction of void ratio on inundation at 200kPa stress as suggested by Jennings and Knight (1975). Table 2-5 shows the severity of the collapsible potential evaluated as per the classification suggested by Jennings and Knight (1975).

**Table 2-5: Classification of collapsibility (Jennings and Knight, 1975)**

| Collapse potential (%) | Severity of problem |
|---|---|
| 0 – 1.0 | No problem |
| 1.0 – 5.0 | Moderate trouble |
| 5.0 – 10.0 | Trouble |
| 10.0 – 20.0 | Severe trouble |
| > 20.0 | Very severe trouble |

One undisturbed sample from test pit TP-MP01 was tested to assess its collapse potential. The result indicates a collapse potential of 1.09%, which according to Jennings and Knights (1975) may be considered as "moderate trouble".

## 2.6 GEOTECHNICAL ASSESSMENT AND RECOMMENDATIONS

### 2.6.1 EARTHWORKS

Based on COLTO Subclause 3303 (1998), the transported materials on the site may be classified as 'soft' excavation to a depth of at least 3.5m. With the concrete encountered in TP-MP04, it is worth considering making an allowance in the earthworks contract for the removal of boulders.

### 2.6.2 GROUNDWATER

No water seepage was encountered in any of the test pits. The dry riverbed confirms that during the time of the investigation, the water table is at least as deep as the riverbed. Note that it may be possible for a shallow water table to be present below the riverbed, hence cognisance must be taken thereof by the contractor at the commencement of any excavations.

The time of the year that the construction will occur will also have an influence on the probability of a shallow water table. The ephemeral stream will at some stage during the year come down during storm events, and this will result in at least a temporary raised water table.

### 2.6.3 STABILITY OF SLOPES

For temporary works, all slopes should be battered to 1V:1.5H to ensure safe working conditions. Permanent slopes should be battered at 1V:2H. Note that no surcharge loads were accounted for in the determination of these safe slope angles.

Should water seepage be encountered during the excavations, the batters should be reduced to 1V:2H and 1V:2.5H respectively.

### 2.6.4 PROBLEM SOILS

Although initially thought to be a problem, the laboratory test results indicate that none of the insitu soils exhibit any tendency to be dispersive. Engineering problems are seldom caused by a single source acting in isolation and it is postulated that the erosion problem in this area is no different. It is, therefore, our belief that the erosion is mostly due to the combined effect of overgrazing, high temperatures, very high evaporation rates and sporadic high-intensity rainfall events resulting in washing away of the exposed soil.

All that being said, the severe erosion visible all around the site is clearly a serious problem that requires careful consideration in the design of any stream crossing structure. This matter is discussed further in paragraph 2.6.7.

Also, negligible problems with regards to collapsible, heaving or any other problematic soils are expected for this site.

### 2.6.5 AGGRESSIVENESS OF SOIL

The soil samples tested from the test pits indicate pH values ranging from 7.2 to 7.8, which is essentially neutral. According to CSIR (1997), the tested electrical conductivities of 0.005 to 0.046S/m indicates “generally not corrosive” to “corrosive” ratings. According to SANS 1200-G (1982), this translates to “moderate” exposure conditions. The minimum cover to concrete should hence be in line with the recommendations of Table 2-6 below to ensure adequate protection of the reinforcing bars against corrosion. It is recommended that buried steel pipes and electrical wiring be adequately insulated. PVC pipes may be considered where possible.

**Table 2-6: Potential aggressive soils - Mampa**

| **Exposure Conditions** | **Specified strength of concrete (MPa)** | | | | | |
|---|---|---|---|---|---|---|
| | 20 | 25 | 30 | 40 | 50 | **Minimum cover for various exposure conditions (mm)** |
| **Mild** | 20 | 20 | 15 | 15 | 15 | |
| **Moderate** | 40 | 40 | 30 | 25 | 20 | |
| **Severe** | N/A | 50 | 40 | 40 | 35 | |
| **Very Severe** | N/A | 75 | 60 | 60 | 50 | |

### 2.6.6 FOUNDATIONS

#### *2.6.6.1 FOUNDATION DETAILS*

The preliminary bridge layout plan as provided by the Client indicates that a culvert crossing is planned. The box culverts will be placed on a cast-insitu reinforced concrete surface bed. It is expected that this surface bed will be placed within the transported sandy soil horizon, with relatively low bearing pressures. No problems with this founding approach are foreseen, as long as the resultant bearing pressures do not exceed 70kPa as is calculated in the following section.

#### *2.6.6.2 ALLOWABLE BEARING CAPACITIES*

The test pits indicate that the transported soil horizon comprises sandy clay to clayey sand material. The laboratory test results, however, indicate that the stratum’s behaviour will be dominated by the sand-fractions of the grading curve. The sandy material is described as having a medium dense to a dense consistency. From the test pit results the following effective shear strength parameters are estimated for this material, which will be used for bearing capacity calculations of the normal construction:

$c' = 0\text{kPa}$

$\phi' = 28°$

$\gamma' = 18\text{kN/m}^3$

Using the formulations of Vesic (1975) and the above shear strength parameters, an allowable bearing capacity of 70kPa at a factor of safety of 3.5 is applicable.

Using the formulations of Burland and Burbidge (1985), an elastic (immediate) settlement of 15mm is calculated when founding using a 2.0m wide strip footing placed at 0.5m below NGL at a maximum bearing pressure of 70kPa. The moderate fines content is indicative that minor consolidation settlements will occur, which is expected to be <5mm over and above the elastic settlements.

### 2.6.7 STORMWATER MANAGEMENT

As mentioned, the abundant indications of erosion wash gulleys and dongas present at and around the site, indicate that stormwater management is a critical aspect that needs to be carefully considered to ensure the long-term durability of this stream crossing structure.

The current bridge design indicates that the stream bed upstream from the crossing will be lined with reno mattresses and the embankments with gabion baskets. Concrete culvert headwalls will channel the water flow into the culverts. Downstream is very much the same configuration.

In general, we are in agreement with the downstream portion of this design. The upstream, however, may require some rethinking. The principal mechanism to control erosion/scouring problems at any impediment placed in a stream channel is to reduce the flow energy gradient. The reno mattresses upstream will achieve this to a minor degree, while also serving to protect the integrity of the stream channel and embankment materials. It is, however, our belief that additional measures may be required to further reduce the flow energy. From past experience, this can be best achieved by means of a series of upstream “check dams”. These structures are in effect small weirs that can be constructed using gabion baskets. The overspill levels of these weirs are critical, in that they must be designed to allow silting up of the weir, thereby creating a more gradual stream channel gradient with resultant reduced flow velocities. Ideally one should consider having a minimum of 3 weirs in the 100m run-up to the main crossing structure, with each weir at least 1m higher than the next. This will thus result in the flow first attenuating at each weir and then cascading over it and onto the next weir with a reduced flow energy.

# 3. SWAZI MNYAMANE ACCESS BRIDGE

## 3.1 GENERAL

The Swazi Mnyamane Access Bridge, from this point onwards only referred to as Swazi Mnyamane, is situated next to the Ga-Mampa township just to the west of the R37 regional route. Figure 2-1 and Figure 2-2 show closer views of the crossing structure, while Figure 2-3 and Figure 2-4 show recent aerial photographs of the crossing. The current structure comprises a level crossing with a single concrete pipe culvert.

Similar to Mampa, it is clear from the surrounding areas that the ground conditions are prone to severe erosion problems, possibly due to dispersive soils combined with overgrazing. There are severe erosion gulleys at the outlet of the culvert.

The current design of the bridge upgrade works entails a culvert crossing, comprising numerous box culverts placed next to each other, together with a network of rock-filled gabions before and after the bridge. The latter is aimed to negate the erosion effects of the high flow energy during the seasonal flood events when the stream comes down.

**Figure 3-1: Close-up aerial view of the Swazi Mnyamane Access Bridge.**

**Figure 3-2: View of the existing stream crossing with severe erosion visible downstream (east).**

**Figure 3-3: Sideways view of the existing stream crossing with severe erosion gulleys downstream.**

## 3.2 SITE DESCRIPTION AND GEOLOGY

### 3.2.1 GEOLOGY

The Swazi Mnyamane site is underlain by the same geology as the Mampa site – see Section 2.2.1.

### 3.2.2 WEATHERING

The type and rate of rock weathering are determined by the climate of an area. Weinert (1980) developed an N-value system, which is used to derive the type of weathering likely to occur in an area based on macro-climatic conditions (evaporation and rainfall). Mechanical weathering is likely to occur in locations where N>5, while chemical weathering occurs in regions where N<5.

An N-value ranging from 2-5 was determined for this site, using the diagram provided in Figure 2-5 (TRH4, 1996). This indicates that moderate climatic conditions occur on the site and that rock and soil are therefore expected to be subject to predominantly chemical weathering.

### 3.2.3 SEISMICITY

According to the Seismic Hazard Map of South Africa (Kijko et al., 2003), the peak ground acceleration is 0.12g for the site. The peak ground acceleration may be described as the maximum acceleration of the ground shaking during an earthquake, which has a 10% probability of being exceeded in a 50-year period.

## 3.3 SITE INVESTIGATION

### 3.3.1 FIELD TESTING

The fieldwork for the Swazi Mnyamane geotechnical investigation comprised the excavation of two test pits and a DCP test next to each hole. The hole positions were chosen so that both sides of the crossing and of the road could be investigated – see Figure 3-4. The planned excavation depth was 3.0m, which typically is the maximum reach of a TLB, or until effective refusal conditions are encountered.

The investigation was conducted according to SANS 634 (2012) and SAICE’s Site Investigation Code of Practice (2010), and test pits were profiled by a geotechnical engineer in accordance with the current South African standard procedures as per Brink and Bruin (2002). Detailed profiles and photographs are included in **Appendix A**. General site photographs are included in **Appendix D**.

The DCP tests were conducted according to the ASTM D6951/D6951M standard and interpreted using formulations from Paige-Green and Du Plessis (2009). The results are included in **Appendix B**.

**Figure 3-4: Layout of test pits on the Swazi Mnyamane site.**

### 3.3.2 LABORATORY TESTING

Two soil samples were taken from test pit TP-SM01 and submitted for testing at Specialised Testing Laboratory, a SANAS accredited soil laboratory. Table 3-1 summarises the type and quantity of tests requested.

**Table 3-1: Laboratory test schedule summary – Swazi Mnyamane**

| Type of Test | Test Method | Quantity |
|---|---|---|
| Foundation Indicators | SANS 3001: GR1-3, GR10-13 | 1 |
| California Bearing Ratio | SANS 3001: GR30 | 1 |
| Moisture Density | SANS 3001: GR40 | 1 |
| pH & Conductivity | TMH1: A20, A21T | 1 |
| Chemical Dispersion | | 1 |
| Swell Pressure | BS 1377 Part 5 | 1 |

## 3.4 FIELD TEST RESULTS

### 3.4.1 TEST PITS

The test pits were excavated using a hired Tractor Loader Backhoe (TLB), with no refusal conditions encountered in either of the holes. The generalised sequence of subsurface strata encountered is summarised in Table 3-2 and can be defined as follows:

- **ALLUVIUM**

A uniform moist alluvial horizon was found to cover the stream crossing site with a thickness up to 3.30m. This layer was typically described as light brown to grey, slickensided clay with a soft to firm consistency. This is in line with the DCP results. Small grassroots were present at the surface of this layer.

It is important to note the slickensided structure of the clay material, as this is indicative of an active clay that historically has undergone significant heave and shrinkage movements with changes in the moisture regime.

**Table 3-2: Summary of profiles encountered on site – Swazi Mnyamane**

| TP No. | CLAY, Alluvium (m) | Excavation Depth (m) | Refusal (Y/N) | Water (m) |
|---|---|---|---|---|
| TP-SM01 | 0 – 3.30 | 3.30 | N | - |
| TP-SM02 | 0 – 3.30 | 3.30 | N | - |

### 3.4.2 DCP RESULTS

Figure 3-5 summarises the DCP results in terms of DN values (mm/blow), which was translated to CBR values in Figure 3-6 using the formulations of Paige-Green and Du Plessis (2009). These CBR values can then be used to estimate stiffness values (Young's Modulus, E') using E' = 0.7 x CBR, which is presented in Figure 3-7.

The results correlate well with the insitu consistency assessment of soft to firm soils.

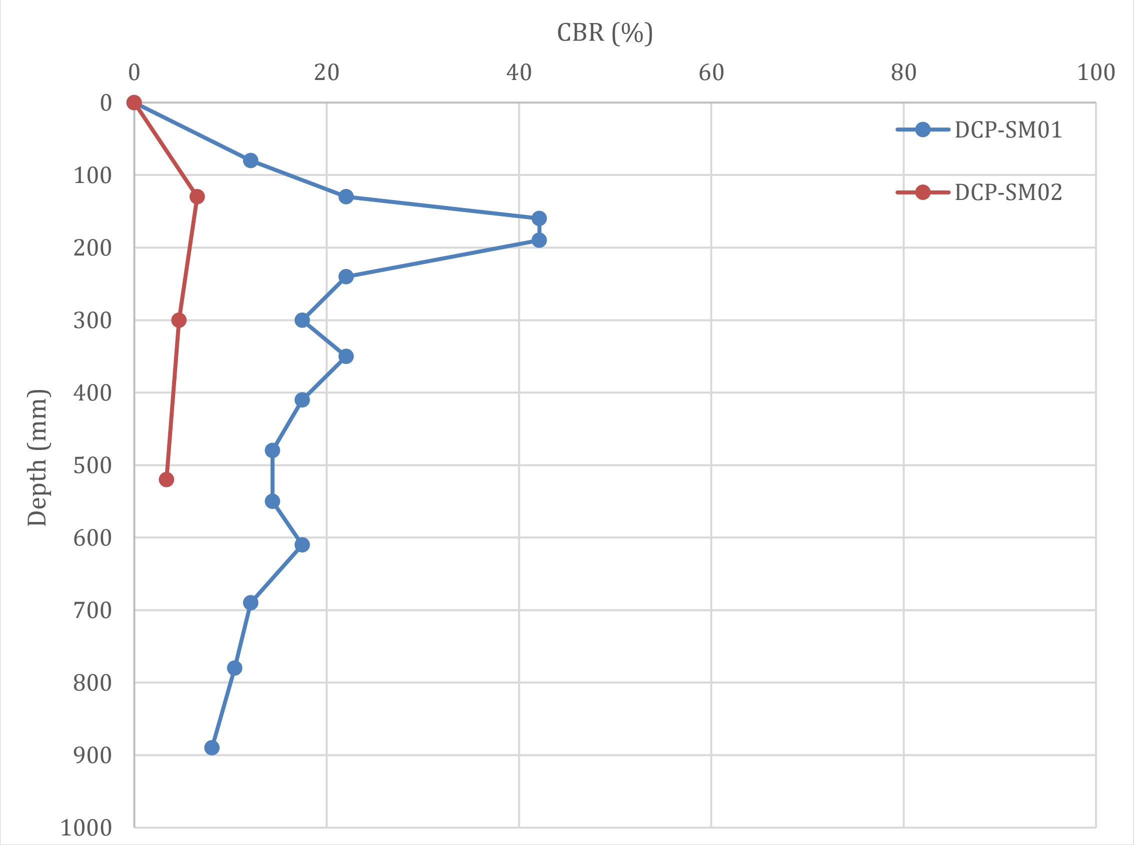


**Figure 3-5: Summary of DCP results – Swazi Mnyamane.**

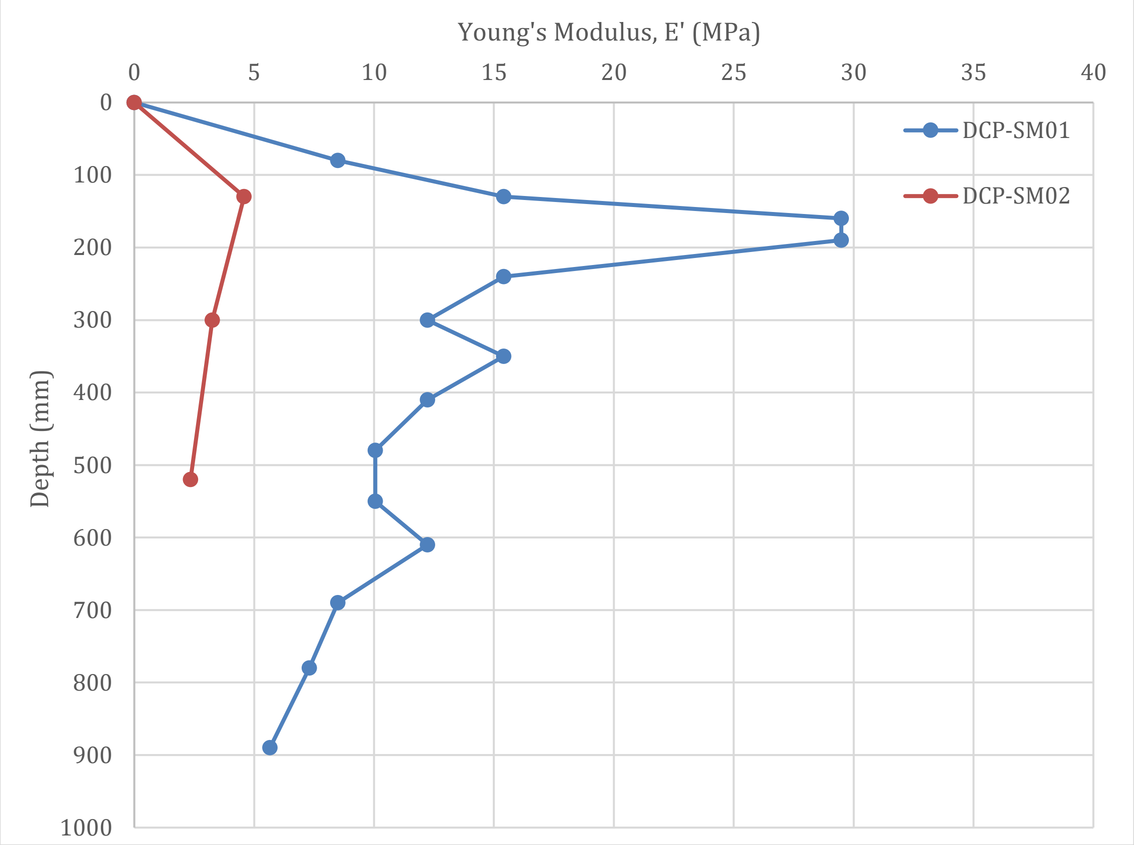


**Figure 3-6: DCP test results converted to CBR values – Swazi Mnyamane.**

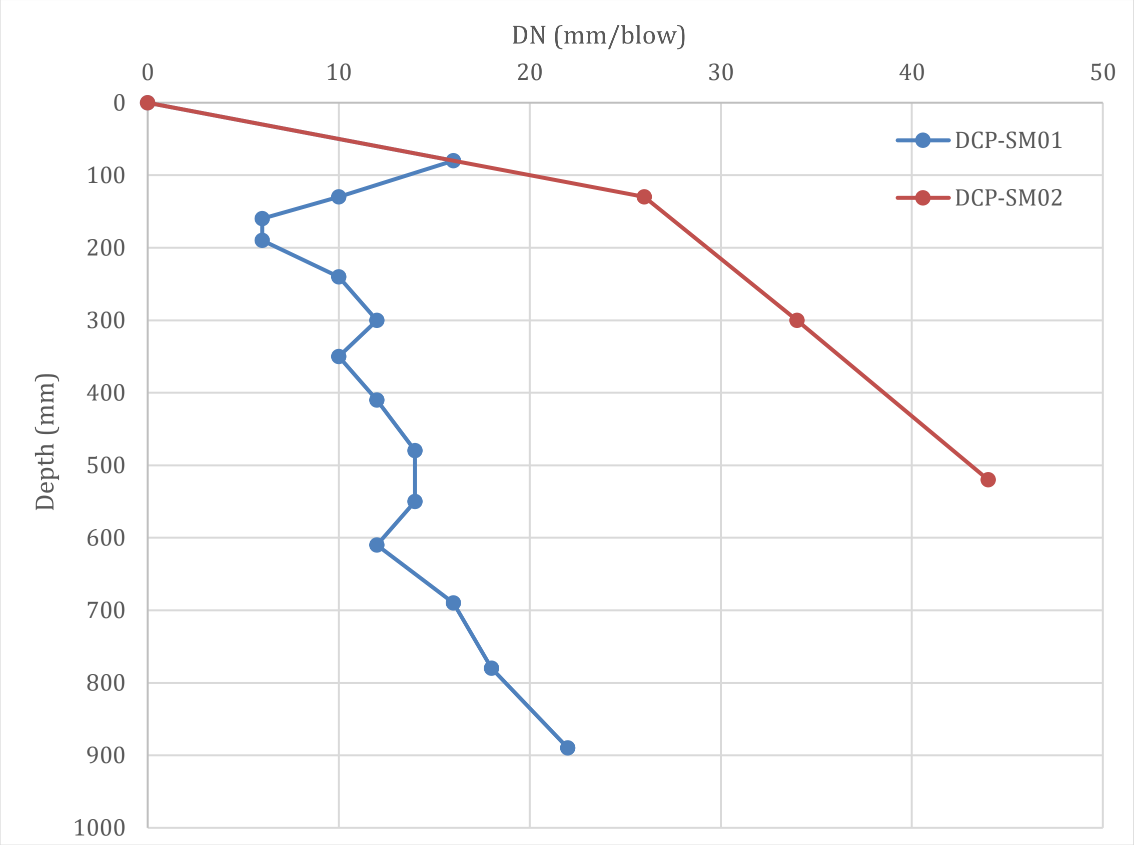


**Figure 3-7: DCP results converted to Young's Moduli – Swazi Mnyamane.**

## 3.5 LABORATORY TEST RESULTS

### 3.5.1 INDICATOR, STRENGTH AND CHEMICAL TESTING

Table 3-3 summarises the results of the laboratory tests conducted on disturbed samples taken from test pit TP-SM01. The detailed results of all the laboratory testing are included in **Appendix C**.

As expected, the alluvial soil tested indicate a very high clay content and associated high PI value. According to Van Der Merwe (1964), the sample classifies with a “very high” expansiveness rating.

The moisture-density and compaction testing confirmed that the clayey material will not compact well and will therefore not be suitable for use in layerworks.

**Table 3-3: Summary of test results conducted on disturbed samples – Swazi Mnyamane**

| **TP No.** | | **TP-SM01** |
|---|---|---|
| **Depth (m)** | | **0 – 3.3** |
| **Description** | | **Alluvium** |
| Gravel (%) | | 3 |
| Sand (%) | | 25 |
| Silt (%) | | 27 |
| Clay (%) | | 45 |
| Liquid Limit | | 76 |
| Plasticity Index | | 37 |
| Linear Shrinkage (%) | | 23.5 |
| Grading Modulus | | 0.28 |
| Expansiveness Rating | | Very high |
| Maximum Dry Density (kg/m$^3$) | | 1 463 |
| Optimum Moisture Content (%) | | 25.5 |
| CBR at % Mod AASHTO density | 100% | 2.2 |
| | 98% | 2.0 |
| | 97% | 2.0 |
| | 95% | 1.8 |
| | 93% | 1.6 |
| | 90% | 1.4 |
| Swell (%) | | 12.9 |
| COLTO Classification (1998) | | NC* |
| AASHTO Classification (1993) | | A-7-5 |
| Unified (ASTM D2487) | | MH |
| pH | | 8.1 |
| Electrical conductivity (S/m) | | 0.167 |
| Corrosivity rating (CSIR, 1997) | | Very corrosive |

### 3.5.2 DISPERSIVE SOILS

As noted, evidence of dispersive soils was noted on site and hence it was decided to evaluate the dispersivity of the insitu soils. A flow diagram for the evaluation of dispersive soils was prepared by Gerber and Harmse (1987) and is presented in Figure 2-10. The laboratory test results are summarised in Table 3-4 below.

**Table 3-4: Chemical analysis of soil – Swazi Mnyamane**

| **Parameter** | **TP-SM01** |
|---|---|
| **Depth (m)** | **0 – 3.3** |
| **Description** | **Alluvium** |
| pH | 8.23 |
| Conductivity (µS/cm) | 2300.0 |
| Na (me/ℓ) | 15.6 |
| Ca (me/ℓ) | 65.0 |
| Mg (me/ℓ) | 24.7 |
| SAR | 2.33 |
| ESP | 3.63 |
| ESP + EMgP | 9.37 |
| **Dispersive rating** | **Non-dispersive** |

In accordance with Gerber and Harmse's flow diagram and test results detailed above, the tested material is non-dispersive.

### 3.5.3 HEAVING SOILS

The assessed high clay content together with the slickensided structure visible in the test pits, lead to the conclusion that this material will be prone to heave movements. In order to assess the effect that heave will have on the bridge crossing structure, an undisturbed block sample was taken from TP-SM01 (0 – 3.3m) for swell pressure testing.

The swelling pressure may be defined as the pressure required for preventing volume expansion of soil in contact with water. The tested soil indicated a swell pressure of 27.9kPa, meaning that an overburden pressure of basically 28kPa is required to prevent the soil from swelling/heaving.

Furthermore, the swell potential of the tested soil was assessed using the formulations of Weston (1980), with a total heave of 4mm estimated.

## 3.6 GEOTECHNICAL ASSESSMENT AND RECOMMENDATIONS

### 3.6.1 EARTHWORKS

Based on COLTO Subclause 3303 (1998), the alluvial materials on the site may be classified as 'soft' excavation to a depth of at least 3.30m.

### 3.6.2 GROUNDWATER

No water seepage was encountered in either of the test pits nor was any water seepage visible in the erosion gulley at the outlet of the culvert.

The time of the year that the construction will occur will have an influence on the probability of a shallow water table. The stream will at some stage during the year come down due to the storm events, and this will result in at least a temporary raised water table.

### 3.6.3 STABILITY OF SLOPES

For temporary works, all slopes should be battered to 1V:1.5H to ensure safe working conditions. Permanent slopes should be battered at 1V:2H. Note that no surcharge loads were accounted for in the determination of these safe slope angles.

Should water seepage be encountered during the excavations, the batters should be reduced to 1V:2H and 1V:2.5H respectively.

### 3.6.4 PROBLEM SOILS

Again as per Mampa, although initially thought to be a problem, the laboratory test results indicate that none of the insitu soils exhibit any tendency to be dispersive. Engineering problems are seldom caused by a single source acting in isolation and it is postulated that the erosion problem in this area is no different. It is, therefore, our belief that the erosion is mostly due to the combined effect of overgrazing, high temperatures, very high evaporation rates and sporadic high-intensity rainfall events resulting in washing away of the exposed soil.

All that being said, the severe erosion visible all around the site is clearly a serious problem that requires careful consideration in the design of any stream crossing structure. This matter is discussed further in paragraph 3.6.7.

Also, negligible problems with regards to collapsible, heaving or any other problematic soils are expected for this site.

### 3.6.5 AGGRESSIVENESS OF SOIL

The soil sample tested from the test pits indicate a pH value of 8.1, which is slightly basic. According to CSIR (1997), the tested electrical conductivity of 0.167S/m indicates a “very corrosive” rating. According to SANS 1200-G (1982), this translates to “severe” to “very severe” exposure conditions. The minimum cover to concrete should hence be in line with the recommendations of Table 3-5 below to ensure adequate protection of the reinforcing bars against corrosion. It is recommended that buried steel pipes and electrical wiring be adequately insulated. PVC pipes may be considered where possible.

**Table 3-5: Potential aggressive soils – Swazi Mnyamane**

| **Exposure Conditions** | **Specified strength of concrete (MPa)** | | | | | |
|---|---|---|---|---|---|---|
| | **20** | **25** | **30** | **40** | **50** | |
| **Mild** | 20 | 20 | 15 | 15 | 15 | **Minimum cover for various exposure conditions (mm)** |
| **Moderate** | 40 | 40 | 30 | 25 | 20 | |
| **Severe** | N/A | 50 | 40 | 40 | 35 | |
| **Very Severe** | N/A | 75 | 60 | 60 | 50 | |

### 3.6.6 FOUNDATIONS

#### *3.6.6.1 FOUNDATION DETAILS*

The preliminary bridge layout plan provided by the Client for Swazi Mnyamane indicates that a culvert crossing is planned. The box culverts will be placed on a cast-insitu reinforced concrete surface bed. It is expected that this surface bed will be placed within the alluvial clayey soil horizon, with relatively low resultant bearing pressures. No problems with this founding approach are foreseen, as long as the resultant bearing pressures do not exceed 50kPa as is calculated in the following section.

#### *3.6.6.2 ALLOWABLE BEARING CAPACITIES*

The test pits indicate that the transported soil horizon comprises sandy clay to clayey sand material. The laboratory test results, however, indicate that the stratum's behaviour will be dominated by the sand-fractions of the grading curve. The sandy material is described as having a medium dense to a dense consistency. From the test pit results the following effective shear strength parameters are estimated for this material, which will be used for bearing capacity calculations of the normal construction:

$c' = 3\text{kPa}$

$\phi' = 25°$

$\gamma' = 18\text{kN/m}^3$

Using the formulations of Vesic (1975) and the above shear strength parameters, an allowable bearing capacity of 50kPa at a factor of safety of 3.5 is applicable.

Using the formulations of Burland and Burbidge (1985), an elastic (immediate) settlement of 10mm is calculated when founding using a 2.0m wide strip footing placed at 0.5m below NGL at a maximum bearing pressure of 50kPa. The high fines content is indicative that significant consolidation settlements may occur, which is expected to be in the order of 20mm over and above the elastic settlements.

### 3.6.7 STORMWATER MANAGEMENT

As mentioned, the abundant indications of erosion wash gulleys and dongas present at the culvert outlet indicate that stormwater management is a critical aspect that needs to be carefully considered to ensure the long-term durability of this stream crossing structure.

The current design indicates that the stream bed upstream from the crossing will be lined with reno mattresses and the embankments with gabion baskets. Concrete culvert headwalls will channel the water flow into the culverts. Downstream is very much the same configuration, but with the gabion embankment incrementally narrowing downstream to force the flow into a channel narrower than the total culvert opening.

As with Mampa, generally we agree with the downstream portion of this design. The upstream, however, may require some rethinking. The principal mechanism to control erosion/scouring problems at any impediment placed in a stream channel is to reduce the flow energy gradient. The reno mattresses upstream will achieve this to a minor degree, while also serving to protect the integrity of the stream channel and embankment materials. It is, however, our belief that additional measures may be required to further reduce the flow energy. From past experience, this can be best achieved by means of a series of upstream "check dams". These structures are in effect small weirs that can be constructed using gabion baskets. The overspill levels of these weirs are critical, in that they must be designed to allow silting up of the weir, thereby creating a more gradual stream channel gradient with resultant reduced flow velocities. Ideally one should consider having a minimum of 3 weirs in the 100m run-up to the main crossing structure, with each weir at least 1m higher than the next. This will thus result in the flow first attenuating at each weir and then cascading over it and onto the next weir with a reduced flow energy.

## 4. REFERENCES

AASHTO. 1993. *Recommended Practice for the Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes*. AASHTO designation M 145-91, Standard Specifications for Transportation Materials and Methods of Sampling and Testing. American Association of Highway and Transportation Officials. Washington DC.

ASTM D2487. 2011. *Standard Practice for Classification of Soils for Engineering Purposes* (Unified Soil Classification System).

Brink, A.B.A. and Bruin, R.M.H. 2002. *Guidelines for soil and rock logging in South Africa, 2nd impression 2002*. Proceedings of geo-terminology workshop organised by AEG, SAICE and SAIEG.

BS 1377-5. 1990. Soils for civil engineering purposes – Part 5: Compressibility, permeability and durability tests.

Burland, J. B. and Burbidge, M.C. 1985. Settlement of foundations on sand and gravel. Procedures of the Institution of Civil Engineers.

COLTO. 1998. Committee of Land Transport Officials. *Standard Specification for Road and Bridge Works for State Authorities*.

Craig, R.F. 2004. *Craig's Soil Mechanics*. Seventh Edition. Spon Press London.

DRAFT TRH4. 1996. *Structural design of flexible pavements for interurban and rural roads*. Committee of Land Transport Officials.

Gerber, F.A. and Harmse, H.J. Von Maltitz. 1987*. Proposed procedure for identification of dispersive soils by chemical testing.* The Civil Engineer in South Africa. October 1987, pp 397-399.

Jennings, J.E. and Knight, K. 1975. *A guide to construction on or with materials exhibiting additional settlement due to 'collapse' of grain structure.* 6th Regional Conference for Africa on Soil Mechanics and Foundation Engineering, Durban, South Africa, Volume 1. pp 99-105.

Kijko, A., Graham, G., Bejaichund, M., Roblin, D. and Brandt, M.B.C. 2003. *Probabilistic peak ground acceleration and spectral seismic maps for South Africa*. Report number 2003-053. Council for Geoscience. 33pp.

Paige-Green, P. and Du Plessis, L. 2009. *The use and interpretation of the Dynamic Cone Penetrometer (DCP) test*. Version 2. CSIR Built Environment, Pretoria.

SANS 10400-H. 2012. The application of the national building regulations - Part H: Foundations.

SANS 1200-G. 1982. Standardised specification for civil engineering construction - Part G: Concrete (Structural).

SANS 3001. Series of standards describing Civil Engineering Test Methods.

Site Investigation Code of Practice, 1st Edition. 2010. South African Institution of Civil Engineering - Geotechnical Division.

TMH1. 1986. *Standard methods of testing road construction materials.* Published for the Department of Transport for the Committee for State Road Authorities.

Van der Merwe, D.H. 1964. *The prediction of Heave from the Plastic Index and the Clay Fraction*. Civil Engineering, South Africa. Vol 6 No 6.

Vesic, A.S. 1975. *Bearing capacity of shallow foundations.* In Foundation Engineering Handbook, Ed. Winterkorn, H.F. and Fang, H Y. Pub: Van Nostrand Reinhold Co.

Viljoen, M.J. and Schurmann, L.W. 1998. *Platinum-group metals*. Wilson, M.G.C. and Anheausser, C.R. (eds), The Mineral Resources of South Africa, Council for Geoscience, Handbook 16, 6th Edition, Pretoria. pp 532–568.

Weinert, H.H. 1980. *The natural road construction materials of Southern Africa*. National Institute for Transport and Road Research, Pretoria. 298pp.

Weston, D.J. 1980. *Expansive roadbed treatment for Southern Africa*. Proceedings of the 4th International Conference on Expansive Soils. ASCE. Denver, Colorado, USA. pp 339-360.

## 5. LIMITATIONS

The findings contained in this report are the result of limited discrete investigations conducted in accordance with normal practices and standards. To the best of our knowledge, they represent a reasonable interpretation of the general condition of the site.

For and on behalf of **Peregrine Geoconsultants (Pty) Ltd**:

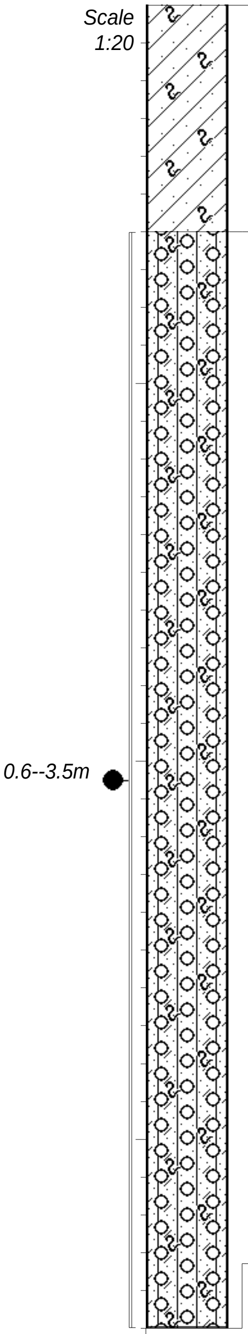
| | |
|---|---|
| **Compiled by:** | **Reviewed/Approved by:** |
| Ngoetjane | |
| Mary Ngoetjane<br>Project Geotechnical Engineer | Louis du Plessis<br>Geotechnical Engineer, PrEng |

# APPENDIX A:
# TEST PIT PROFILES & PHOTOGRAPHS

**Ilifa Africa Engineers (Pty) Ltd**
Mampa & Swazi Mnyamane Bridges
Geotechnical Investigation

*HOLE No:* TP-MP01
*Sheet 1 of 1*

*JOB NUMBER:* PG19-090



*0.00*

Dry to slightly moist, brown banded light brown, soft, intact, sandy CLAY. **ALLUVIUM**.

Notes:
Traces of small roots.

*0.60*

Dry to slightly moist, red, medium dense to dense, intact, clayey SAND. **TRANSPORTED**.

Notes:
Pockets of brown silt within layer.
Small area where a pinholed structure is visible.
Traces of small roots.
Slightly ferruginised gravel encountered.

*3.50*

NOTES

1) No refusal. Excavation stopped at end of TLB reach.

2) No seepage encountered.

3) Sidewalls stable.

4) Profiled insitu.

5) Bulk samples taken at 0--0.6m and 0.6--3.5m.

6) Coordinates captured with handheld GPS.

*CONTRACTOR :*
*MACHINE :* JCB 3CX (TLB)
*EXCAVATED BY :*
*PROFILED BY :* MN

*TYPE SET BY : MN*
*SETUP FILE : PGTEST~2.SET*

*LENGTH :* Vertical
*WIDTH :* 0.7m wide trench
*DATE :* 2019/11/14
*DATE :* 2019/11/14

*DATE : 19/02/2020 18:13*
*TEXT : ..19090TPProfilesRev00.TXT*

*ELEVATION :* 799m
*EASTING :* S 24 20 40.04
*NORTHING :* E 30 01 41.71

*HOLE No:* TP-MP01

**TP-MP01**

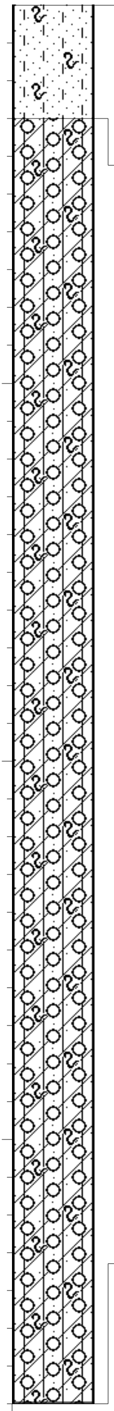
PEREGRINE
GEOCONSULTANTS

**Ilifa Africa Engineers (Pty) Ltd**
Mampa & Swazi Mnyamane Bridges
Geotechnical Investigation

*HOLE No:* TP-MP02
*Sheet 1 of 1*

*JOB NUMBER:* PG19-090

*Scale*
*1:20*



*0.00*

Dry to slightly moist, brown, <u>loose</u>, intact, silty SAND. **ALLUVIUM**.

<u>Notes</u>:
Traces of small roots.

*0.30*

Dry to slightly moist, red, <u>firm to stiff</u>, intact, sandy CLAY. **TRANSPORTED**.

<u>Notes</u>:
Pockets of brown silt within layer.
Traces of small roots.
Slightly ferruginised gravel encountered .

*3.70*

NOTES

1) No refusal. Excavation stopped at end of TLB reach.

2) No seepage encountered.

3) Sidewalls stable.

4) Profiled insitu.

5) No sample taken.

6) Coordinates captured with handheld GPS.

*CONTRACTOR :*
*MACHINE :* JCB 3CX (TLB)
*EXCAVATED BY :*
*PROFILED BY :* MN

*TYPE SET BY : MN*
*SETUP FILE : PGTEST~2.SET*

*LENGTH :* Vertical
*WIDTH :* 0.7m wide trench
*DATE :* 2019/11/14
*DATE :* 2019/11/14

*DATE : 19/02/2020 18:13*
*TEXT : ..19090TPProfilesRev00.TXT*

*ELEVATION :* 799m
*EASTING :* S 24 20 40.30
*NORTHING :* E 30 01 42.02

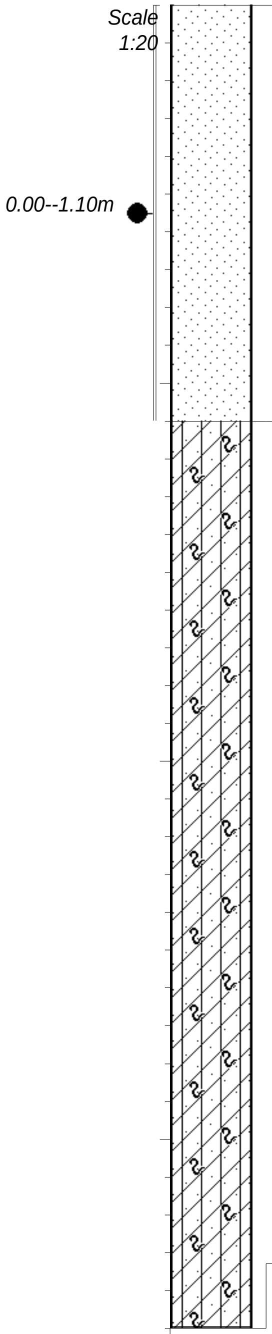
*HOLE No:* TP-MP02

**TP-MP02**

**Ilifa Africa Engineers (Pty) Ltd**
Mampa & Swazi Mnyamane Bridges
Geotechnical Investigation

*HOLE No:* TP-MP03
*Sheet 1 of 1*

*JOB NUMBER:* PG19-090



*0.00*

Moist, orange brown, <u>loose</u>, intact, fine SAND. **ALLUVIUM**.

<u>Notes</u>:
Sidewalls unstable with partial collapse.

*1.10*

Moist, red, <u>firm to stiff</u>, intact, sandy CLAY. **TRANSPORTED**.

<u>Notes</u>:
Pockets of brown silt within layer.
Traces of small roots.

*3.50*

NOTES

1) No refusal. Excavation stopped at end of TLB reach.

2) No seepage encountered.

3) Sidewalls unstable up to 1.1m deep.

4) Profiled insitu.

5) Disturbed sample taken at 0.00--1.10m.

6) Coordinates captured with handheld GPS.

*CONTRACTOR :*
*MACHINE :* JCB 3CX (TLB)
*EXCAVATED BY :*
*PROFILED BY :* MN

*TYPE SET BY :* MN
*SETUP FILE :* PGTEST~2.SET

*LENGTH :* Vertical
*WIDTH :* 0.7m wide trench
*DATE :* 2019/11/14
*DATE :* 2019/11/14

*DATE :* 19/02/2020 18:13
*TEXT :* ..19090TPProfilesRev00.TXT

*ELEVATION :* 799m
*EASTING :* S 24 20 40.00
*NORTHING :* E 30 01 42.78

*HOLE No:* TP-MP03

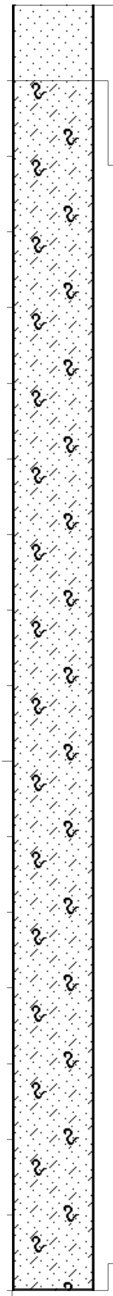
**TP-MP03**

**Ilifa Africa Engineers (Pty) Ltd**
Mampa & Swazi Mnyamane Bridges
Geotechnical Investigation

*HOLE No:* TP-MP04
*Sheet 1 of 1*

*JOB NUMBER:* PG19-090

*Scale*
*1:10*



*0.00*

Moist, orange brown, <u>medium dense</u>, intact, fine SAND. **ALLUVIUM**.

<u>Notes</u>:
Sidewalls unstable in this layer.

*0.10*

Moist, red, <u>medium dense</u> to <u>dense</u>, intact, clayey SAND. **TRANSPORTED**.

<u>Notes</u>:
Small area where a pinholed structure is visible.
Traces of small roots.

*1.70*

NOTES

1) Refusal at 1.70m on unknown concrete structure.

2) No seepage encountered.

3) Sidewalls generally stable, but with some collapse in upper 0.1m.

4) Profiled insitu.

5) No sample taken.

6) Coordinates captured with handheld GPS.

*CONTRACTOR :*
*MACHINE :* JCB 3CX (TLB)
*EXCAVATED BY :*
*PROFILED BY :* MN

*TYPE SET BY : MN*
*SETUP FILE : PGTEST~2.SET*

*LENGTH :* Vertical
*WIDTH :* 0.7m wide trench
*DATE :* 2019/11/14
*DATE :* 2019/11/14

*DATE : 19/02/2020 18:13*
*TEXT : ..19090TPProfilesRev00.TXT*

*ELEVATION :* 799m
*EASTING :* S 24 20 39.85
*NORTHING :* E 30 01 42.28

*HOLE No:* TP-MP04

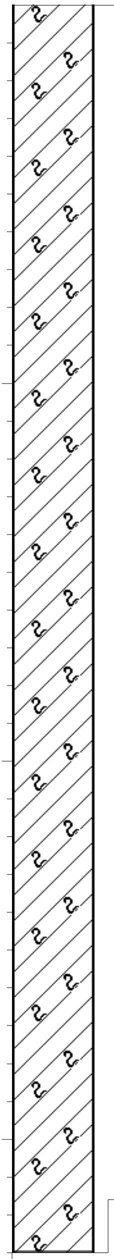
**TP-MP04**

**Ilifa Africa Engineers (Pty) Ltd**
Mampa & Swazi Mnyamane Bridges
Geotechnical Investigation

*HOLE No:* TP-SM01
*Sheet 1 of 1*

*JOB NUMBER:* PG19-090

*Scale*
*1:20*



*0.00*

Moist, grey, firm, slickensided, CLAY. **ALLUVIUM**.

Notes:
Minor roots at top 0.1m.

*3.30*

NOTES
1) No refusal. Excavation stopped at end of TLB reach.
2) No water seepage encountered.
3) Sidewalls stable.
4) Profiled insitu.
5) Bulk sample taken at 0--3.3m.
6) Undisturbed sample taken at 0--0.3m.
7) Coordinates captured with handheld GPS.

*CONTRACTOR :*
*MACHINE :* JCB 3CX (TLB)
*EXCAVATED BY :*
*PROFILED BY :* MN

*TYPE SET BY : MN*
*SETUP FILE : PGTEST~2.SET*

*LENGTH :* Vertical
*WIDTH :* 0.7m wide trench
*DATE :* 2019/11/14
*DATE :* 2019/11/14

*DATE : 19/02/2020 18:13*
*TEXT : ..19090TPProfilesRev00.TXT*

*ELEVATION :* 871m
*EASTING :* S 24 23 48.47
*NORTHING :* E 29 59 31.23

*HOLE No:* TP-SM01

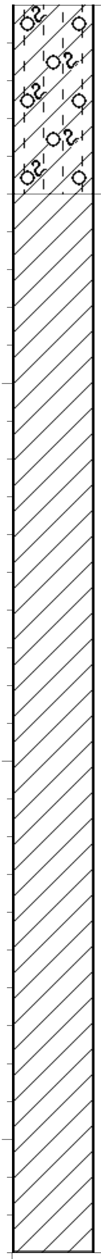
**TP-SM01**

**Ilifa Africa Engineers (Pty) Ltd**
Mampa & Swazi Mnyamane Bridges
Geotechnical Investigation

*HOLE No:* TP-SM02
*Sheet 1 of 1*

*JOB NUMBER:* PG19-090

*Scale*
*1:20*



| | |
|---|---|
| *0.00* | Moist, light brown, <u>soft</u>, intact, silty CLAY. **ALLUVIUM**.<br><u>Notes</u>:<br>Minor roots at top 0.1m.<br>Band of reddish brown firm gravelly clay at 0.4-0.5m. |
| *0.50* | Moist, grey, <u>firm</u>, slickensided, CLAY. **ALLUVIUM**. |
| *3.30* | |

NOTES

1) No refusal. Excavation stopped at end of TLB reach.

2) No water seepage encountered.

3) Sidewalls stable.

4) Profiled insitu.

5) No samples taken.

6) Coordinates captured with handheld GPS.

*CONTRACTOR :*
*MACHINE :* JCB 3CX (TLB)
*EXCAVATED BY :*
*PROFILED BY :* MN

*TYPE SET BY : MN*
*SETUP FILE : PGTEST~2.SET*

*LENGTH :* Vertical
*WIDTH :* 0.7m wide trench
*DATE :* 2019/11/14
*DATE :* 2019/11/14

*DATE : 19/02/2020 18:13*
*TEXT : ..19090TPProfilesRev00.TXT*

*ELEVATION :* 871m
*EASTING :* S 24 23 48.32
*NORTHING :* E 29 59 31.91

*HOLE No:* TP-SM02

**TP-SM02**

PEREGRINE
GEOCONSULTANTS

**Ilifa Africa Engineers (Pty) Ltd**
Mampa & Swazi Mnyamane Bridges
Geotechnical Investigation

LEGEND
*Sheet 1 of 1*

*JOB NUMBER:* PG19-090

|  |  |  |  |
|---|---|---|---|
|  | ○○○ | GRAVEL | {SA02} |
|  | ○ | GRAVELLY | {SA03} |
|  | ⁙ | SAND | {SA04} |
|  | ∴ | SANDY | {SA05} |
|  | \|\|\| | SILT | {SA06} |
|  | ¦ ¦ | SILTY | {SA07} |
|  | //// | CLAY | {SA08} |
|  | ⁄ ⁄ | CLAYEY | {SA09} |
| *Name* ● |  | DISTURBED SAMPLE | {SA38} |
|  | ∾ | ROOTS | {SA40} |

*CONTRACTOR :*
*MACHINE :*
*EXCAVATED BY :*
*PROFILED BY :*

*LENGTH :*
*WIDTH :*
*DATE :*
*DATE :*

*ELEVATION :*
*EASTING :*
*NORTHING :*

*TYPE SET BY : MN*
*SETUP FILE : PGTEST~2.SET*

*DATE : 19/02/2020 18:13*
*TEXT : ..19090TPProfilesRev00.TXT*

LEGEND
*SUMMARY OF SYMBOLS*

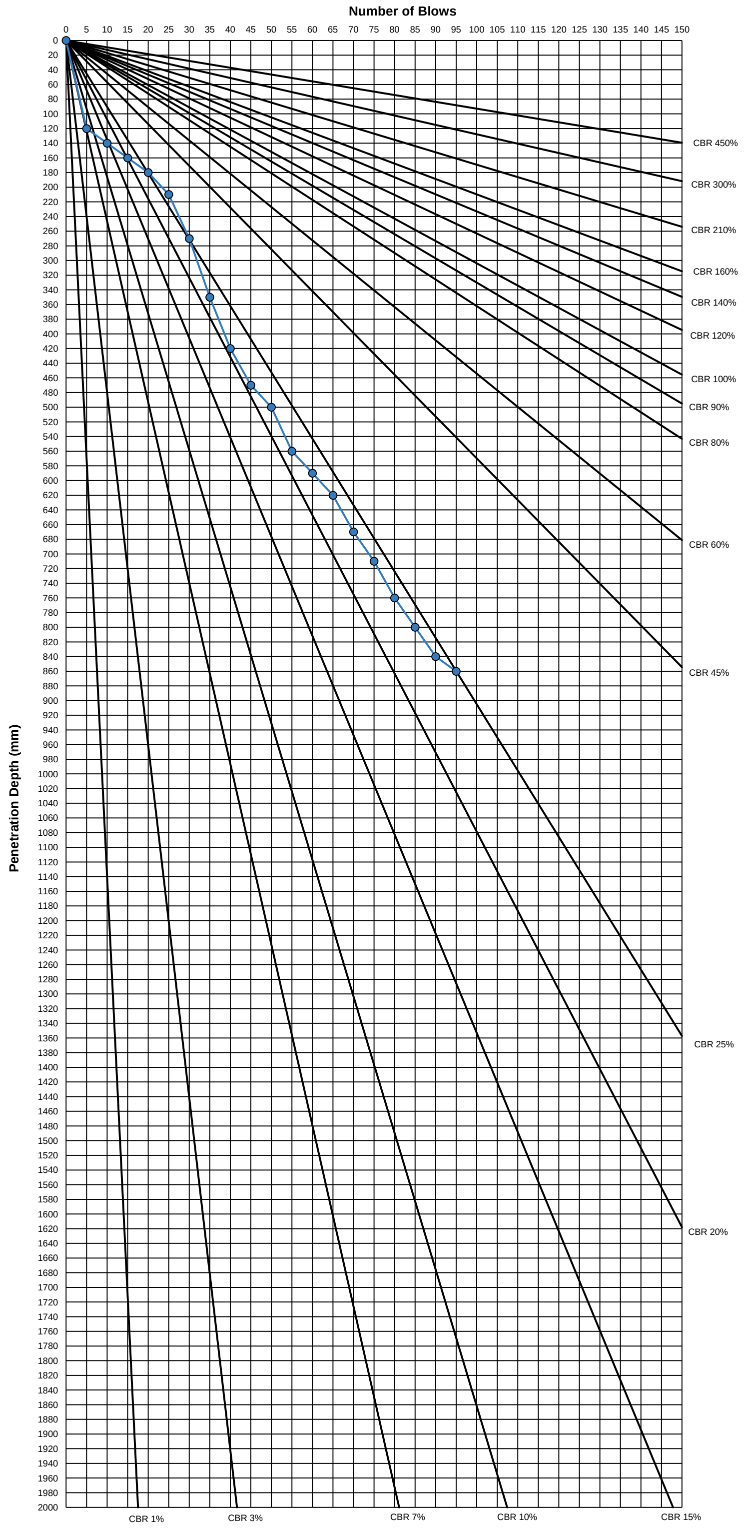
# APPENDIX B:
# DCP TEST RESULTS

# DYNAMIC CONE PENETROMETER TEST: DCP-MP01

**Project No:** PG19-090
**Project Name:** Mampa & Swazi Mnyamane Access Bridges
**Client:** Ilifa Africa Engineers
**Date:** 2019/11/14
**Test No:** DCP-MP01

PEREGRINE
GEOCONSULTANTS

Tel: 072 284 1826
Email: louis@peregrinegeo.co.za



| No of Blows | Penetration Depth (mm) | DN (mm/blow) | CBR %<br>From Paige-Green and Du Plessis (2009) |
|---|---|---|---|
| 0 | 0 | | |
| 5 | 120 | 24 | 7% |
| 10 | 140 | 4 | 70% |
| 15 | 160 | 4 | 70% |
| 20 | 180 | 4 | 70% |
| 25 | 210 | 6 | 42% |
| 30 | 270 | 12 | 17% |
| 35 | 350 | 16 | 12% |
| 40 | 420 | 14 | 14% |
| 45 | 470 | 10 | 22% |
| 50 | 500 | 6 | 42% |
| 55 | 560 | 12 | 17% |
| 60 | 590 | 6 | 42% |
| 65 | 620 | 6 | 42% |
| 70 | 670 | 10 | 22% |
| 75 | 710 | 8 | 29% |
| 80 | 760 | 10 | 22% |
| 85 | 800 | 8 | 29% |
| 90 | 840 | 8 | 29% |
| 95 | 860 | 4 | 70% |

Notes:

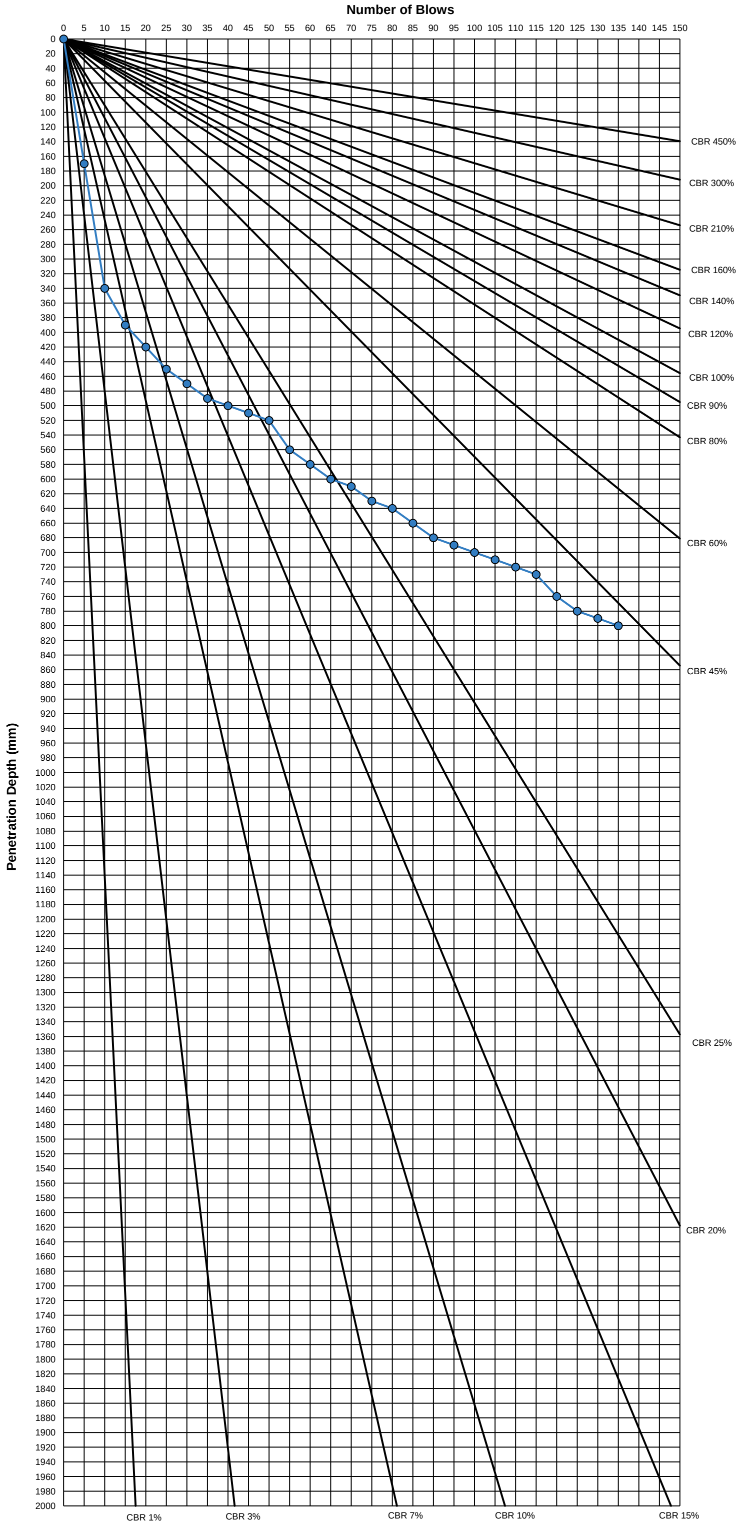
Conducted from surface next to TP-MP01.

# DYNAMIC CONE PENETROMETER TEST: DCP-MP02

**Project No:** PG19-090
**Project Name:** Mampa & Swazi Mnyamane Access Bridges
**Client:** Ilifa Africa Engineers
**Date:** 2019/11/14
**Test No:** DCP-MP02

PEREGRINE
GEOCONSULTANTS

Tel: 072 284 1826
Email: louis@peregrinegeo.co.za



| No of Blows | Penetration Depth (mm) | DN (mm/blow) | CBR %<br>From Paige-Green and Du Plessis (2009) |
|---|---|---|---|
| 0 | 0 | | |
| 5 | 170 | 34 | 5% |
| 10 | 340 | 34 | 5% |
| 15 | 390 | 10 | 22% |
| 20 | 420 | 6 | 42% |
| 25 | 450 | 6 | 42% |
| 30 | 470 | 4 | 70% |
| 35 | 490 | 4 | 70% |
| 40 | 500 | 2 | 170% |
| 45 | 510 | 2 | 170% |
| 50 | 520 | 2 | 170% |
| 55 | 560 | 8 | 29% |
| 60 | 580 | 4 | 70% |
| 65 | 600 | 4 | 70% |
| 70 | 610 | 2 | 170% |
| 75 | 630 | 4 | 70% |
| 80 | 640 | 2 | 170% |
| 85 | 660 | 4 | 70% |
| 90 | 680 | 4 | 70% |
| 95 | 690 | 2 | 170% |
| 100 | 700 | 2 | 170% |
| 105 | 710 | 2 | 170% |
| 110 | 720 | 2 | 170% |
| 115 | 730 | 2 | 170% |
| 120 | 760 | 6 | 42% |
| 125 | 780 | 4 | 70% |
| 130 | 790 | 2 | 170% |
| 135 | 800 | 2 | 170% |

Notes:

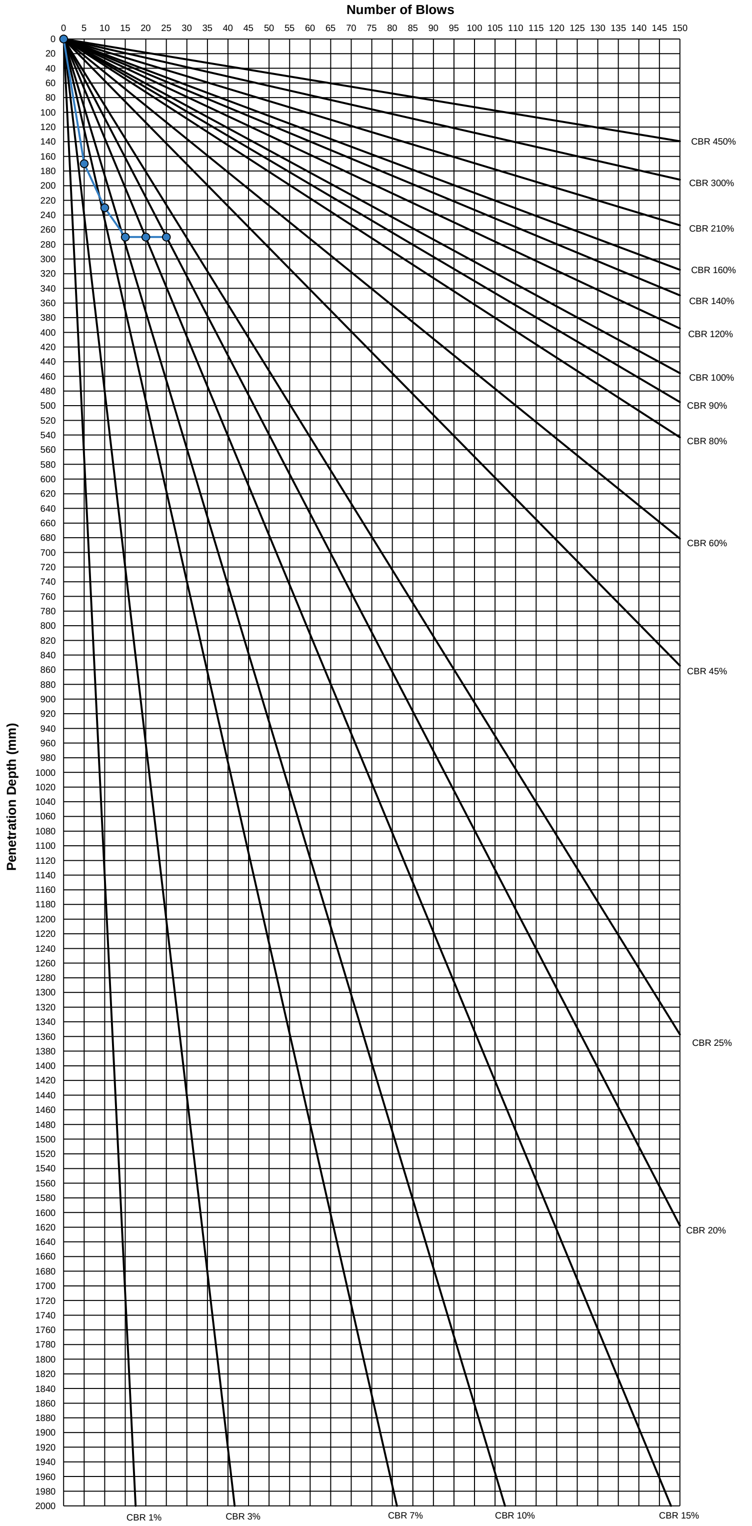
Conducted from surface next to TP-MP02.

# DYNAMIC CONE PENETROMETER TEST: DCP-MP03

**Project No:** PG19-090
**Project Name:** Mampa & Swazi Mnyamane Access Bridges
**Client:** Ilifa Africa Engineers
**Date:** 2019/11/14
**Test No:** DCP-MP03

PEREGRINE
GEOCONSULTANTS

Tel: 072 284 1826
Email: louis@peregrinegeo.co.za



| No of Blows | Penetration Depth (mm) | DN (mm/blow) | CBR %<br>From Paige-Green and Du Plessis (2009) |
|---|---|---|---|
| 0 | 0 | | |
| 5 | 170 | 34 | 5% |
| 10 | 230 | 12 | 17% |
| 15 | 270 | 8 | 29% |
| 20 | 270 | 0 | 563% |
| 25 | 270 | 0 | 563% |

Notes:

Refusal @ 0.27m deep, presumably on boulder.

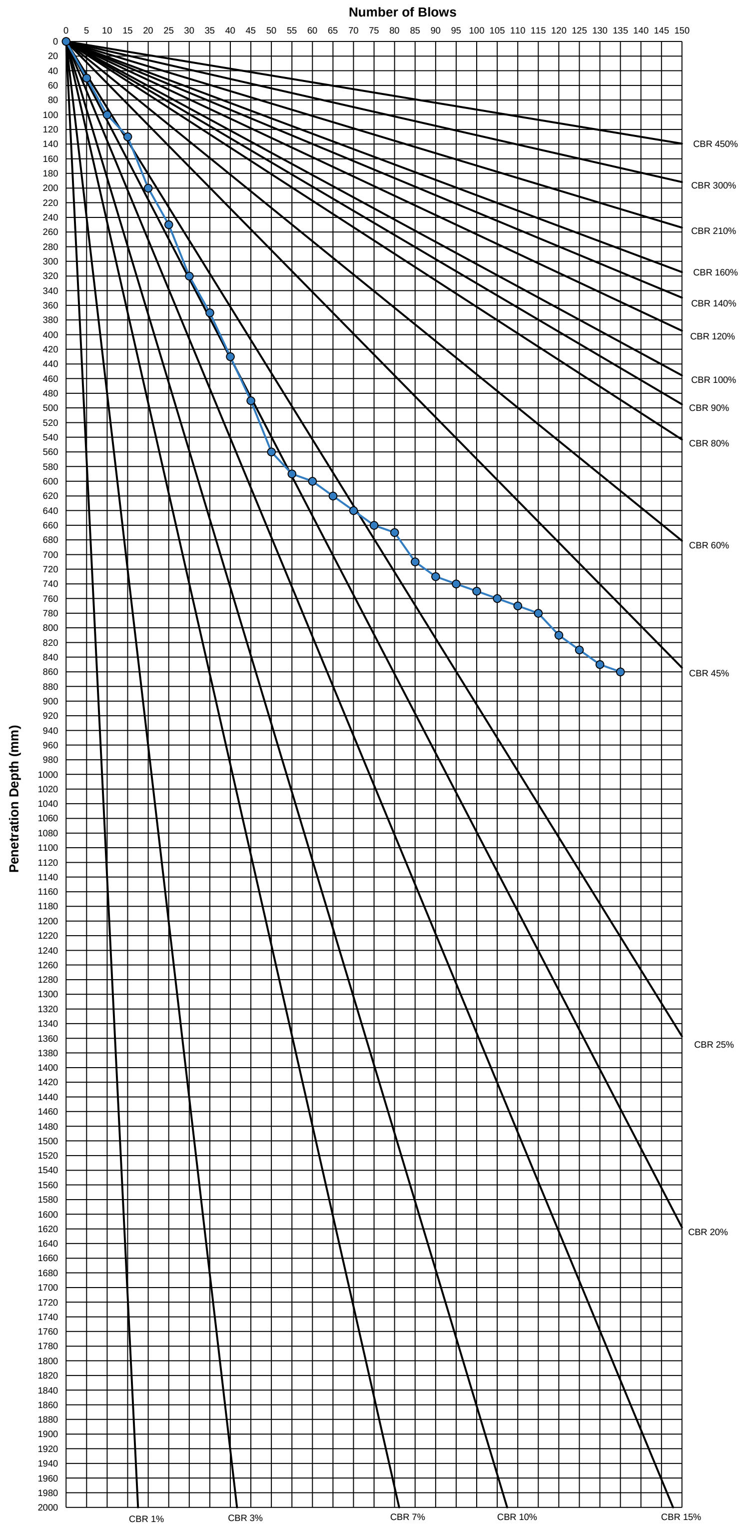
Conducted from surface next to TP-MP03.

# DYNAMIC CONE PENETROMETER TEST: DCP-MP04

**Project No:** PG19-090
**Project Name:** Mampa & Swazi Mnyamane Access Bridges
**Client:** Ilifa Africa Engineers
**Date:** 2019/11/14
**Test No:** DCP-MP04

PEREGRINE
GEOCONSULTANTS

Tel: 072 284 1826
Email: louis@peregrinegeo.co.za



| No of Blows | Penetration Depth (mm) | DN (mm/blow) | CBR %<br>From Paige-Green and Du Plessis (2009) |
|---|---|---|---|
| 0 | 0 | | |
| 5 | 50 | 10 | 22% |
| 10 | 100 | 10 | 22% |
| 15 | 130 | 6 | 42% |
| 20 | 200 | 14 | 14% |
| 25 | 250 | 10 | 22% |
| 30 | 320 | 14 | 14% |
| 35 | 370 | 10 | 22% |
| 40 | 430 | 12 | 17% |
| 45 | 490 | 12 | 17% |
| 50 | 560 | 14 | 14% |
| 55 | 590 | 6 | 42% |
| 60 | 600 | 2 | 170% |
| 65 | 620 | 4 | 70% |
| 70 | 640 | 4 | 70% |
| 75 | 660 | 4 | 70% |
| 80 | 670 | 2 | 170% |
| 85 | 710 | 8 | 29% |
| 90 | 730 | 4 | 70% |
| 95 | 740 | 2 | 170% |
| 100 | 750 | 2 | 170% |
| 105 | 760 | 2 | 170% |
| 110 | 770 | 2 | 170% |
| 115 | 780 | 2 | 170% |
| 120 | 810 | 6 | 42% |
| 125 | 830 | 4 | 70% |
| 130 | 850 | 4 | 70% |
| 135 | 860 | 2 | 170% |

Notes:

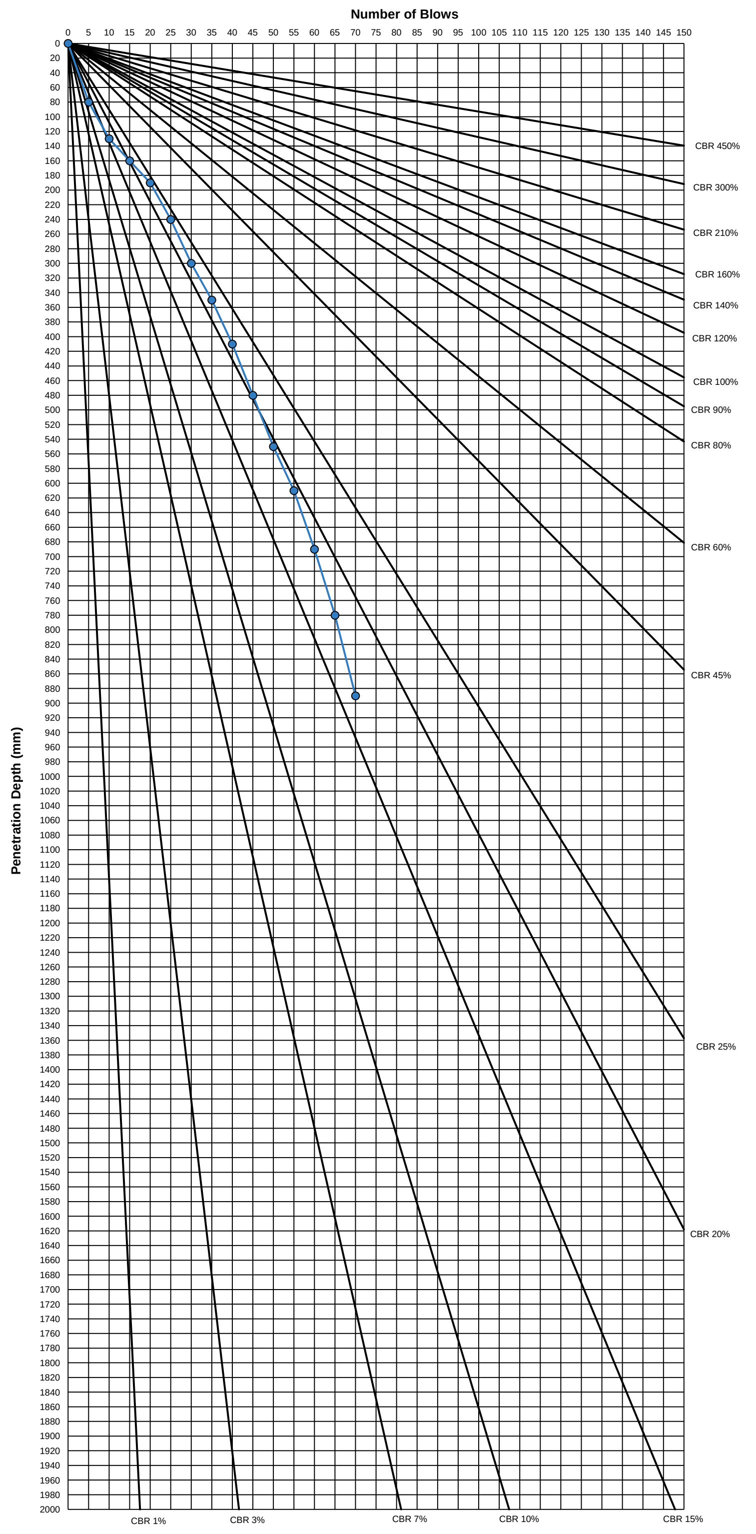
Conducted from surface next to TP-MP04.

# DYNAMIC CONE PENETROMETER TEST: DCP-SM01

**Project No:** PG19-090
**Project Name:** Mampa & Swazi Mnyamane Access Bridges
**Client:** Ilifa Africa Engineers
**Date:** 2019/11/14
**Test No:** DCP-SM01

PEREGRINE
GEOCONSULTANTS

Tel: 072 284 1826
Email: louis@peregrinegeo.co.za



| No of Blows | Penetration Depth (mm) | DN (mm/blow) | CBR % From Paige-Green and Du Plessis (2009) |
|---|---|---|---|
| 0 | 0 | | |
| 5 | 80 | 16 | 12% |
| 10 | 130 | 10 | 22% |
| 15 | 160 | 6 | 42% |
| 20 | 190 | 6 | 42% |
| 25 | 240 | 10 | 22% |
| 30 | 300 | 12 | 17% |
| 35 | 350 | 10 | 22% |
| 40 | 410 | 12 | 17% |
| 45 | 480 | 14 | 14% |
| 50 | 550 | 14 | 14% |
| 55 | 610 | 12 | 17% |
| 60 | 690 | 16 | 12% |
| 65 | 780 | 18 | 10% |
| 70 | 890 | 22 | 8% |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |

Notes:

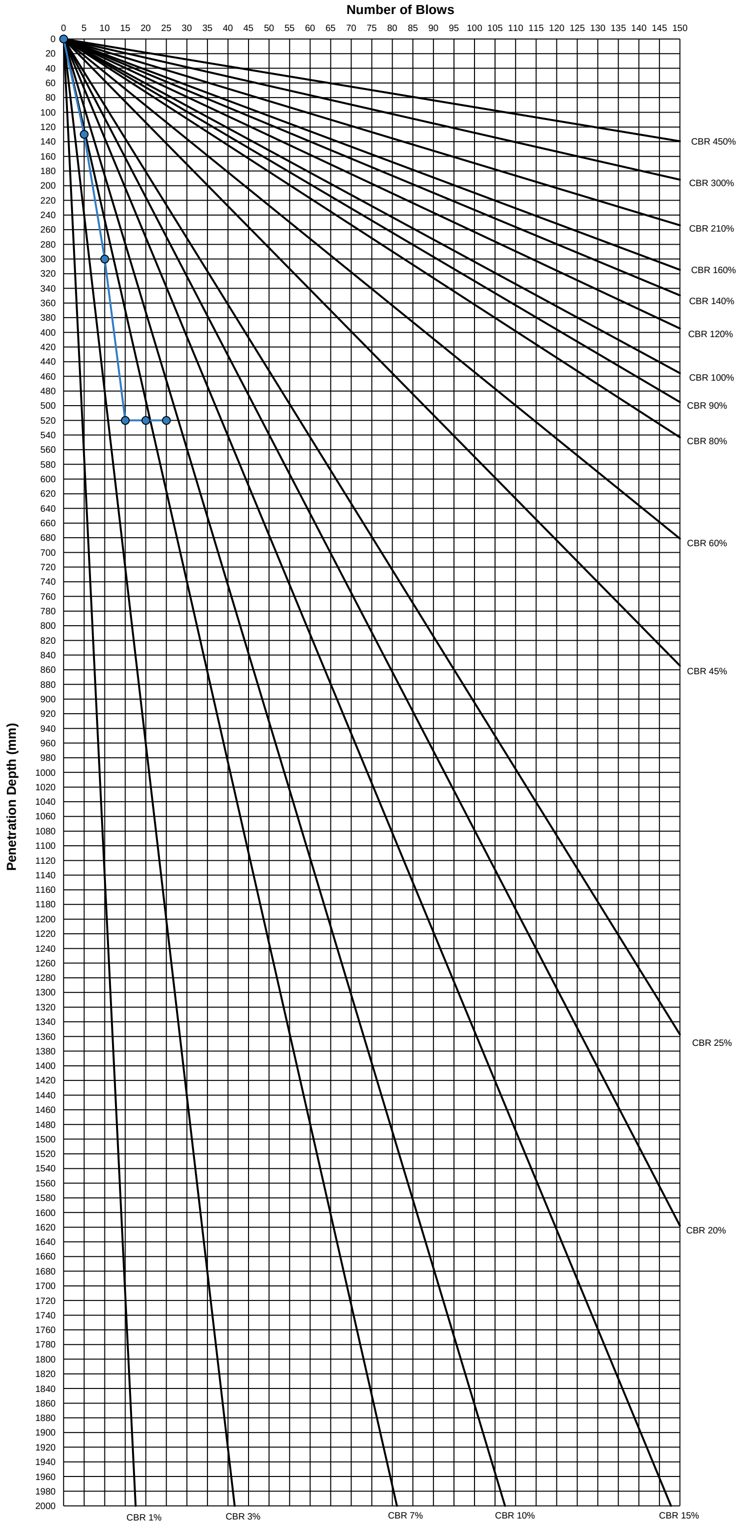
Conducted from surface next to TP-SM01.

# DYNAMIC CONE PENETROMETER TEST: DCP-SM02

**Project No:** PG19-090
**Project Name:** Mampa & Swazi Mnyamane Access Bridges
**Client:** Ilifa Africa Engineers
**Date:** 2019/11/14
**Test No:** DCP-SM02

PEREGRINE
GEOCONSULTANTS

Tel: 072 284 1826
Email: louis@peregrinegeo.co.za



| No of Blows | Penetration Depth (mm) | DN (mm/blow) | CBR %<br>From Paige-Green and Du Plessis (2009) |
|---|---|---|---|
| 0 | 0 | | |
| 5 | 130 | 26 | 7% |
| 10 | 300 | 34 | 5% |
| 15 | 520 | 44 | 3% |
| 20 | 520 | 0 | 563% |
| 25 | 520 | 0 | 563% |

Notes:
Refusal @ 0.52m deep, presumably on boulder or cobble.
Conducted from surface next to TP-SM02.

# APPENDIX C:
# LABORATORY TEST RESULTS

**Client Name:** Peregrine GeoConsultants
**Project Name:** PG19-090: Mampa & Swazi Mnyamane Access Bridges
**Job Number:** PGC-48
**Date:** 20-Jan-20
**Method:** SANS 3001 GR1, GR3, GR10, GR12 GR20, GR30, GR31, GR40, GR50, GR53, GR54 & BS 1377 (where applicable)

## SUMMARY OF TEST DATA

### Grading & Hydrometer Analysis (% Passing)

| Sample | TP-SM01 | TP-MP01 | TP-MP01 | TP-MP03 | | | | |
|---|---|---|---|---|---|---|---|---|
| Depth (m) | 0.0 - 3.3 | 0.0 - 0.6 | 0.6 - 3.3 | 0.0 - 1.1 | | | | |
| Lab No | PGC-48-182 | PGC-48-184 | PGC-48-185 | PGC-48-187 | | | | |
| 53.0 | **100** | **100** | **95** | **100** | | | | |
| 37.5 | **100** | **100** | **87** | **100** | | | | |
| 26.5 | **100** | **100** | **76** | **100** | | | | |
| 19.0 | **100** | **100** | **75** | **100** | | | | |
| 13.2 | **100** | **100** | **74** | **100** | | | | |
| 9.5 | **100** | **100** | **72** | **100** | | | | |
| 6.7 | **100** | **99** | **69** | **99** | | | | |
| 4.75 | **99** | **98** | **66** | **99** | | | | |
| 2.00 | **97** | **96** | **56** | **96** | | | | |
| 1.00 | **96** | **88** | **48** | **72** | | | | |
| 0.425 | **94** | **66** | **38** | **24** | | | | |
| 0.250 | **91** | **46** | **29** | **6** | | | | |
| 0.150 | **86** | **33** | **22** | **3** | | | | |
| 0.075 | **81** | **25** | **15** | **2** | | | | |
| 0.060 | **72** | **18** | **11** | **1** | | | | |
| 0.050 | **70** | **16** | **10** | **1** | | | | |
| 0.035 | **66** | **14** | **7** | **1** | | | | |
| 0.020 | **63** | **11** | **5** | **1** | | | | |
| 0.006 | **57** | **9** | **2** | **1** | | | | |
| 0.002 | **45** | **7** | **1** | **1** | | | | |
| GM | **0.28** | **1.13** | **1.91** | **1.78** | | | | |

### Atterberg Limits

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| LL (%) | **76** | **32** | **24** | **-** | | | | |
| PI (%) | **37** | **12** | **4** | **NP** | | | | |
| LS (%) | **23.5** | **5.5** | **2.5** | **0.0** | | | | |

### pH & Conductivity

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| pH | **8.1** | **7.7** | **7.8** | **7.2** | | | | |
| EC (S/m) | **0.167** | **0.031** | **0.046** | **0.005** | | | | |

### MDD / OMC

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| MDD ($kg/m^3$) | **1463** | | **1903** | | | | | |
| OMC (%) | **25.5** | | **12.5** | | | | | |

### CBR

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 100% | **2.2** | | **48** | | | | | |
| 98% | **2.0** | | **43** | | | | | |
| 97% | **2.0** | | **41** | | | | | |
| 95% | **1.8** | | **36** | | | | | |
| 93% | **1.6** | | **27** | | | | | |
| 90% | **1.4** | | **18** | | | | | |
| Swell (%) | **12.9** | | **0.2** | | | | | |

### UCS (MPa)

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 100% | | | | | | | | |
| 97% | | | | | | | | |
| 90% | | | | | | | | |

### COLTO Classification

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| | ***** | | **G6** | | | | | |

Remarks: * = Not Classifiable

Specialised Testing Laboratory (Pty) Ltd
Asphalt | Aggregate | Bitumen | Geotechnical
Quality | Excellence | On Time

Unit 1, 13 Bloubokkie Street, Koedoespoort 0186
Roelof | 072 674 6343 | roelof@stlab.co.za
Gerrie | 082 309 4448 | gerrie@stlab.co.za
www.stlab.co.za

| | |
|---|---|
| **Client Name:** | Peregrine GeoConsultants |
| **Project Name:** | PG19-090: Mampa & Swazi Mnyamane Access Bridges |
| **Job Number:** | PGC-48 |
| **Date:** | 2020-01-20 |
| **Method:** | SANS 3001 GR1, GR3, GR10 GR12 & BS 1377 (where applicable) |

# FOUNDATION INDICATOR

**Sheet Ref:**
**R-STL-011-Rev02**

## Grading & Hydrometer Analysis
(Particle Size (mm) & % Passing)

| Sample | TP-SM01 | TP-MP01 | TP-MP01 |
|---|---|---|---|
| Depth (m) | 0.0 - 3.3 | 0.0 - 0.6 | 0.6 - 3.3 |
| Lab No | PGC-48-182 | PGC-48-184 | PGC-48-185 |
| 53.0 | **100** | **100** | **95** |
| 37.5 | **100** | **100** | **87** |
| 26.5 | **100** | **100** | **76** |
| 19.0 | **100** | **100** | **75** |
| 13.2 | **100** | **100** | **74** |
| 9.5 | **100** | **100** | **72** |
| 6.7 | **100** | **99** | **69** |
| 4.75 | **99** | **98** | **66** |
| 2.00 | **97** | **96** | **56** |
| 1.00 | **96** | **88** | **48** |
| 0.425 | **94** | **66** | **38** |
| 0.250 | **91** | **46** | **29** |
| 0.150 | **86** | **33** | **22** |
| 0.075 | **81** | **25** | **15** |
| 0.060 | **72** | **18** | **11** |
| 0.050 | **70** | **16** | **10** |
| 0.035 | **66** | **14** | **7** |
| 0.020 | **63** | **11** | **5** |
| 0.006 | **57** | **9** | **2** |
| 0.002 | **45** | **7** | **1** |

## Atterberg Limits & Classification

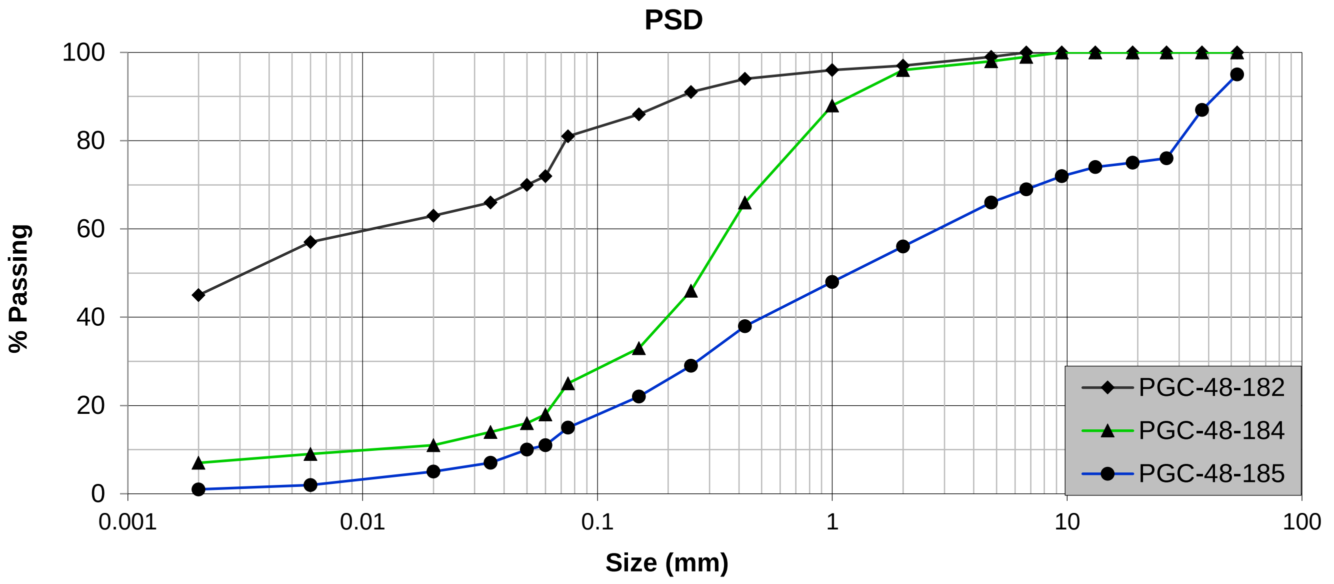
| Sample | TP-SM01 | TP-MP01 | TP-MP01 |
|---|---|---|---|
| Depth (m) | 0.0 - 3.3 | 0.0 - 0.6 | 0.6 - 3.3 |
| Lab No | PGC-48-182 | PGC-48-184 | PGC-48-185 |
| Liquid Limit (%) | **76** | **32** | **24** |
| Plastic Limit (%) | **39** | **20** | **20** |
| Plasticity Index (%) | **37** | **12** | **4** |
| Linear Shrinkage (%) | **23.5** | **5.5** | **2.5** |
| PI of whole sample | **35** | **8** | **2** |
| | | | |
| % Gravel | **3** | **4** | **44** |
| % Sand | **25** | **78** | **45** |
| % Silt | **27** | **11** | **10** |
| % Clay | **45** | **7** | **1** |
| Activity | **0.8** | **1.7** | **4.0** |
| | | | |
| % Soil Mortar | **97** | **96** | **56** |
| | | | |
| Grading Modulus | **0.28** | **1.13** | **1.91** |
| Moisture Content (%) | **N / T** | **N / T** | **N / T** |
| Relative Density (SG)* | **2.65** | **2.65** | **2.65** |
| | | | |
| Unified (ASTM D2487) | **MH** | **SC** | **SM** |
| AASHTO (M145-91) | **A - 7 - 5** | **A - 2 - 6** | **A - 1 - b** |

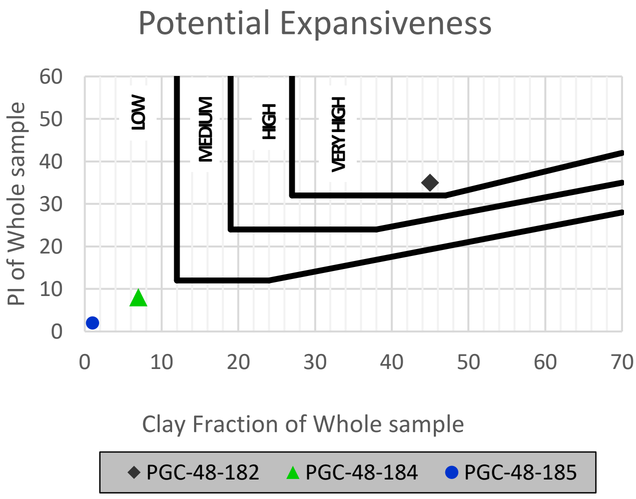
Remarks: *: Assumed
N / T: Not Tested

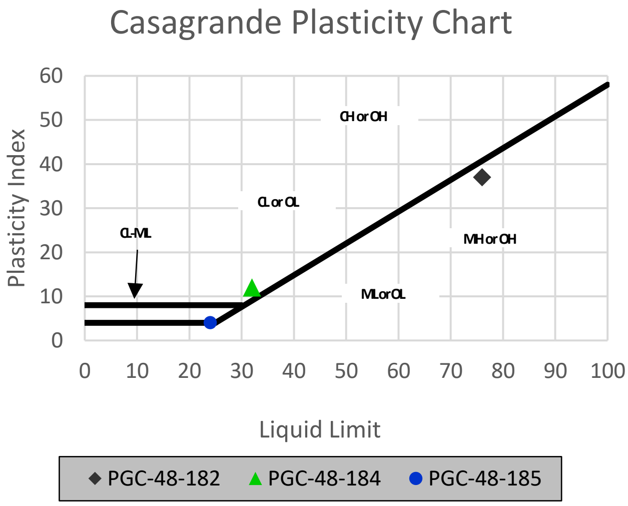
| | |
|---|---|
| **Client Name:** | Peregrine GeoConsultants |
| **Project Name:** | PG19-090: Mampa & Swazi Mnyamane Access Bridges |
| **Job Number:** | PGC-48 |
| **Date:** | 2020-01-20 |
| **Method:** | SANS 3001 GR1, GR3, GR10 GR12 & BS 1377 (where applicable) |

# FOUNDATION INDICATOR

**Sheet Ref:**
**R-STL-011-Rev02**







**Client Name:** Peregrine GeoConsultants
**Project Name:** PG19-090: Mampa & Swazi Mnyamane Access Bridges
**Job Number:** PGC-48
**Date:** 2020-01-20
**Method:** SANS 3001 GR1, GR3, GR10 GR12 & BS 1377 (where applicable)

# FOUNDATION INDICATOR

**Sheet Ref: R-STL-011-Rev02**

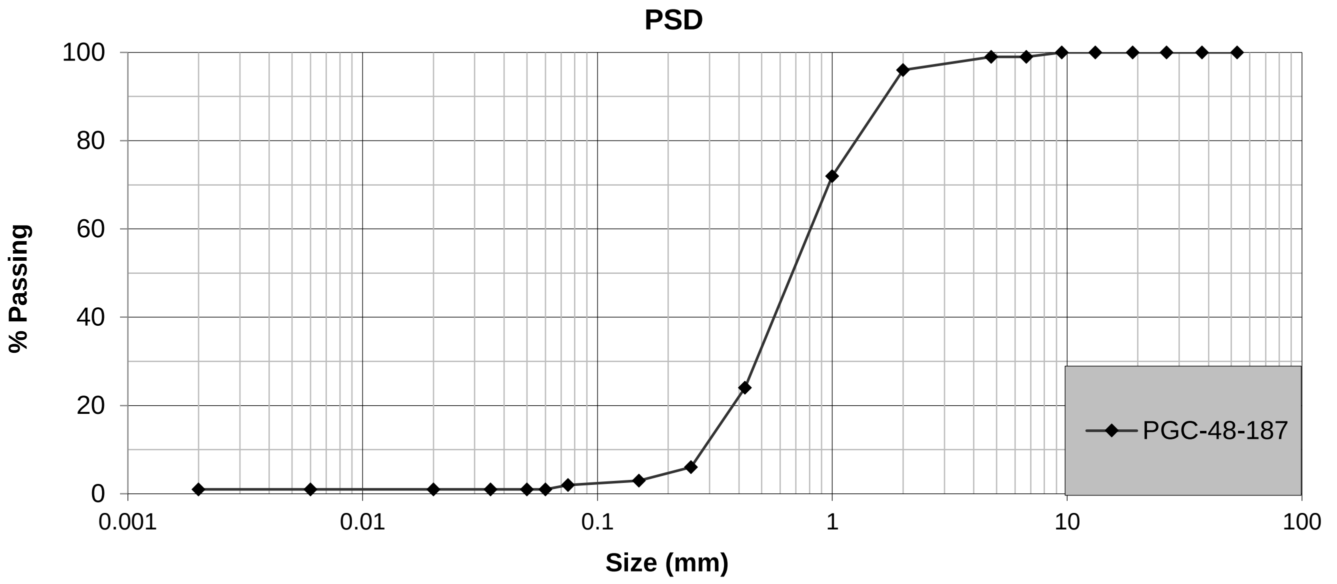
| **Grading & Hydrometer Analysis** (Particle Size (mm) & % Passing) | | | | **Atterberg Limits & Classification** | | | |
|---|---|---|---|---|---|---|---|
| Sample | TP-MP03 | | | Sample | TP-MP03 | | |
| Depth (m) | 0.0 - 1.1 | | | Depth (m) | 0.0 - 1.1 | | |
| Lab No | PGC-48-187 | | | Lab No | PGC-48-187 | | |
| 53.0 | **100** | | | Liquid Limit (%) | **-** | | |
| 37.5 | **100** | | | Plastic Limit (%) | **-** | | |
| 26.5 | **100** | | | Plasticity Index (%) | **NP** | | |
| 19.0 | **100** | | | Linear Shrinkage (%) | **0.0** | | |
| 13.2 | **100** | | | PI of whole sample | **-** | | |
| 9.5 | **100** | | | | | | |
| 6.7 | **99** | | | % Gravel | **4** | | |
| 4.75 | **99** | | | % Sand | **95** | | |
| 2.00 | **96** | | | % Silt | **0** | | |
| 1.00 | **72** | | | % Clay | **1** | | |
| 0.425 | **24** | | | Activity | **0.0** | | |
| 0.250 | **6** | | | | | | |
| 0.150 | **3** | | | % Soil Mortar | **96** | | |
| 0.075 | **2** | | | | | | |
| 0.060 | **1** | | | Grading Modulus | **1.78** | | |
| 0.050 | **1** | | | Moisture Content (%) | **N / T** | | |
| 0.035 | **1** | | | Relative Density (SG)* | **2.65** | | |
| 0.020 | **1** | | | | | | |
| 0.006 | **1** | | | Unified (ASTM D2487) | **SP** | | |
| 0.002 | **1** | | | AASHTO (M145-91) | **A - 1 - b** | | |

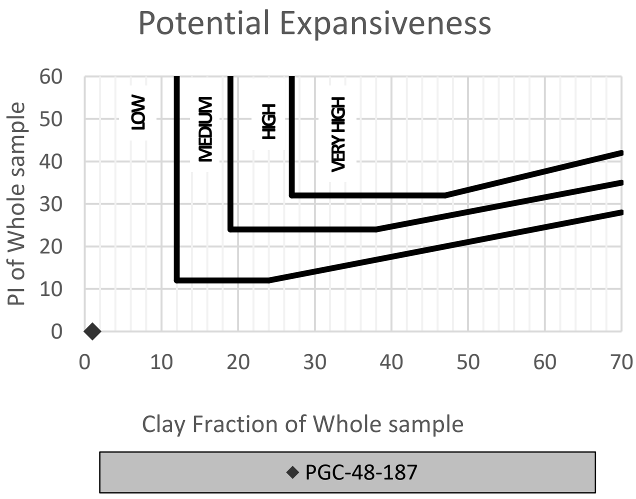
Remarks: *: Assumed
N / T: Not Tested

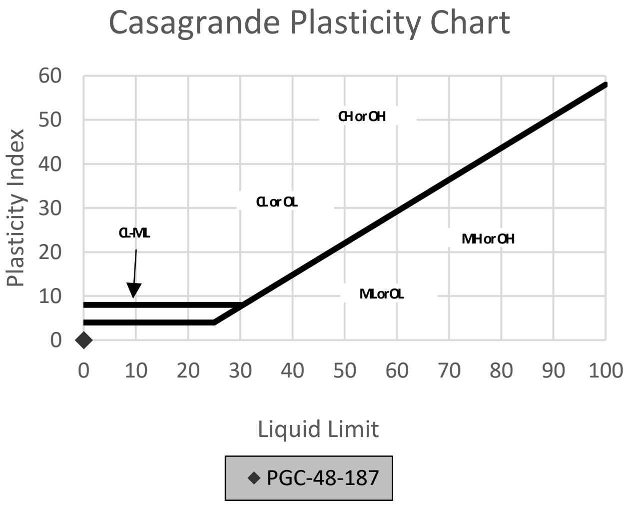
| | |
|---|---|
| **Client Name:** | Peregrine GeoConsultants |
| **Project Name:** | PG19-090: Mampa & Swazi Mnyamane Access Bridges |
| **Job Number:** | PGC-48 |
| **Date:** | 2020-01-20 |
| **Method:** | SANS 3001 GR1, GR3, GR10 GR12 & BS 1377 (where applicable) |

# FOUNDATION INDICATOR

**Sheet Ref:**
**R-STL-011-Rev02**







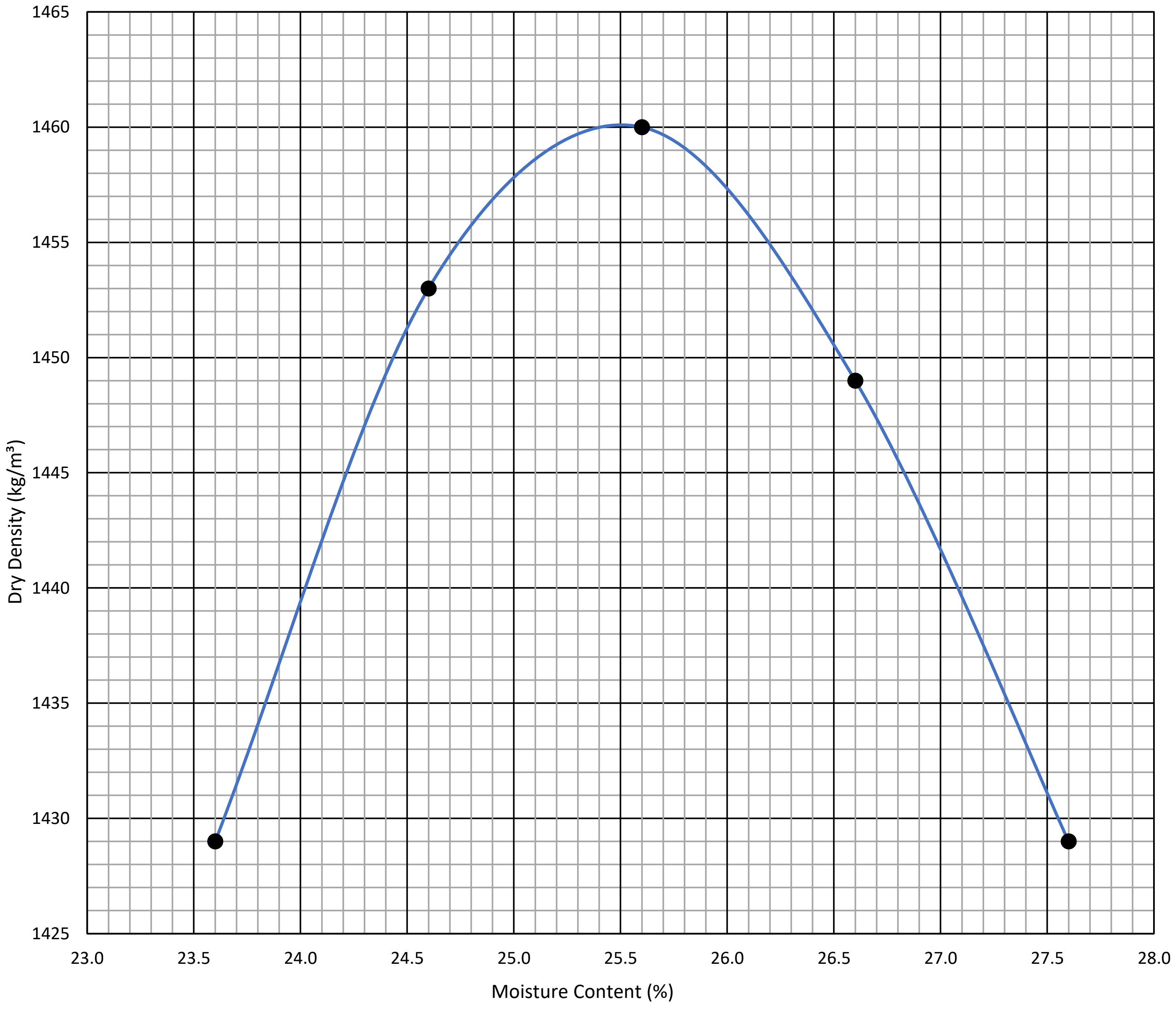
| | | | |
|---|---|---|---|
| **Client Name:** | Peregrine GeoConsultants | **Job Number:** | PGC-48 |
| **Project Name:** | PG19-090: Mampa & Swazi Mnyamane Access Bridges | **Lab Number:** | PGC-48-182 |
| **Sample:** | TP-SM01 | **Method:** | SANS 3001 GR30 |
| **Depth: (m)** | 0.0 - 3.3 | **Date:** | 20-Jan-20 |

# MDD & OMC DETERMINATION (Mod. AASHTO)

Maximum Dry Density: **1463** kg/m³

Optimum Moisture Content: **25.5** %

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Moisture Content (%): | 23.6 | 24.6 | 25.6 | 26.6 | 27.6 | | | |
| Dry Density (kg/m³) | 1429 | 1453 | 1460 | 1449 | 1429 | | | |

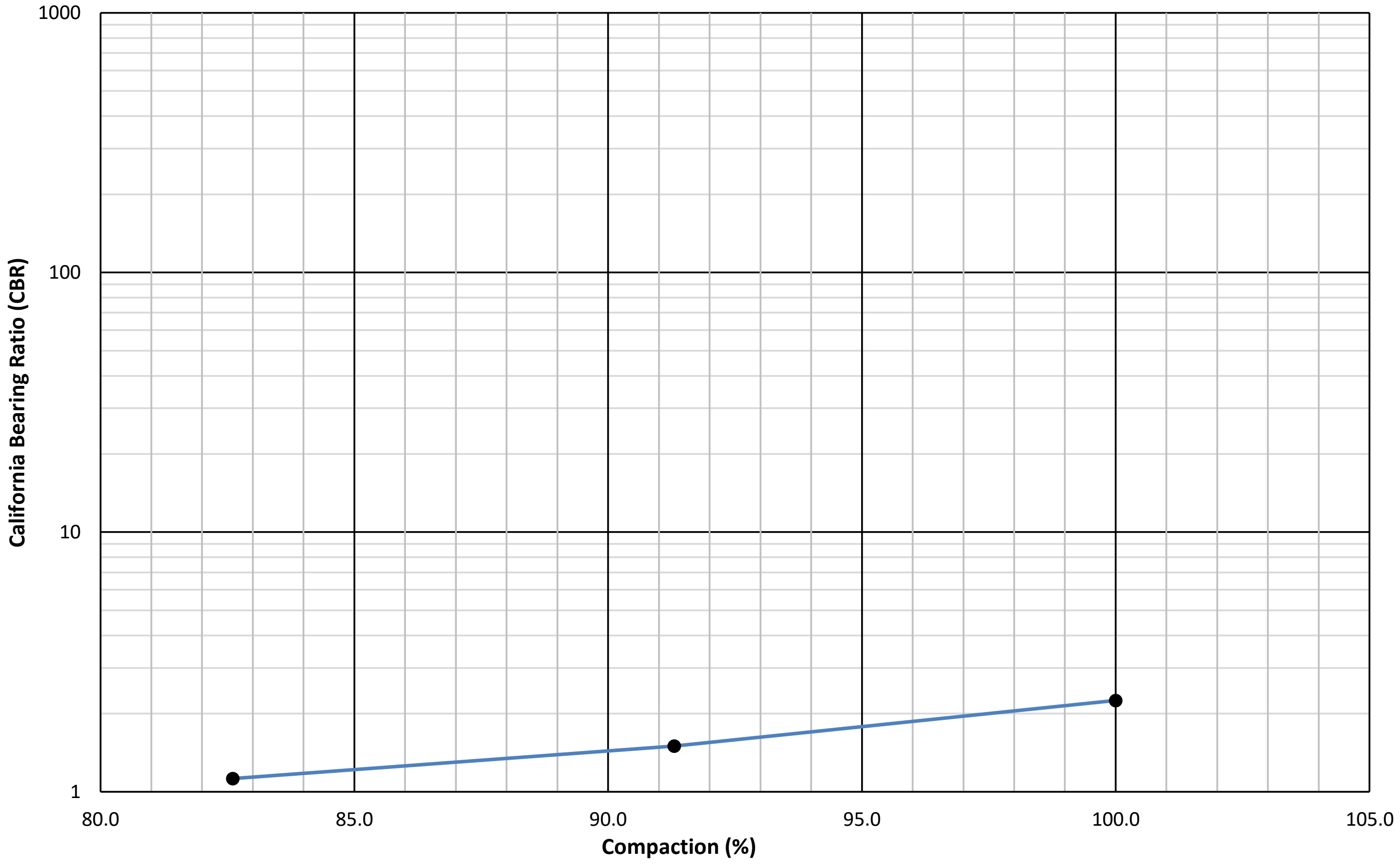


**Client Name:** Peregrine GeoConsultants
**Project Name:** PG19-090: Mampa & Swazi Mnyamane Access Bridges
**Sample:** TP-SM01
**Depth: (m)** 0.0 - 3.3

**Job Number:** PGC-48
**Lab Number:** PGC-48-182
**Method:** SANS 3001 GR40
**Date:** 20-Jan-20

# CALIFORNIA BEARING RATIO

| Mod. AASHTO Values | | Compaction Data: CBR | | | Swell | CBR at (mm) | | | CBR Values | |
|---|---|---|---|---|---|---|---|---|---|---|
| MDD | OMC | Dry Dens. | MC | Comp. | | | | | | |
| (kg/m³) | (%) | (kg/m³) | (%) | (%) | (%) | 2.5 | 5.0 | 7.5 | Compaction (%) | CBR |
| 1463 | 25.5 | 1437 | 24.8 | 100.0 | 12.9 | 2 | 1 | 1 | 100 | **2.2** |
| | | | | | | | | | 98 | **2.0** |
| 1463 | 25.5 | 1312 | 24.8 | 91.3 | 12.1 | 1 | 1 | 1 | 97 | **2.0** |
| | | | | | | | | | 95 | **1.8** |
| 1463 | 25.5 | 1187 | 24.8 | 82.6 | 10.4 | 1 | 1 | 1 | 93 | **1.6** |
| | | | | | | | | | 90 | **1.4** |



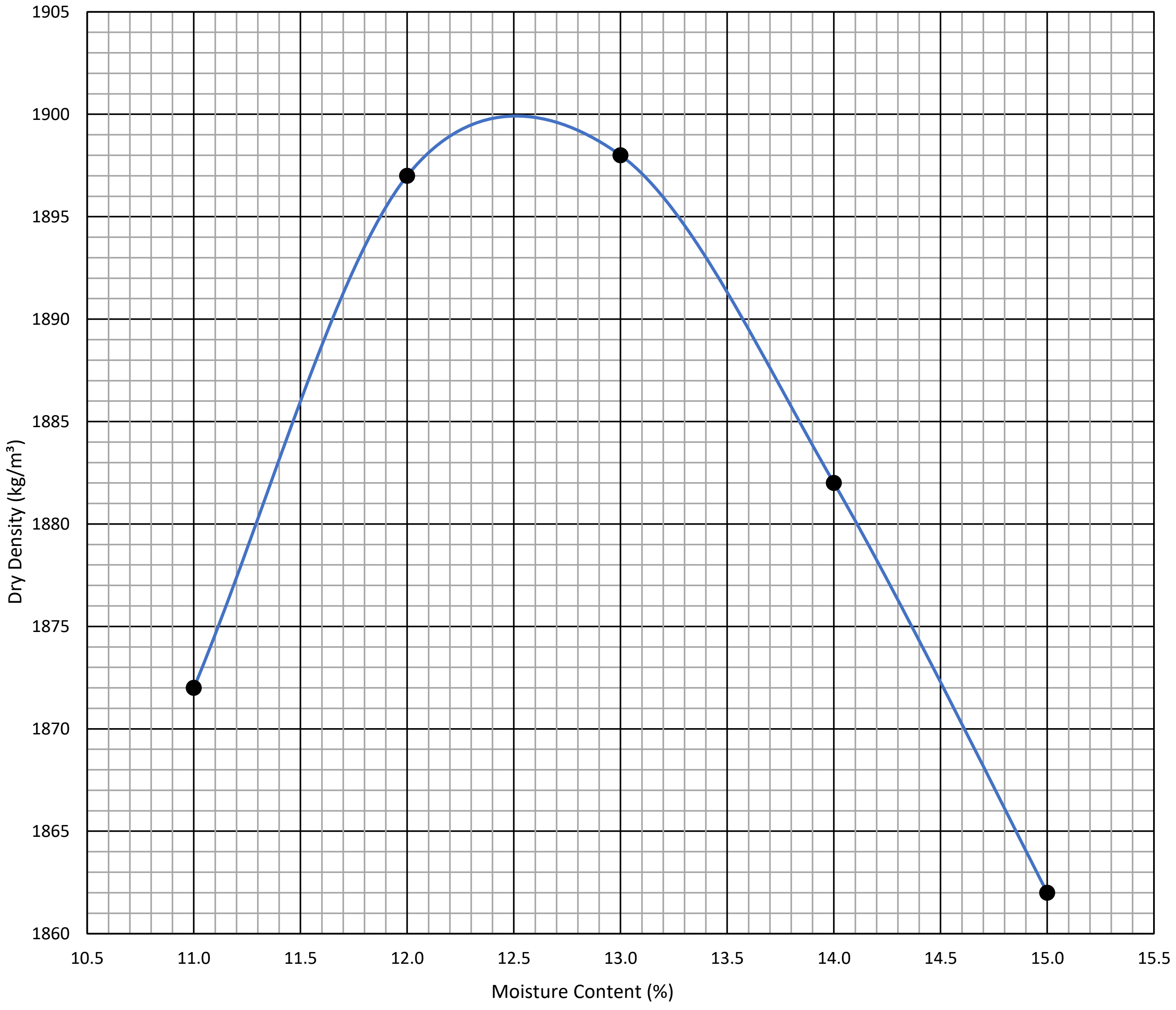
| | | | |
|---|---|---|---|
| **Client Name:** | Peregrine GeoConsultants | **Job Number:** | PGC-48 |
| **Project Name:** | PG19-090: Mampa & Swazi Mnyamane Access Bridges | **Lab Number:** | PGC-48-185 |
| **Sample:** | TP-MP01 | **Method:** | SANS 3001 GR30 |
| **Depth: (m)** | 0.6 - 3.3 | **Date:** | 20-Jan-20 |

# MDD & OMC DETERMINATION (Mod. AASHTO)

Maximum Dry Density: **1903** kg/m³

Optimum Moisture Content: **12.5** %

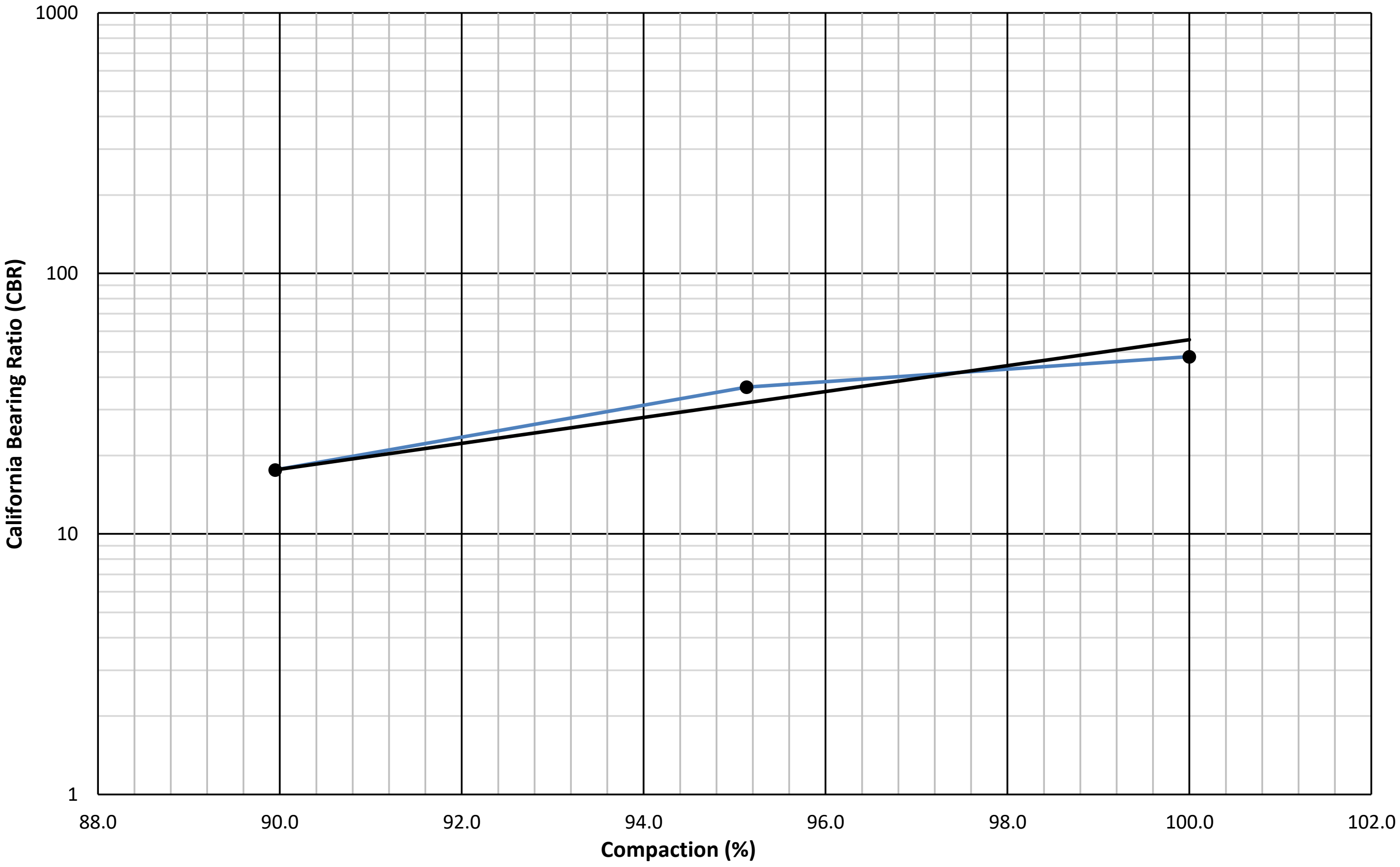
| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Moisture Content (%): | 11.0 | 12.0 | 13.0 | 14.0 | 15.0 | | | |
| Dry Density (kg/m³) | 1872 | 1897 | 1898 | 1882 | 1862 | | | |



| | | | |
|---|---|---|---|
| **Client Name:** | Peregrine GeoConsultants | **Job Number:** | PGC-48 |
| **Project Name:** | PG19-090: Mampa & Swazi Mnyamane Access Bridges | **Lab Number:** | PGC-48-185 |
| **Sample:** | TP-MP01 | **Method:** | SANS 3001 GR40 |
| **Depth: (m)** | 0.6 - 3.3 | **Date:** | 20-Jan-20 |

# CALIFORNIA BEARING RATIO

| **Mod. AASHTO Values** | | **Compaction Data: CBR** | | | **Swell** | **CBR at (mm)** | | | **CBR Values** | |
|---|---|---|---|---|---|---|---|---|---|---|
| **MDD** | **OMC** | **Dry Dens.** | **MC** | **Comp.** | | | | | | |
| (kg/m³) | (%) | (kg/m³) | (%) | (%) | (%) | 2.5 | 5.0 | 7.5 | Compaction (%) | CBR |
| | | | | | | | | | 100 | **48** |
| 1903 | 12.5 | 1910 | 12.3 | 100.0 | 0.2 | 48 | 54 | 50 | 98 | **43** |
| | | | | | | | | | 97 | **41** |
| 1903 | 12.5 | 1817 | 12.3 | 95.1 | 0.3 | 37 | 40 | 36 | 95 | **36** |
| | | | | | | | | | 93 | **27** |
| 1903 | 12.5 | 1718 | 12.3 | 89.9 | 0.5 | 18 | 16 | 14 | 90 | **18** |



Specialised Testing Laboratory (Pty) Ltd
Asphalt | Aggregate | Bitumen | Geotechnical

Unit 1, 13 Bloubokkie Street, Koedoespoort 0186
Roelof | 072 674 6343 | roelof@stlab.co.za
Gerrie | 082 309 4448 | gerrie@stlab.co.za
www.stlab.co.za

Quality | Excellence | On Time

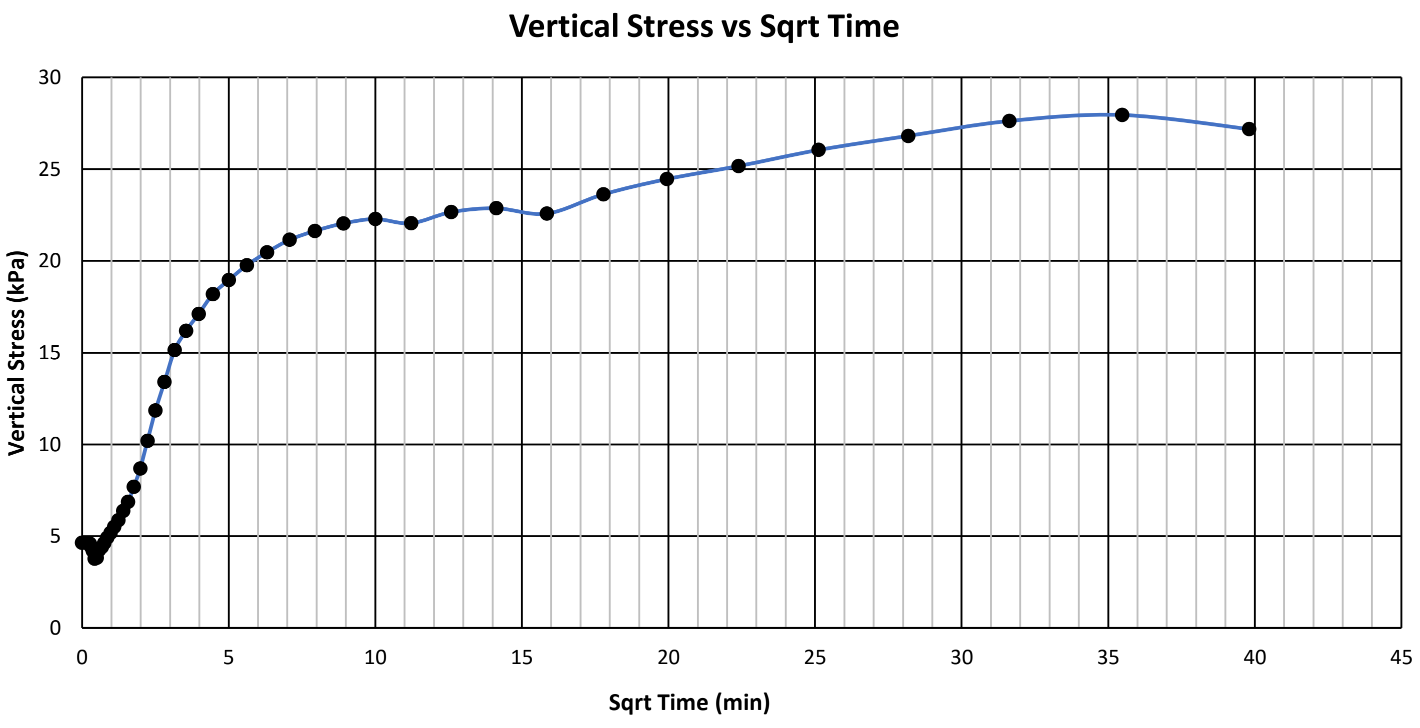
| | | | |
|---|---|---|---|
| **Client Name:** | Peregrine GeoConsultants | **Job Number:** | PGC-48 |
| **Project Name:** | PG19-090: Mampa & Swazi Mnyamane Access Bridges | **Lab Number:** | PGC-48-183 |
| **Sample:** | TP-SM01 | **Method:** | BS 1377 Part 5 |
| **Depth: (m)** | 0 - 3.3 | **Date:** | 20-Jan-20 |

# SWELL PRESSURE TEST

| Sample Info | | Unit | Initial | Test Remarks: |
|---|---|---|---|---|
| Test Specimen Height | | mm | 25.4 | Undisturbed |
| Moisture Content | Initial | % | 28.6 | |
| | Final | % | 40.2 | |
| Dry Density | | kg/m³ | 1014 | |
| Void Ratio | | - | 1.612 | |
| Degree of Saturation | | % | 46.9 | |
| Relative Density (SG) | | - | 2.650 | Assumed |

| | | | |
|---|---|---|---|
| Swell Pressure | kPa | 27.9 | |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Stress | kPa | 4.64 | 4.61 | 4.58 | 4.39 | 4.20 | 3.78 | 3.82 | 4.24 | 4.42 | 4.63 | 4.92 | 5.18 | 5.51 |
| | | 5.87 | 6.38 | 6.86 | 7.69 | 8.69 | 10.19 | 11.85 | 13.41 | 15.13 | 16.19 | 17.11 | 18.19 | 18.96 |
| | | 19.77 | 20.47 | 21.15 | 21.63 | 22.04 | 22.28 | 22.05 | 22.66 | 22.87 | 22.6 | 23.6 | 24.5 | 25.2 |
| | | 26.0 | 26.8 | 27.6 | 27.9 | 27.2 | | | | | | | | |
| Time | Sqrt min | 0.00 | 0.18 | 0.26 | 0.32 | 0.37 | 0.43 | 0.50 | 0.58 | 0.67 | 0.75 | 0.86 | 0.97 | 1.10 |
| | | 1.24 | 1.40 | 1.57 | 1.77 | 1.98 | 2.23 | 2.50 | 2.81 | 3.16 | 3.54 | 3.98 | 4.46 | 5.01 |
| | | 5.62 | 6.31 | 7.08 | 7.94 | 8.91 | 10.00 | 11.22 | 12.59 | 14.12 | 15.85 | 17.78 | 19.95 | 22.39 |
| | | 25.12 | 28.18 | 31.62 | 35.48 | 39.81 | | | | | | | | |

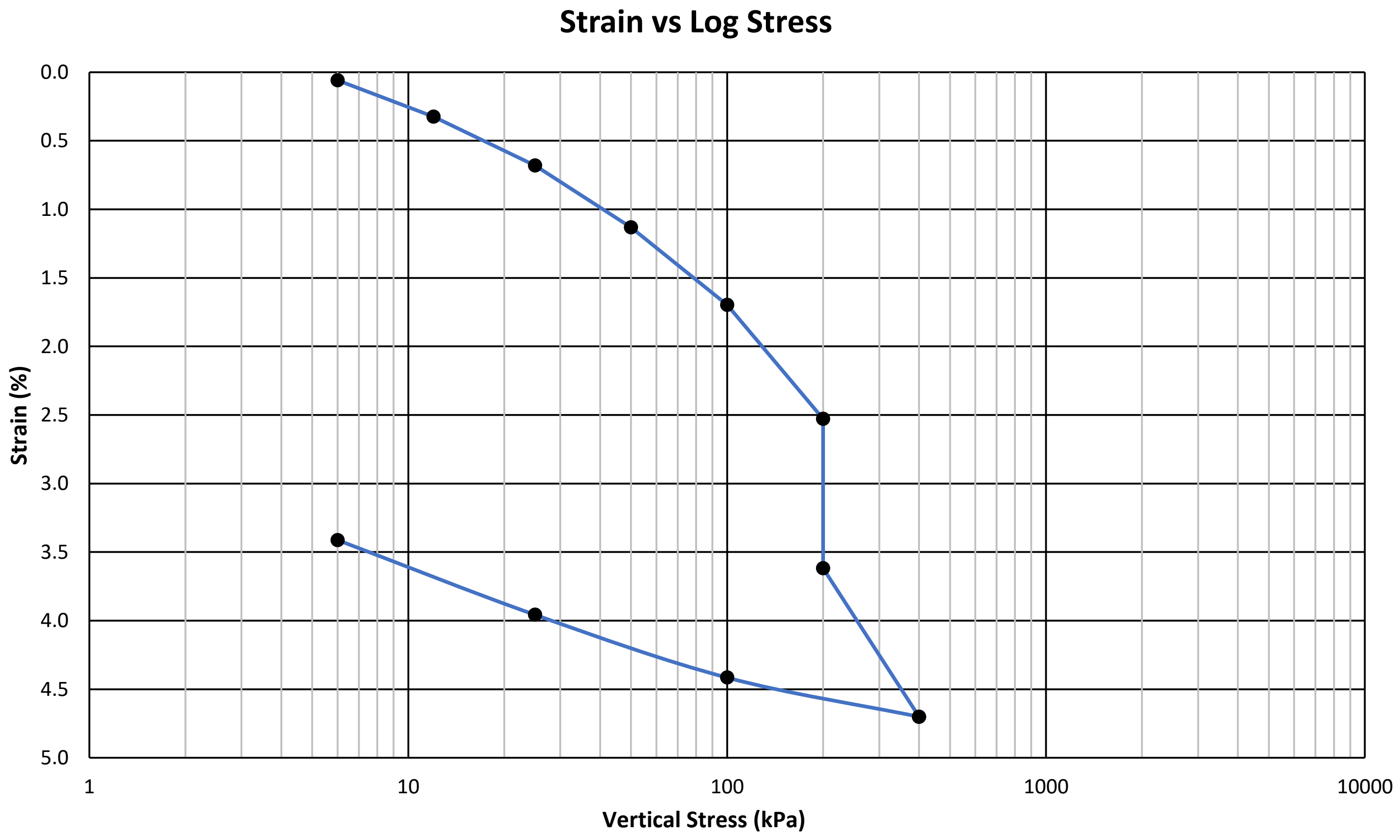


| | | | |
|---|---|---|---|
| **Client Name:** | Peregrine GeoConsultants | **Job Number:** | PGC-48 |
| **Project Name:** | PG19-090: Mampa & Swazi Mnyamane Access Bridges | **Lab Number:** | PGC-48-186 |
| **Sample:** | TP-MP01 | **Method:** | BS 1377 Part 5 |
| **Depth: (m)** | 0.6 - 3.3 | **Date:** | 20-Jan-20 |

# ONE DIMENSIONAL COLLAPSE POTENTIAL TEST

| Sample Info | | Unit | Initial | Test Remarks: |
|---|---|---|---|---|
| Test Specimen Height | | mm | 25.4 | **Collapse Potential:** 1.09 % |
| Moisture Content | Initial | % | 9.5 | |
| | Final | % | 23.4 | |
| Dry Density | | kg/m³ | 1527 | |
| Void Ratio | | - | 0.736 | |
| Degree of Saturation | | % | 34.3 | |
| Relative Density (SG) | | - | 2.650 | Assumed |

| Vertical Stress Applied: | kPa | 6 | 12 | 25 | 50 | 100 | 200 | 200 | 400 | 100 | 25 | 6 | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Load applied for: | Hrs | 1 | 1 | 1 | 1 | 1 | 1 | 24 | 1 | 1 | 1 | 1 | | |
| Height after increment | mm | 25.39 | 25.32 | 25.23 | 25.11 | 24.97 | 24.76 | 24.48 | 24.21 | 24.28 | 24.39 | 24.53 | | |
| Total Strain | % | 0.06 | 0.32 | 0.68 | 1.13 | 1.70 | 2.53 | 3.62 | 4.70 | 4.42 | 3.96 | 3.41 | | |
| Void Ratio | - | 0.735 | 0.730 | 0.724 | 0.716 | 0.706 | 0.692 | 0.673 | 0.654 | 0.659 | 0.667 | 0.677 | | |
| Mv (1/Mpa) | - | - | 0.442 | 0.276 | 0.181 | 0.115 | 0.085 | - | 0.056 | 0.010 | 0.064 | 0.299 | | |



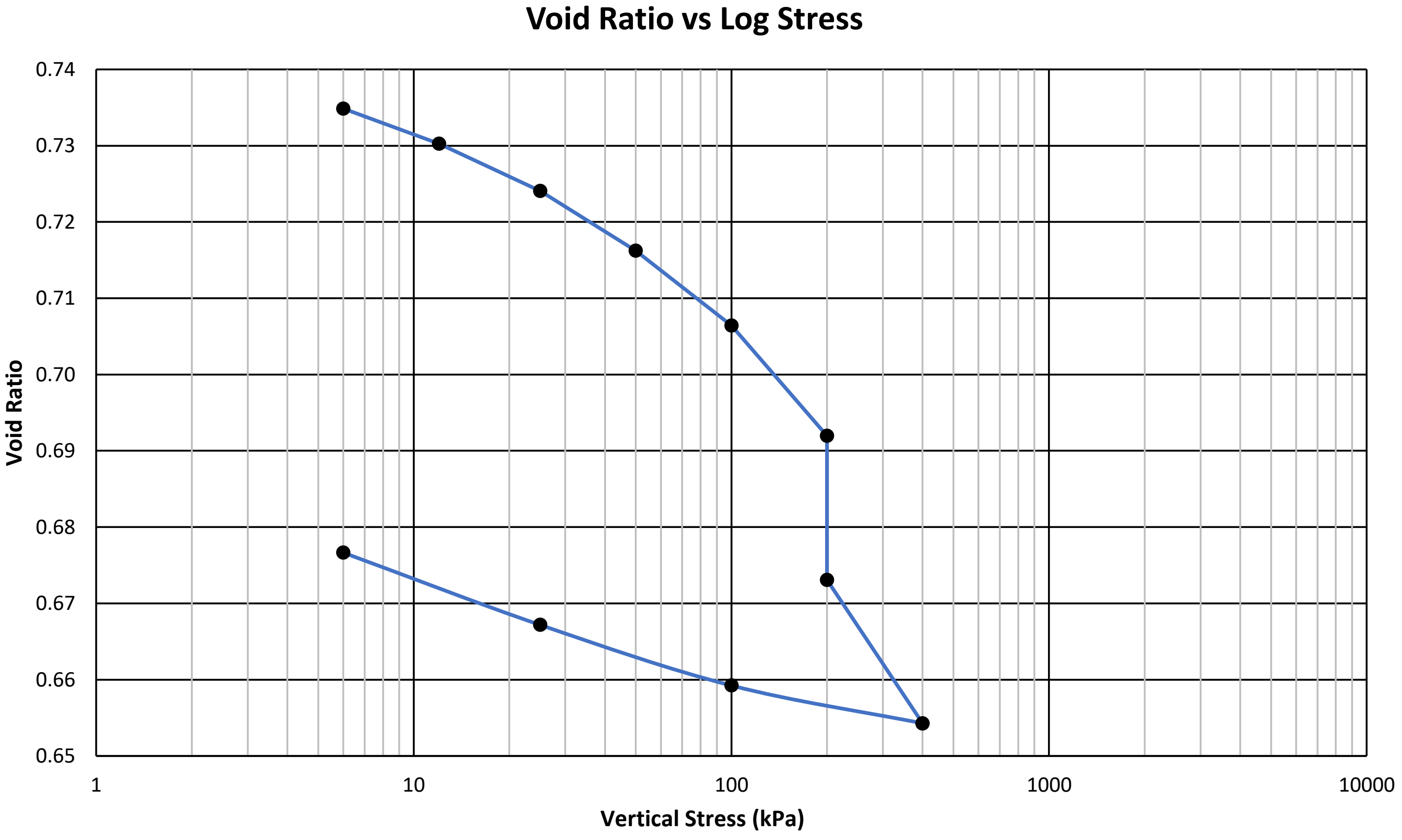
**Client Name:** Peregrine GeoConsultants
**Project Name:** PG19-090: Mampa & Swazi Mnyamane Access Bridges
**Sample:** TP-MP01
**Depth: (m)** 0.6 - 3.3

**Job Number:** PGC-48
**Lab Number:** PGC-48-186
**Method:** BS 1377 Part 5
**Date:** 20-Jan-20

# ONE DIMENSIONAL COLLAPSE POTENTIAL TEST

| **Sample Info** | | **Unit** | **Initial** | **Test Remarks:** |
|---|---|---|---|---|
| Test Specimen Height | | mm | 25.4 | **Collapse Potential:** 1.09 % |
| Moisture Content | Initial | % | 9.5 | |
| | Final | % | 23.4 | |
| Dry Density | | kg/m³ | 1527 | |
| Void Ratio | | - | 0.736 | |
| Degree of Saturation | | % | 34.3 | |
| Relative Density (SG) | | - | 2.650 | Assumed |

| | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Vertical Stress Applied: | kPa | 6 | 12 | 25 | 50 | 100 | 200 | 200 | 400 | 100 | 25 | 6 | | |
| Load applied for: | Hrs | 1 | 1 | 1 | 1 | 1 | 1 | 24 | 1 | 1 | 1 | 1 | | |
| Height after increment | mm | 25.39 | 25.32 | 25.23 | 25.11 | 24.97 | 24.76 | 24.48 | 24.21 | 24.28 | 24.39 | 24.53 | | |
| Total Strain | % | 0.06 | 0.32 | 0.68 | 1.13 | 1.70 | 2.53 | 3.62 | 4.70 | 4.42 | 3.96 | 3.41 | | |
| Void Ratio | - | 0.735 | 0.730 | 0.724 | 0.716 | 0.706 | 0.692 | 0.673 | 0.654 | 0.659 | 0.667 | 0.677 | | |
| Mv (1/Mpa) | - | - | 0.442 | 0.276 | 0.181 | 0.115 | 0.085 | - | 0.056 | 0.010 | 0.064 | 0.299 | | |



Client: SPECIALISED TESTING LABORATORY

Project: PG19-090: MAMPA & SWAZI MNYAMANE ACCESS BRIDGES

Project No.: S19-2310

Date: 2020-01-28

## TEST RESULTS: CHEMICAL DISPERSION

| **Soillab No.:** | S19-2310-01 | S19-2310-02 |
|---|---|---|
| **Sample No.:** | TP-SM01 0-3.3m | TP-MP01 0-0.6m |
| **pH** (TMH1) A20 | 8.23 | 8.59 |
| **EC (mS/m)** (TMH1) A21T | 230.0 | 70.10 |
| *** Na (me/100g)** # | 1.56 | 0.39 |
| *** K (me/100g)** # | 0.75 | 0.21 |
| *** Ca (me/100g)** # | 6.50 | 6.24 |
| *** Mg (me/100g)** # | 2.47 | 2.34 |
| *** CEC (me/100g)** # | 42.99 | 13.40 |
| *** ESP =** $\frac{\mathbf{Na}}{\mathbf{CEC}}$ X100 | 3.63 | 2.91 |
| *** EmgP =** $\frac{\mathbf{Mg}}{\mathbf{CEC}}$ X100 | 5.74 | 17.42 |
| *** ESP + EMgP** | 9.37 | 20.33 |

Note:* Not Accredited # Science Society of South Africa.

Client: SPECIALISED TESTING LABORATORY

Project: PG19-090: MAMPA & SWAZI MNYAMANE ACCESS BRIDGES

Project No.: S19-2310

Date: 2020-01-28

## TEST RESULTS: CHEMICAL DISPERSION

| **Soillab No.:** | S19-2310-03 | S19-2310-04 |
|---|---|---|
| **Sample No.:** | TP-MP01 0.6-3.3m | TP-MP03 0-1.1m |
| **pH** (TMH1) A20 | 8.54 | 9.03 |
| **EC (mS/m)** (TMH1) A21T | 58.60 | 15.50 |
| * **Na (me/100g)** # | 0.46 | 0.15 |
| * **K (me/100g)** # | 0.22 | 0.08 |
| * **Ca (me/100g)** # | 5.94 | 3.68 |
| * **Mg (me/100g)** # | 2.34 | 1.91 |
| * **CEC (me/100g)** # | 14.91 | 4.97 |
| * **ESP** = $\frac{\mathbf{Na}}{\mathbf{CEC}}$ X100 | 3.09 | 3.02 |
| * **EmgP** = $\frac{\mathbf{Mg}}{\mathbf{CEC}}$ X100 | 15.69 | 38.43 |
| * **ESP + EMgP** | 18.78 | 41.45 |

Note:* Not Accredited # Science Society of South Africa.

# APPENDIX D:
# GENERAL PHOTOGRAPHS

**Figure D-1: Excavation of TP-MP01**

**Figure D-2: Condition of Mampa stream crossing at the time of the investigation.**

**Figure D-3: Condition of Swazi Mnyamane stream crossing at the time of the investigation.**

**Figure D-4: Erosion dongas at outlet of Swazi Mnyamane.**

**Figure D-5: View of erosion dongas downstream of Swazi Mnyamane.**