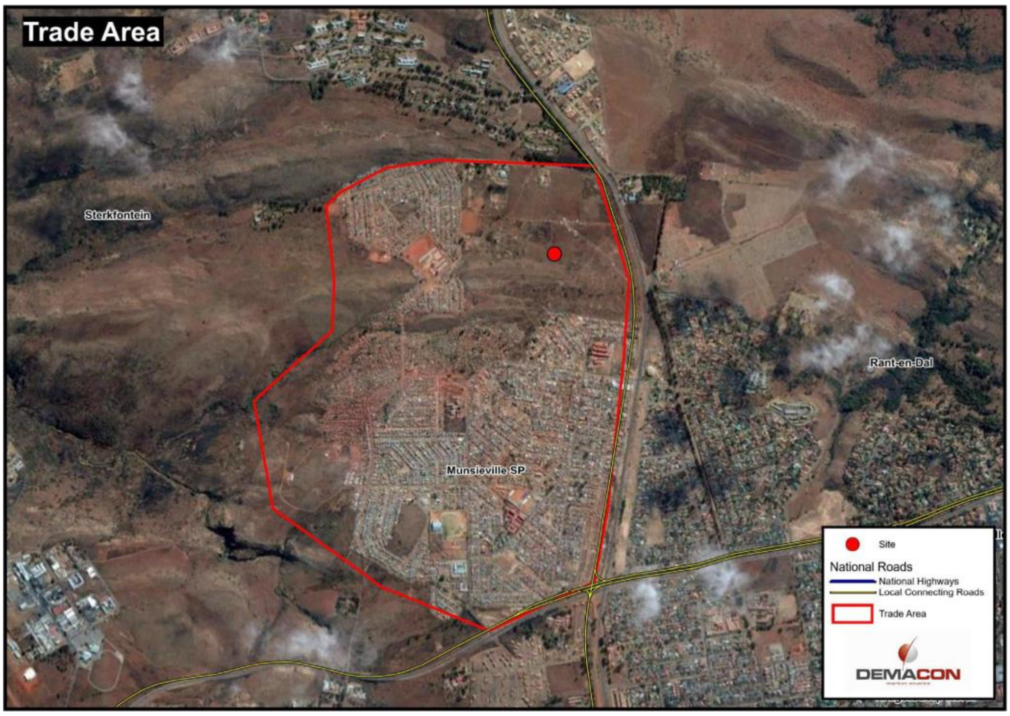
GEOTECHNICAL INVESTIGATION REPORT AT MUNSIEVILLE EXTENSION 10 (PORTIONS 26, 37, 40 & 41 OF FARM PAARDEPLAATS 177-IQ) MOGALE CITY LOCAL MUNICIPALITY IN WEST RAND DISTRICT MUNICIPALITY GAUTENG PROVINCE



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GEOTECHNICAL INVESTIGATION REPORT AT MUNSIEVILLE EXTENSION 10

(PORTIONS 26, 37, 40 & 41 OF FARM PAARDEPLAATS 177-IQ) MOGALE CITY LOCAL MUNICIPALITY IN WEST RAND DISTRICT MUNICIPALITY GAUTENG PROVINCE.

Report date: January 2017

Prepares By; Nomfundo Exploration and Consulting (Pty) Ltd

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EXECUTIVE SUMMARY

The property owner, Uvuko Civils Maintenance and Construction (Pty) Ltd, has appointed Nomfundo Exploration and Consulting (Pty) Ltd, a geotechnical and geological consulting company, in the month of July 2016, to undertake geotechnical investigation for the project: Portion on 26, 37, 40 & 41 of Paardeplaats 177 Munsieville Mogale City, West Rand District Municipality , proposed to be developed as Human Settlement Mixed Development.

According to the regional and site geology, the study area is underlined by shale, quartzite, conglomerate, diamictite of the Government Sub-group (Rg), West Rand Group, of the Witwatersrand Supergroup. Thus the conditions encountered are none-dolomitic.

Gradient along the north – south (south facing slope, thus area drains to the south) is 2.4 degrees (slope 1:14) and west – east (west facing slope, thus area drains to the west) the maximum slope is 11 degree and averaged slope from north-south is at 5.5 degrees (slope 1:6). Thus the terrain elevations are classified as Relief Class 2: Rolling and irregular plains – fairly low relief with moderate percentage of near-level land; low to moderate steep slopes.

The climatic N-value 2 – 5 nearest approximation to Thornthweite's climatic regions is Sub-humid warm. The residual soils derived from weathering of Government Sub-group (Rg), West Rand Group, of the Witwatersrand Supergroup giving rise to secondary minerals, resulting in weakly cemented grain structures, resulting in quartz minerals cemented by clayey-silty bridges, thus forming collapsible and compressible residual soils.

Thus the Munsieville Extension 10 is underlined by soil horizons subject to both consolidation and collapse settlement, the soil class designation is C2.

Foundations design solutions for this soil class designations C2 includes;

- Stiffened strip footings, stiffened or cellular raft
- Deep strip foundations compaction of insitu soils below individual footings
- Soil raft

Construction limitations, shear strength; unstable slopes; semi-pervious to impervious soil; poor to good compaction and workability. Rippability rating chart (adapted after Weaver 1975) based on all rock descriptive parameters weathering, hardness, joint spacing and joint continuity; our company's evaluation of the rock rippability has been estimated from the Tractor Loader Backhoe, we have concluded the following; Good rock (Rock Class II) - Fair rock (Rock Class III) Very hard ripping to blasting, Tractor selection DD9G/D9G (Horsepower 770/385 Kilowatts 575/290) - D9/D8 (Horsepower 385/270 Kilowatts 290/200.

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1 Introductions

1.1 Terms of reference

The property owner, Uvuko Civils Maintenance and Construction (Pty) Ltd, has appointed Nomfundo Exploration and Consulting (Pty) Ltd, a geotechnical and geological consulting company, in the month of July 2016, to undertake geotechnical investigation for the project: Portion on 26, 37, 40 & 41 of Paardeplaats 177 Munsieville Mogale City, West Rand District Municipality , proposed to be developed as Human Settlement Mixed Development.

1.2 Project background

The Munsieville Extension 10, property area sizes estimated at approximately 28.64 hectares, thus, the proposed development concept aims to maximize the full potential of this prime property by providing mixed use opportunities for RDP houses, rental housing stock, low cost housing, bonded housing stock, and commercial development boasting offices, convenient store and a filling station.

1.3 Project location

The size of the property is approximately 28.64 hectares, comprising Portions 26, 37, 40 and 41 respectively of Farm Paardeplaats 177-IQ, in Munsieville, Krugersdor (**Figure 1**).

The geographicalcoordinates are 26o 3' 57.11" South, and 27o 45' 24.9" East respectively.

Figure 1: Munsieville Extension 10

1.4 Munsieville Extension 10 Topography

The property is bounded by the following features:

- north by Helena Street which also borders the Sterkfontein Psychiatric Hospital;
- east by Van Riebeeck Road/R563 provincial road.
- west by Portions 31, 42 and 85 of Farm Paardeplaats 177-IQ, bordering Munsieville Extension 4; and
- south by Portion 1 of Farm Paardeplaats 177-IQ, adjoining Munsieville Extension 5.

The topographycal descriptors are for the Munsievile Extension 10 have been derived from the regional and site specific physilogical descritpors observed at the immediate site. The topomaps showing site contour elevation maps are presented within the figures;

- **Figure 2** - Munsieville Extension 10 site specific topography survey
- **Figure 3** - Munsieville Extension 10 topography map

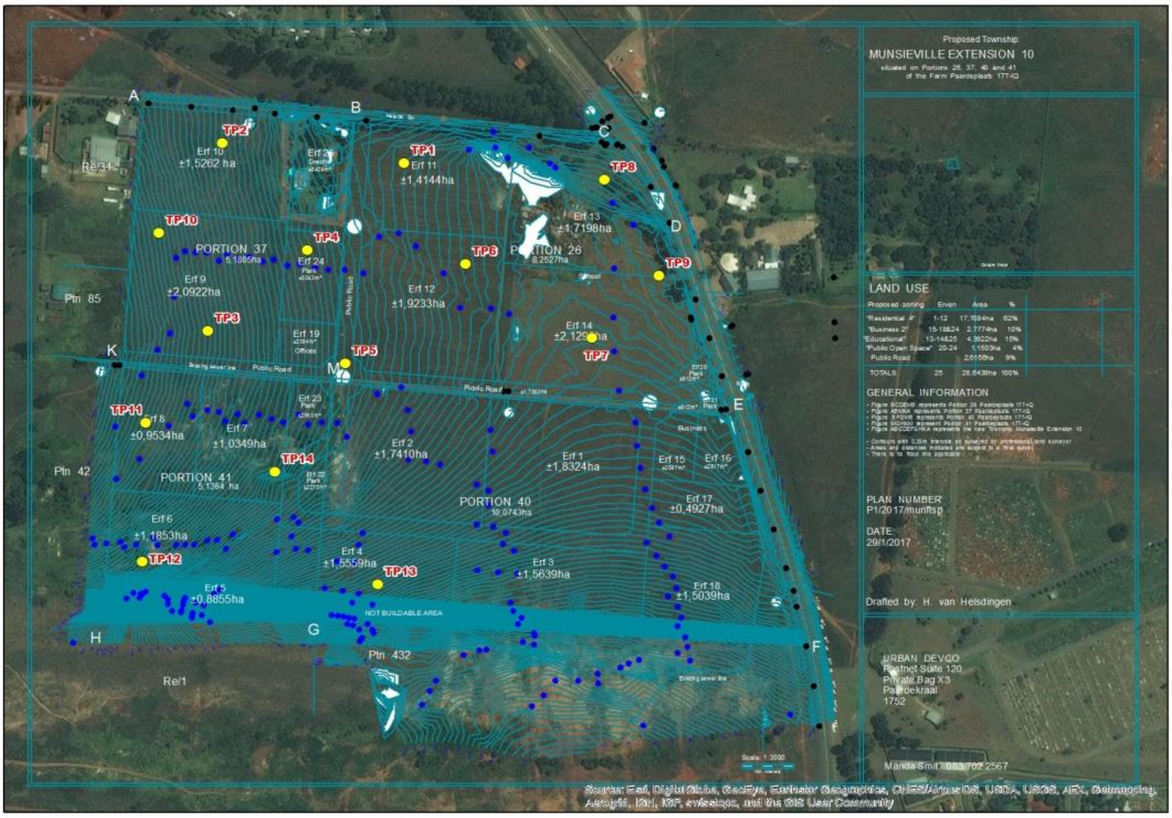

Figure 2: Munsieville Extension 10 site specific topography survey

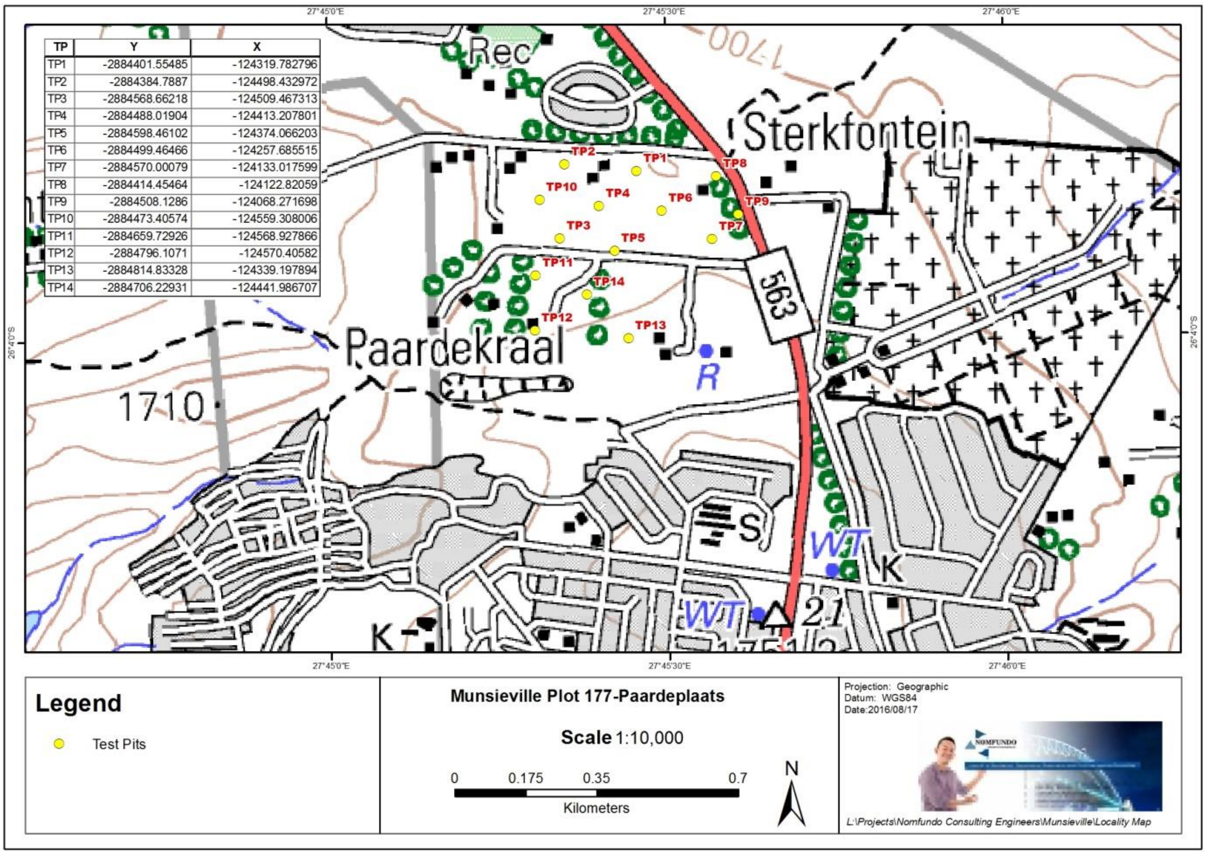

Figure 3: Munsieville Extension 10 topography map

2 Geotechnical Objectives

2.1 Planning soil evaluations

In the planning stages of the investigation, these “problem soils” should be identified from published geological maps or literature and catered for by the investigation methods.

2.2 Geotechnical Engineer

According with SANS documents, the competent geotechnical engineer defined as

- person who is registered with the Engineering Profession Act, 2000 Act No.46 of 2000 as either a Professional Engineer or Professional Technologist, has tertiary qualification degree or diploma in civil engineering and
- person who is registered as a Professional Natural Scientist in terms of Natural Scientific Professions Act, 2003 (Act No. 27 of 2003), and has a BSc (Hons) degree in engineering geology and has suitable experience in geotechnical site investigations or foundation design or both.

2.3 Geotechnical Division

The Geotechnical Division of South African Institution of Civil Engineers has published the relevant technical documents that govern the Geotechnical Site Investigations as Code of Practice in January 2010.

Several technical documents and national standards are utilized by our company Nomfundo Exploration and Consulting (Pty) Ltd when planning and preparing the geotechnical reports, this includes, but not limited to;

- The South African National Standards has published SANS 633 Geotechnical Investigation for Township Development – Soil profiling and rotary percussion borehole logging on dolomite land in South Africa for Engineering Purpose.
- The South African National Standards has published SANS 10400 Part H Foundations – The Application of the National Building Regulations.
- Council for Geoscience published a detailed review of problem soils in South Africa. Titled "*A review on Problem Soils in South Africa*" Authored by S. Diop, F. Stapelberg, K. Tegegn, S.Ngebelanga, L. Heath. CGS report number: 2011-0062. Western Cape Unit.
- Project Team BKS. "*Document to Assist with The Evaluation of Preliminary Geotechnical Investigation Reports*". Prepared for Department of Public Works. August 2010. Report no 108/940. Project no. J01075-1-002.

2.3.1 Stage of soils investigations

The geotechnical planning takes several stages to be accomplished i.e. Feasibility stage and Design Foot-print investigations. ***This geotechnical report is consider to be Phase 1 Feasibility Geotechnical Investigations, thus, we recommend a Phase 2 Foot-Print design level investigation***.

The soil evaluation report must answer these technical questions,

2.3.2 Soil conditions

i.e. Dolomitic terrain; Undermined land; Landfill/backfilled sites; Expansive soils; Collapsible soils; Highly compressible soils; Dispersive soils.

2.3.3 Suitability of the development

After the assessment of the soil and physiological site conditions, the engineer is also required to indicate the suitability of the site in relation to the proposed development after the comprehensive assessment of geotechnical conditions. The site suitability can be described as following;

- most favourable,
- intermediately favourable, and
- least favourable

2.3.4 Physiographic description

The physiographical descriptors for the geotechnical terrain mapping have been retrieved from Technical Recommendations for Highways **TRH 2 Geotechnical and soil engineering mapping for roads and the storage of material data 1978**.

Relief class	Physiographic description	Relief (m)
Relief class 1	Nearly flat plains – low relief, much of it nearly level	<5
Relief class 2	Rolling and irregular plains – fairly low relief with high percentage of near-level land; no high steep slopes	5 - 100
Relief class 3	Low hills – moderate relief; low percentage of near-level land	100 - 200
Relief class 4	Not described	Not described
Relief class 5	High hills – moderate to high relief; low percentage of near-level land	200 - 300
Relief class 6	Not described	Not described
Relief class 7	Low mountains and escarpments – high relief; low percentage of near-level land	300 - 1000
Relief class 8	High mountains and escarpments – very high relief; little near-level ground	>1000

2.3.5 Physiological descriptors

The Land form group descriptors for the geotechnical terrain mapping have been retrieved from Technical Recommendations for Highways **TRH 2 Geotechnical and soil engineering mapping for roads and the storage of material data 1978**.

Land form group	Descriptive terms	Land form group	Descriptive terms
Crest	Mountain crest	Drainage features	Gully head
	Hill crest		Gully
	Ridge crest		Pan side
	Plateau crest		Pan floor
	Bump		River terrace
Free face	Free face		River bank and/or levee
Cliff	Cliff		Flood plain
Slope	Talus slope		Swamp
	Convex side slope		Delta
	Concave side slope		Sand bank
	Constant slope		River channel
	Pediment	Surface water	Dams
	Ledge		Spring
	Landslide		Lake
	Fan	Coast	Lagoon
Plains and dunes	Plain		Raised beach
	Shifting dunes		Beach
	Stabilized dunes		
	Dune sheet		

2.4 Weinert's N-Value

In arid conditions, the weathering of rock results mainly from mechanical disintegration through wind erosion and temperature changes. The resultant soils consists mainly of the original rock forming minerals without significant changes that have taken place of the minerals compositions.

Climate does not only determine the mode of weathering which is likely to take place, but also the rate of weathering. The effect of climate on the weathering process i.e. soil formation is determined by the Weinert climatic N-Value, as depicted within the **Figure 4 Climatic zones for southern Africa**.

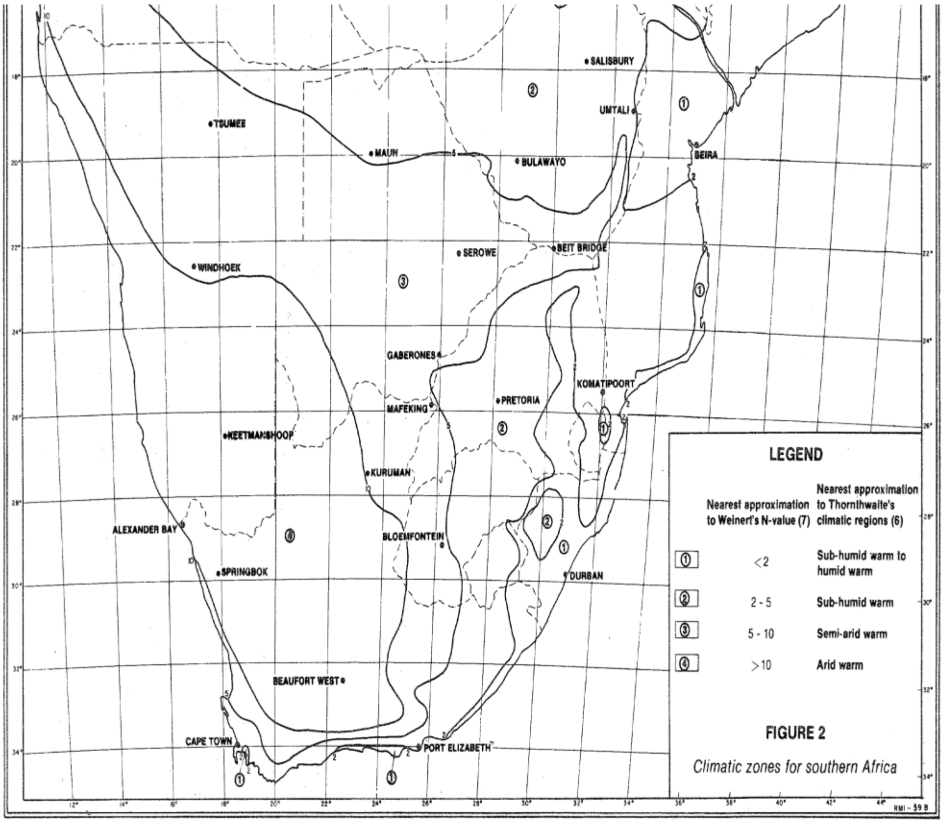

Figure 4: Climatic zones for southern Africa

In warm humid conditions chemical decomposition is the dominant mode of weathering which may change the original rock forming minerals into secondary minerals within the zone of weathering.

Minerals in this zone react with water, oxygen and carbon dioxide at atmospheric pressures to produce residual soils.

The residual soils produced are a mixture of resistant primary minerals such as quartz, insoluble weathering products such as alumina or silica and new or secondary minerals such as clays. It may also contain soluble products such as chloride, sulphate and bicarbonate of sodium, potassium, magnesium, or calcium, which may subsequently be leached out.

According with the Weinert climatic N-value, the following rock weathering modes are predominant;

- N-value <2 nearest approximation to Thornthweite’s climatic regions Sub-humid warm to humid warm.
- N-value 2 – 5 nearest approximation to Thornthweite’s climatic regions Sub-humid warm.
- N-value 5 – 10 nearest approximation to Thornthweite’s climatic regions Semi-arid warm.
- N-value >10 nearest approximation to Thornthweite’s climatic regions Arid warm.

Deep residual soils are usually found in areas of relative high rainfall in the eastern areas of South Africa, where the Weinert N-Value is less than 5 and chemical weathering is dominant.

Shallow bedrock with a thin cover of residual soil is usually found in the arid western area of South Africa, where the Weinert N-value is more than 5 and mechanical disintegration is dominant.

2.5 Origin of residual soils

The weathering of products of rock depend mainly on the rock forming minerals parent material, the climatic conditions under which they had formed and the time of exposure to weathering processes.

Parent Rock Type	Example of Rock Type	Type of Material Formed	Associated Engineering Impact
Acid igneous rocks	Vein quartz Pegmatite Rhyolite Aplite Granite	Clayey sand or sandy clay often mica rich; clayey gravel; corestone; gravel. Cobbles and boulder	Collapsible grain structure; dispersive soils; sand boils, high permeability; high erodibility; good compaction and workability
Basic igneous rocks	Basalt Dolerite Andesite Diorite Norite Pyroxenite	Clay (turf); silty clay changing to sandy clay with depth; corestones; gravel, cobbles and boulders	Expansive clay; low shear strength semi to impervious soil; poor compaction and workability; unstable slopes; uneven bedrock surface
Calcareous rocks	Calcrete Limestone Marble Dolomite	Wad; silty or sandy clays; clayey or sandy gravel, cobbles and boulders; large floaters of dolomite	Cavities, sinkholes and dolines; hard rock bands with interbedded loose or soft layers; highly erodible; highly porous; fair to good compaction and workability; troughs and pinnacles; extremely uneven bedrock surface; paleosinkholes
Argillaceous (clayey) Sedimentary rocks	Claystone Mudstone Siltstone Shale Coal	Clay, silt, silty clay	Expansive clay; low shear strength; high settlement; slaking on exposure; semi – or impervious soil; dispersive soil; poor compaction or workability; unstable slopes.
Arenaceous (sandy) Sedimentary rocks	Sandstone Conglomerate Tillite Chert	Clayey sand or gravel; cobbles, boulders or rubble	Expansive clay from tillite; pervious to semi-impervious soil; high erodibility; good to excellent compaction and workability
Metamorphic rocks	Marble Slate Hornfels Quartzite Schist Gneiss Anthracite	Clay, silt and sand angular gravel, cobbles or boulders	Low shear strength; unstable slopes; semi-pervious to impervious soil; poor to good compaction and workability

3 Results of the investigations

3.1 Geology Map

The site geology has been retrieved from the regional geology map Sheet 2626 West Rand published by Council for Geosciences at a Scale of 1:250 000.

The site geology map has been represented within the **Figure 5: Regional geology Sheet 2626 West Rand**.

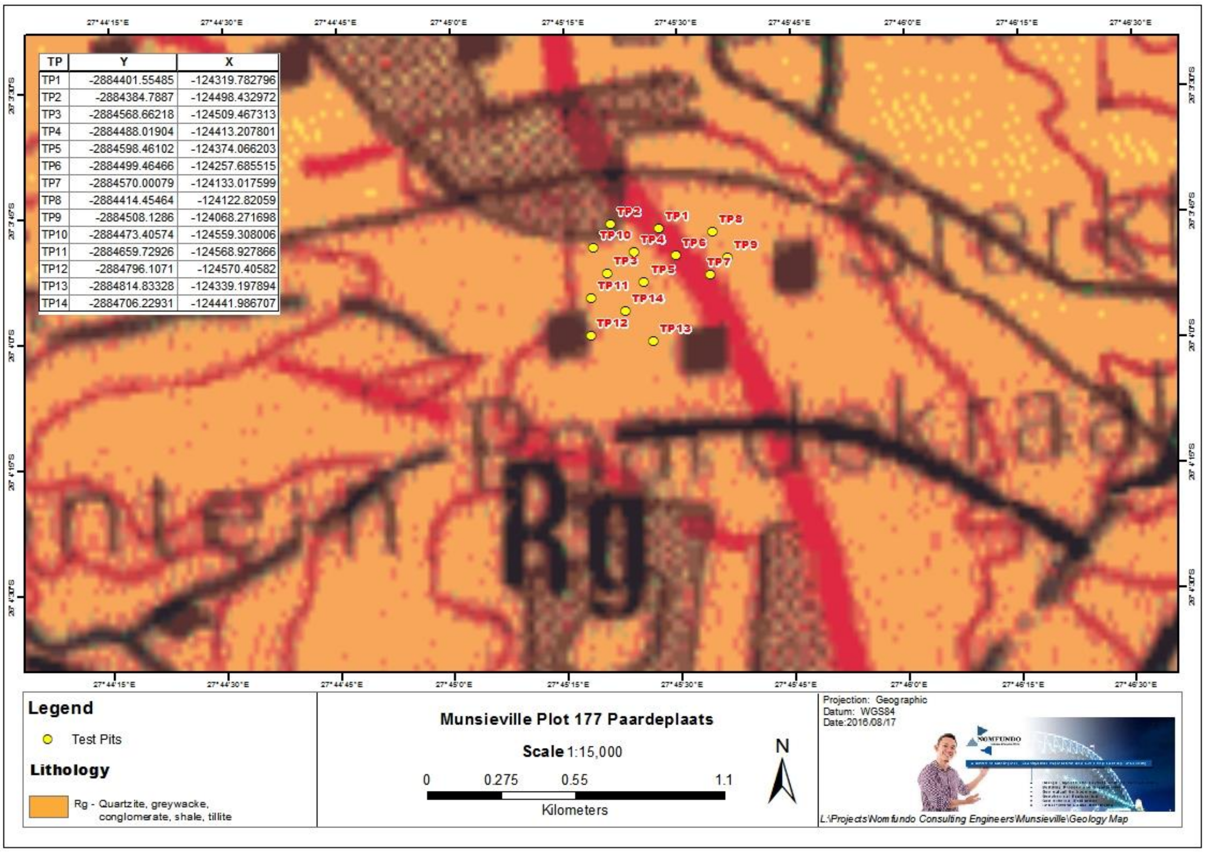

Figure 5: Regional geology Sheet 2626 West Rand

3.2 Geological Formations

The study area is underlined by shale, quartzite, conglomerate, diamictite of the Government Sub-group (Rg), West Rand Group, of the Witwatersrand Supergroup.

See regional geology cross-section North-South within **Figure 6: Regional geology cross section North-South Witwatersrand Supergroup**.

The Government Sub-group is forming concealed geological contacts with the following geology formations, namely;

- Jeppestown (Rj) and Hospital Hill (Rh)
- Orange Grove at the base (Ro)
- Turffontein (Rt) Sub-group
- Johannesburg (Rjo) Sub-group.

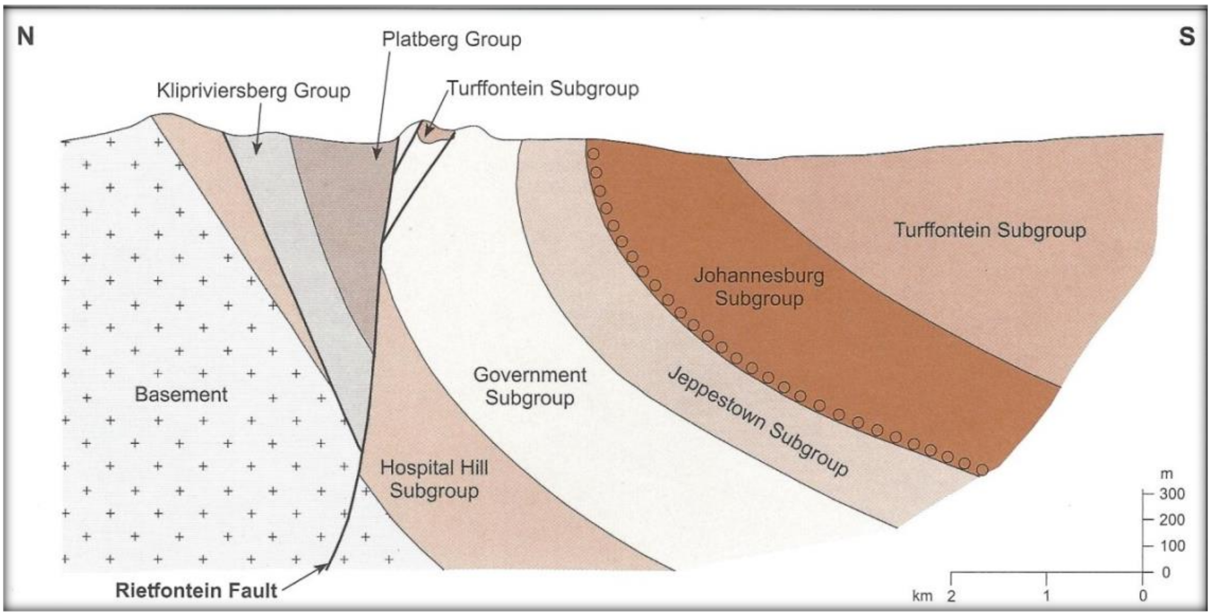

Figure 6: Regional Geology cross section North-South Witwatersrand Supergroup

3.3 Dolomite Formations

According to the published geology map Sheet 2626 West Rand published by Council for Geosciences at a Scale of 1:250 000, the Munsieville Extension 10 is situated in dolomitic conditions.

3.4 Slope assessments

3.4.1 North-South

The site slope gradient for the north-south topographical cross alignment is presented within **Figure 7 - Munsieville North-South topography cross section ©Google Earth Maps**

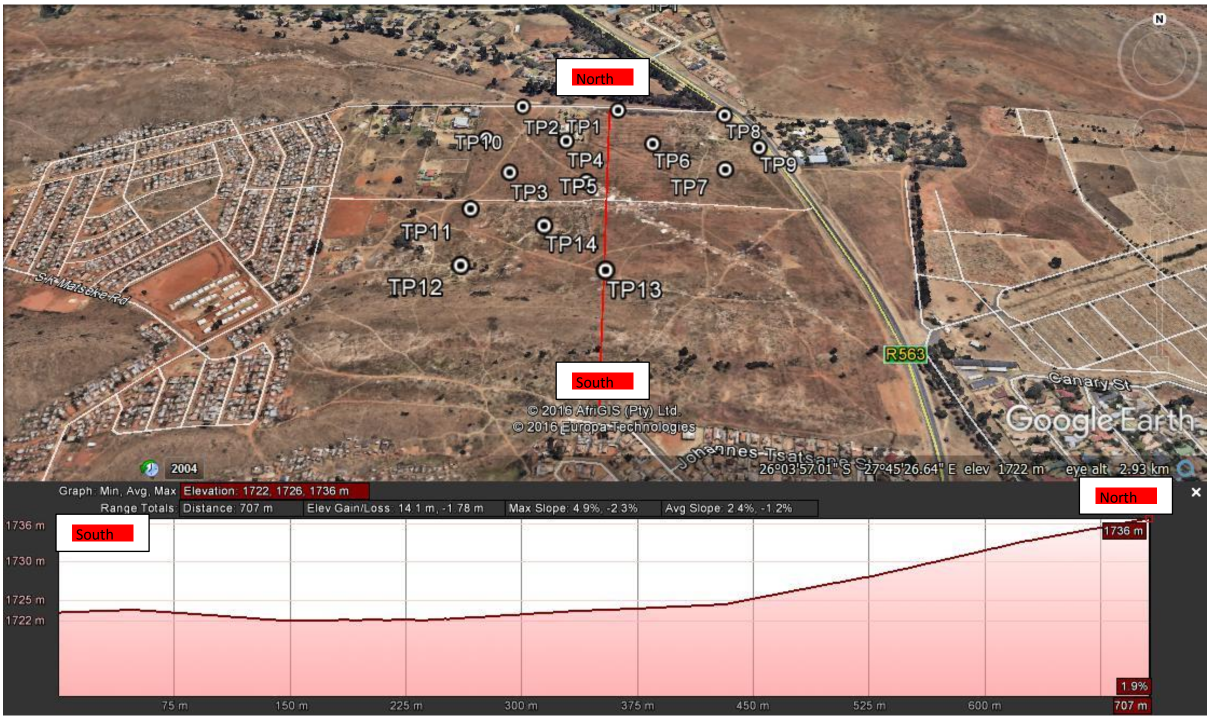

Figure 7: Munsieville North-South topography cross section ©Google Earth Maps

According to the calculations from the Google Earth Map, the evaluated gradient along the north – south (south facing slope, thus area drains to the south) the maximum slope is 4.9 degree and averaged slope from north-south is at 2.4 degrees.

The gradient is 1:14 (for every one meter vertical increase, you need a horizontal distance of about 14m).

Thus the terrain elevations on north-south are best described as Relief Class 2: Rolling and irregular plains – fairly low relief with high percentage of near-level land; no high steep slopes.

3.4.2 West-East

The site slope gradient for the west-east topographical cross alignment is presented within **Figure 8 - Munsieville West-East topography cross section ©Google Earth Maps**

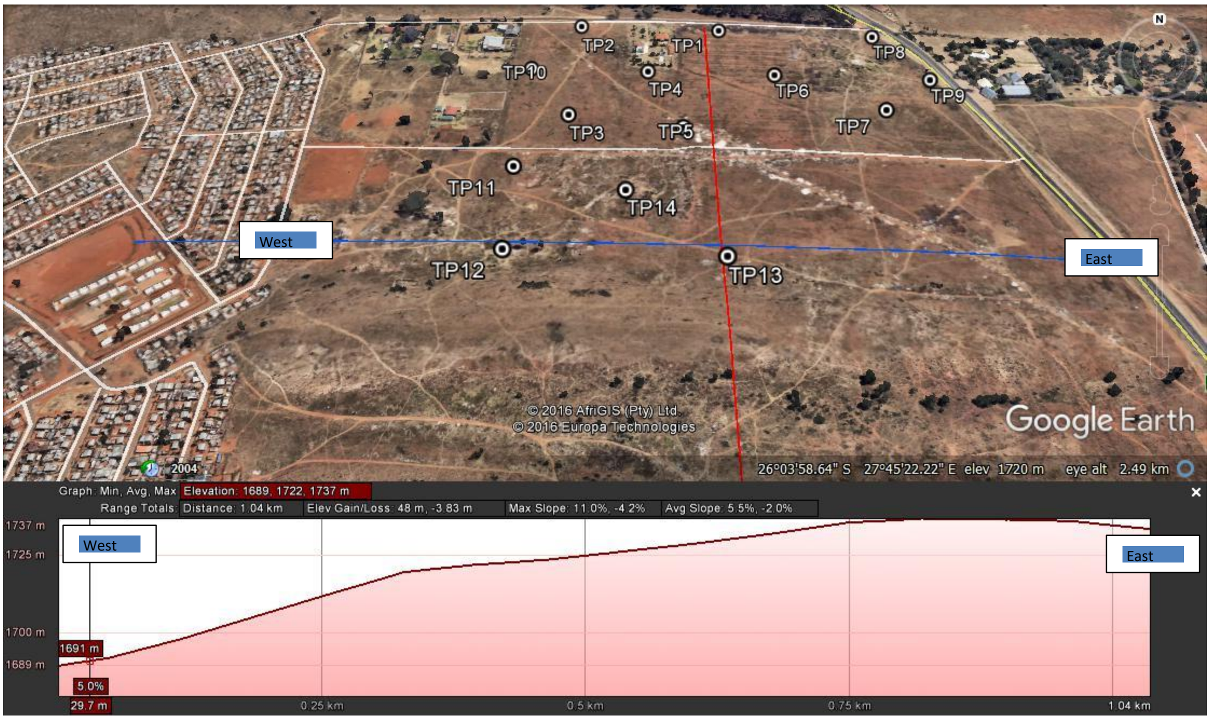

Figure 8: Munsieville West-East topography cross section ©Google Earth Maps

According to the calculations from the Google Earth Map, the evaluated gradient along the west – east (west facing slope, thus area drains to the west) the maximum slope is 11 degree and averaged slope from north-south is at 5.5 degrees.

The gradient is 1:6 (for every one meter vertical increase, you need a horizontal distance of about 6m).

Thus the terrain elevations on west-east are best described as Relief Class 2: Rolling and irregular plains – fairly low relief with moderate percentage of near-level land; low to moderate steep slopes.

3.5 Excavation of Test Pits

In the year 2007 on 30th November, a report was compiled by Soilkraft titled "Geotechnical conditions on a part of the remaining portion of portion 6 (A portion of portion 1), and portion 41 and 42 of the Farm Paaderplaats 177-IQ", we acknowledge this report in our report, it has been located in **Annexure A**.

Geotechnical field investigations was conducted by means of exploration trial pits excavated by Tractor Loader Backhoe for the excavations to maximum reach of the machine or difficult excavation or refusal and / or required depth. Test holes for the purposes of in-situ profiling, sampling and the appraisal of excavatability, slope stability and visual assessment of groundwater seepage.

The geotechnical soil is conducted by competent geotechnical engineer in accordance with the *The South African National Standards has published SANS 633* Geotechnical Investigation for Township Development – Soil profiling and rotary percussion borehole logging on dolomite land in South Africa for Engineering Purpose

The soil profile was describes as per SANS 633, the description parameters as the following moisture, colour, consistency, structure, soil texture, soil origin. The soil profile is presented within **Annexure B**.

The climatic N-value 2 – 5 nearest approximation to Thornthweite's climatic regions is Sub-humid warm. The residual soils derived from weathering of Government Sub-group (Rg), West Rand Group, of the Witwatersrand Supergroup giving rise to secondary minerals, resulting in weakly cemented grain structures, resulting in quartz minerals cemented by clayey-silty bridges, thus forming collapsible and compressible residual soils.

3.5.1 Northeast central soil conditions

Several test pits were terminated on dense highly weathered pinkish reddish fine grained silty sandstone interpreted as quartzitic shales residual soils. Difficult conditions of excavations are prominent within the central part to the north part of the site. The dense horizons averaged depth to difficult excavations with Tractor Loader backhoe is 1.5m.

3.5.2 Southwest soil contions

Southwest part of the site comprises of hillwash derived from the weathering of these silty sandstone interpreted as quartzitic shales residual soils, the thickness is observed to extent below 3.0m.

3.6 Degree of soil cementation

The tables listed within this section have been retrieved from SANS 633:2012 **Soil profiling for Civil Engineering Purposes**. The list of table described the degree of soil cementation and soil structure as described within the document SANS 633;

Descriptor of Degree	Field Identification
Very weakly cemented	Some material can be crumbled between finger and thumb
Weakly cemented	Cannot be crumbled between strong fingers Some material can be crumbled by strong pressure between thumb and a hard surface. Under light hammer blows disintegrates into friable state
Moderately cemented	Material crumbles under firm blows of sharp pick point Grains can be dislodged with some difficulty with knife blade
Strongly cemented	Firm blows of sharp pick point on hand-held show 1 mm to 3 mm indentations Grains cannot be dislodged with knife blade

3.7 Calcified soils and Pedocrete soils

The tables listed within this section have been retrieved from SANS 633:2012 **Soil profiling for Civil Engineering Purposes**. The list of table described the Calcified and Pedocrete Soils as described within the document SANS 633;

Description of Calcified and Pedocrete Soils	Field Identification
Calcareous soil, substitute the terms ferruginous, manganiferous, siliceous, ferrugenised, or silicified, as appropriate	Soils (clay, silt, sand, gravel, etc.) with little or no cementation or nodular concentrations, but that contain some mineralization (calcareous soil effervescence)
Calcified soil, substitute the terms ferruginous, manganiferous, siliceous, ferrugenised, or silicified, as appropriate	A relatively massive platy soil which has been indurated by cementation to a firm of stiff consistency
Powder pedocrete, substitute the terms calcrete, ferricrete, silcrete, or manganocrete, as possible	Mainly loose silt and fine sand-sized cemented or aggregated particles of nearly pure mineral, with few or no host soil particles or nodules Any nodules present are generally weak
Nodular pedocrete, substitute the terms calcrete, ferricrete, silcrete, or manganocrete, as possible	Silt to gravel-sized nodules of cemented host soil Usually in a matrix of calcareous soil Overall consistency of horizon might be loose Nodules can be firm to very hard rock
Honeycombed pedocrete, substitute the terms calcrete, ferricrete, silcrete, or manganocrete, as possible	Stiff to very hard coalesced nodular pedocrete with loose or soft soil filled voids Can occur also as fissure filling in weathered rock resulting in a boxwork structure
Hardpan pedocrete, substitute the terms calcrete, ferricrete, silcrete, or manganocrete, as possible	Stiff to very hard rock, cemented, relatively massive and impermeable sheet-like horizon Normally overlying weak pedocrete forms Hardpan can be structureless, jointed or contain a variety of structures or voids
Boulder / cobble pedoocretes, substitute the terms calcrete, ferricrete, silcrete, or manganocrete, as possible	Discrete or partially connected boulder and cobble-sized fragments usually in a non-mineralized or weakly mineralized soil formed by the weathering of hardpan Fragments usually very hard

3.8 Soil structure

The tables listed within this section have been retrieved from SANS 633:2012 **Soil profiling for Civil Engineering Purposes**. The list of table described the Soils Structure as described within the document SANS 633;

Descriptor Ofsoil Structure	Field Identification
Intact	This term is only typical used in the description of cohesive soils Structureless. No discontinuities identified An absence of fissures or joints
Fissured	Soil contains discontinuities that can be open or closed, stained or unstained and variable origin When cut with a pick, the soil tends to break along these discontinuities
Slickensided	Slickensides might be a sign of fairly recent shearing movements in the soil, but similar shiny surface can also be developed on joint planes along which there has been no displacement. The direction of slickensides should be recorded as can be a major indicator/warning of ground movement. Discontinuity surfaces are smooth or glassy and possibly striated
Shattered	Often associated with expansive soils Very closely to extremely closely spaced discontinuities resulting in gravel-side soil fragments which are usually stiff to very stiff and difficult to break down Presence of fissures in which joints have opened up and permitted the entry of air The soil fragments are usually cubical or granular fragments and are broken up when the soil is cut with a pick
Micro-shattered	Often associated with expansive soils. As for shattered, but sand-sized fragments When micro-shattering is well developed and the soil is cut with a pick, it appears granular but these grains breakdown into a clay or silt or some combination of clay and silt when rubbed with water on the palm of the hand
Stratified, laminated, foliated	These and other geological terms may be used to describe sedimentary structures. Observation of this structure often provides an indication of the parent rock material. Identifiable geological patterns in transported soils and relict structures in residual soils. If the layers are less than 6 mm thick, the structure may be described as laminated (varved if the soil is silty or clayey)
Pinhole voided	Pinhole-sized voids or pores up to 2mm which might require hand lens to identify. Often indicative of potentially collapse or dispersive soil types or both
Clast/matrix supported	Clasts supported by matrix (Matrix-supported). Clast touching (Clast supported).

3.9 Laboratory testing

Munsieville Extension 10 WWTW disturbed soil samples have been submitted to for soil testing and upon receipt of this soil test results, the information shall be made available to the client and will be presented within **Annexure C**. Typical parameters from a geotechnical investigation will include the following:

3.9.1 Atterberg Limits

The objective of material classification is to categorise representative soils from the site stratigraphy into standard classes with similar engineering properties and behaviour. Classification is done on disturbed samples and generally comprises indicator and compaction testing. Material characterisation requires undisturbed representative samples to determine the in-situ state of the soil and rock (stress, density & structure), as well as specific material parameters of strength and compressibility for use in design calculations. If undisturbed samples cannot be obtained, samples can be reconstituted in the laboratory to represent the in-situ state, alternatively in-situ field testing could be considered.

3.9.2 Classification Soils

The soil Grading properties (75mm to 2µm) is derived from sieve analysis and Atterberg limits. Atterberg limits confirms the soil plasticity descriptors provided in the field. These tests are performed on the % passing the 2µm micron sieve. This % should be reported. There are examples of “rock’’ sites having a high PI, when 90% of the sample has been discarded in the test.

Liquid limit – minimum moisture content at which a soil will flow under its own weight. Plastic limit – minimum moisture content at which a 3mm thread of soil can be rolled with the hand without breaking up. Shrinkage limit – Maximum moisture content at which a decrease of moisture content does not cause a decrease in volume of the soils. Linear shrinkage is the minimum moisture content for soil to be mouldable. Plasticity Index= Liquid limit - Plastic limit.

3.9.3 Maximum compacted density

Modified AASHTO density and California Bearing Capacity and Moisture density relationship, Optimum moisture %, all this parameters gives the bulk density and compaction effort required on site to achieve the desired soil density on disturbed soils compacted in-situ.

This test method provides for the determination of the CBR of a material at optimum water content or a range of water content from a specified compaction test and a specified dry unit weight. The dry unit weight is usually given as a percentage of maximum dry unit weight from the compaction tests of Test Methods D 698 or D 1557.

3.9.4 Chemical tests i.e. pH & Conductivity

Langelier Index (LI), a measure of a solution's ability to dissolve or deposit carbonate, is often used as an indicator of the corrosivity of water.

Lingelier Index is not a quantitative measure of calcium carbonate saturation or corrosion.

LI = (pHactual – pHs) where pHs = A+B-C-D. Where;

pHs = pHactual, indicate the water is balanced.

pHs<pHactual = nonaggressive.

pHs>pHactual= aggressive water.

Aggressive index (AI), originally developed for monitoring water in asbestos pipe, is sometimes substituted for the Langelier Index as an indicator of the corrosivity of water. The AI is derived from the actual pH, calcium hardness and total alkalinity. AI does not include the effects of temperature or dissolve solids, it less accurate as an analytical tool than the LI. AI = pHactual+C+D.

4 Soil classifications at Munsieville Extension 10 WWTW

The geotechnical report output discusses the geotechnical site specific conditions with the aim of classifying the soils and the suitable foundation design for all infrastructures planned.

4.1 Soils classifications tables

The transported soils i.e. colluvium, hillwash, alluvium and residual soils derived from various rocks types as described in tables here in, are classified into **Table 1 –** Geotechnial soil classification SANS 10400H describing founding material, behaviour of founding material, estimated soil movement, assumed differential movement as percentage of total soil movement, all this information is evaluated by a competent person to derive at the site soil class designations conditions, thus foundation design recommendations i.e. soils conditions described as following;

Rock “R”

Expansive soil “H; H1-H3”

Compressible and potentially collapsible soils “C; C1-C2”

Compressible soils “S; S1-S2”

Table 1: Geotechnical soil classifications SANS10400H

Typical Founding Material	Founding Material	Movement (mm)	Assumed Differential Movement % of Total	Site Class Designation
Rock (excluding mud rocks which might exhibit swelling to some depth)	Stable	Negligible	-	R
Fine-grained soils with moderate to very high plasticity (clays, silty clays, clayey silts and sandy clays)	Expansive soil	<7.5 7.5 to 15 15 to 30 >30	50 50 50 50	H H1 H2 H3
Silty sands, clayey sands, sands, sandy and gravelly soils	Compressible and potentially collapsible soils	<5 5 to 10 >10.	75 75 75	C C1 C2
Fine-grained soils (clayey silts and clayey sands of low plasticity), sands, sandy and gravelly soils	Compressible soils	<10 10 to 20 >20	50 50 50	S S1 S2
Contaminated soils, controlled fill, dolomite land, landslip landfill, marshy areas, mine waste fill, mining subsidence reclaimed areas, etc.	Variable	Variable	-	P

4.2 Estimated soil movement

Nomfundo Exploration and Consulting (Pty) Ltd has retrieved disturbed soil samples at Munsieville Extension 10 and submitted the samples for laboratory testing.

The various soils have been conducted on the soils collected on the site, this included Grading testing, California bearing ration testing, further more we requested the Oedometer testing of the remoulded soil samples at 93% modified AASHTO density.

Thus our company sub-contracted the settlement soil testing to Langa and Associates (Pty) Ltd, this report is included within **Annexure D**.

4.3 Unified soil classification

The soils are classified according with TRB = Committee on Classification of Materials for Subgrades and Granular Type Roads of the Highway Research Board / AASHTO Classification system and USCS = Unified Soil Classification System.

The descriptors for the Unified soil classification symbols for the soils tested will have the following meaning;

Soil Type	Description	USC Symbol
Gravels	Well graded Poorly graded Silty Clayey	**GW** **GP** **GM** **GC**
Sands	Well graded Poorly graded Silty	**SW** **SP** **SM**
Inorganic silts	Clayey Low plasticity High plasticity	**SC** **ML** **MH**
Inorganic clays	Low plasticity High plasticity	**CL** **CH**
Organic	with silts/clays of low plasticity with silts/clays of high plasticity	**OL** **OH**

4.4 Soil characteristics as construction materials

The soil characteristics as construction material included the assessment of field characteristics of in-situ materials such according with unified soil classification symbols, drainage characteristics etc. adapted from BS 6031 – 1981.

Material type	Description	USC symbol	Drainage characteristics	Shrinkage or swelling properties	Value as a road foundation	Bulk density before excavation		Coefficient of bulking %
						Dry or moist Mg/m^3	Submerged Mg/m^3	
Boulders and cobbles	Boulders-	-	Good	Almost none		-	-	-
Other materials	Hard broken	-	Excellent	Almost none	Very good to excellent	-	-	20 - 60
Other materials	Soft rocks, rubble	-	Fair to practically impervious	Almost none to slight	Good to excellent	1.1 to 2.0	0.65 to 1.25	40
gravels and gravelly soils	Well graded	GW	Excellent	Almost none	Excellent	1.9 to 2.1	1.15 to 1.3	
gravels and gravelly soils	Poorly graded	GP	Excellent	Almost none	Good	1.6 to 2.0	0.9 to 1.25	
gravels and gravelly soils	Silty	GM	Fair to practically impervious	Almost none to slight	Good to excellent	1.8 to 2.1	1.1 to 1.3	10 - 20
gravels and gravelly soils	Clayey	GC	practically impervious	Very slight	excellent	2.0 to 2.254	1.0 to 1.35	10 - 20
Sands and sandy soils	Well graded	SW	Excellent	Almost none	Good to excellent	1.8 to 2.0	1.05 to 1.3	5 to 15
Sands and sandy	Poorly	SP	Excellent	Almost none	Fair to good	1.45 to	0.9 to 1.0	5 to 15

Material type	Description	USC symbol	Drainage characteristics	Shrinkage or swelling properties	Value as a road foundation	Bulk density before excavation		Coefficient of bulking %
						Dry or moist Mg/m^3	Submerged Mg/m^3	
soils	graded					1.7		
Sands and sandy soils	Silty	SM	Fair to practically impervious	Almost none to medium	Fair to good	1.7 to 1.9	1.0 to 1.15	5 to 15
Sands and sandy soils	Clayey	SC	Practically impervious	Very slight	Good to excellent	1.9 to 2.10	1.15 to 1.3	5 to 15
Inorganic silts	Low plasticity	ML	Fair to poor	Slight to medium	Fair to poor	1.7 to 1.9	1.0 to 1.15	20 to 40
Inorganic silts	High plasticity	CH	Poor	High	Poor	1.75	1.0	-
Inorganic clays	Low plasticity	CL	Practically impervious	Medium	Fair to poor	1.6 to 1.8	-	20 to 40
Inorganic clays	High plasticity	CH	Practically impervious	High	Poor to very poor	-	-	-
Organic	With silts/clays of low plasticity	OL	Practically impervious	Medium to high	Poor	1.45 to 1.70	0.9 to 1.0	20 to 40
Organic	With silts/clays of high plasticity	OH	Practically impervious	High	Very poor	1.5	0.5	-
Peat	Highly organic	Pt	Fair to poor	Very high	Extremely poor	1.4	0.4	-

4.5 Soil designations

The climatic N-value 2 – 5 nearest approximation to Thornthweite's climatic regions is Sub-humid warm. The residual soils are as a result of chemical weathering, giving rise to secondary minerals, resulting in weakly cemented grain structures, resulting in quartz minerals cemented by clayey-silty bridges, thus forming collapsible grain structure.

Thus the Munsieville Extension 10 is underlined by founded on soil horizons subject to both consolidation and collapse settlement, the soil class designation is C2.

Foundations design solutions for this soil class designations C2 includes;

- Stiffened strip footings, stiffened or cellular raft
- Deep strip foundations compaction of insitu soils below individual footings
- Soil raft

4.6 Foundation designs

The foundation designs for structures are completed in accordance with SANS10400-H:2012 edi.3. (section 4.2.3) "*For the purpose of this subclause, it may be assumed that total soil movements are approximately equal to 50% for soils that exhibit expansive or compressive characteristics and 75% for soils that exhibit both compression and collapse characteristics*".

Table 2 Foundation design buildings founded on expansive soil horizons.

Foundation design, building procedures and precautionary measures for single-storey type 1 masonry buildings founded on expansive soil horizons.

Table 3 Foundation design buildings founded on soil horizons subject to both consolidation and collapse settlement.

Foundation design, building procedures and precautionary measures for single-storey type 1 buildings founded on soil horizons subject to both consolidation and collapse settlement.

Table 4 Foundation design buildings founded on soil horizons subject to consolidation settlement.

Foundation design, building procedures and precautionary measure for single-storey type 1 buildings founded on soil horizons subject to consolidation settlement.

Table 2: Foundation design on expansive soil horizons

Site class	Estimated total heave (mm)	Construction type	Foundation design and building procedures (expected damage limited to category 1 of expected damage)
H	<7.5	Normal	Normal construction (strip footing or slab-on-the-ground) foundation Site drainage and service and plumbing precautions recommended
H1	7.5 - 15	Modified normal	Lightly reinforced strip footings Articulation joints at all internal and external doors and openings Light reinforcement in masonry Site drainage and plumbing and service precautions
		Soil raft	Remove all or necessary parts of expansive horizon to 1,0 m beyond the perimeter of the building and replace with inert backfill compacted to 93 % MOD AASHTO density at −1 % to +2 % of optimum moisture content Normal construction with lightly reinforced strip footings and light reinforcement in masonry if residual movements are < 7,5 mm, or construction type is appropriate to residual movements Site drainage and plumbing and service precautions
H2	15 - 30	Stiffened or cellular raft	Stiffened or cellular raft of articulated lightly reinforced masonry Site drainage and plumbing and service precautions
		Piled construction	Piled foundations with suspended floor slabs with or without ground beams Site drainage and plumbing and service precautions
		Split construction	Combination of reinforced masonry and full movement joints Suspended floors or fabric reinforced ground slabs acting independently from the building Site drainage and plumbing and service precautions
		Soil raft	As for H1
H3	>30m	Stiffened or cellular raft	As for H2
		Piled construction	As for H2
		Soil raft	As for H1
expected damage limited to category 1 of expected damage Fine internal cracks which can easily be treated during normal decoration see table 4 of SANS 10400-B:2012)			

Table 3: Foundation design on soil horizons subject to both consolidation and collapse settlement

Site class	Estimated settlement (mm)	Construction type	Foundation design and building procedures (expected damage limited to category 1 of expected damage)
C	<5	Normal	Normal construction (strip footing or slab-on-the-ground) foundation Good site drainage
C1	5 - 10	Modified normal	Reinforced strip footings Articulation joints at some internal and all external doors Light reinforcement in masonry Site drainage and service and plumbing precautions Foundation pressure not to exceed 50 kPa
		Compaction of insitu soils below individual footings	Remove in-situ material below foundations to a depth and width of 1,5 times the foundation width or to a suitable soil horizon and replace with material compacted to 93 % MODAASHTO density at –1 % to +2 % of optimum moisture content Normal construction with light reinforcement in masonry
		Deep strip foundations	Normal construction with drainage precautions Founding on a suitable founding horizon below the horizons within which relatively large movements might take place
		Soil raft	Remove in-situ material to 1,0 m beyond the perimeter of the building to a depth of 1,5 times the widest foundation or to a suitable soil horizon and replace with material compacted to 93 % MOD AASHTO density at –1 % to +2 % of optimum moisture content Normal construction with lightly reinforced strip footings and light reinforcement in masonry
C2	>10	Stiffened strip footings, stiffened or cellular raft	Stiffened strip footings or stiffened or cellular raft with lightly reinforced or articulated masonry Bearing pressure not to exceed 50 kPa Fabric reinforcement in floor slabs Site drainage and service and plumbing precautions
		Deep strip foundations compaction of insitu soils below individual footings	As for C1 but with fabric reinforcement in floor slabs
		Piled or pier foundations	Reinforced concrete ground beams or solid slabs on piled or pier foundations Ground slabs with fabric reinforcement Good site drainage
		Soil raft	Reinforced concrete ground beams or solid slabs on piled pier foundations Ground slabs with fabric reinforcement Good site drainage. As for C1
NOTE 1 Differential settlement equals 75 % of total settlement. NOTE 2 The relaxation of some of these requirements, for example, the reduction or omission of reinforcement or articulation joints, might result in a category 2 of expected damage (see table 4 of SANS 10400-B:2012).			

Table 4: Foundation design on soil horizons subject to consolidation settlement

Site class	Estimated settlement (mm)	Construction type	Foundation design and building procedures (expected damage limited to category 1 of expected damage)
S	<10	Normal	Normal construction (strip footing or slab-on-the-ground) foundation Foundation bearing pressure not to exceed 50 kPa Good site drainage
S1	10 - 20	Modified normal	Reinforced strip footings Articulation joints at some internal doors and all external doors Light reinforcement in masonry Site drainage and service and plumbing precautions Foundation pressure not to exceed 50 kPa
		Compaction of insitu soils below individual footings	Remove in-situ material below foundations to a depth and width of 1,5 times the foundation width or to a suitable soil horizon and replace with material compacted to 93 % MODAASHTO density at −1 % to +2 % of optimum moisture content Normal construction with lightly reinforced strip foundations and light reinforcement in masonry
		Deep strip foundations	Normal construction with drainage precautions. Founding on a suitable soil horizon below the problem soil horizon
		Soil raft	Remove in-situ material to 1,0 m beyond the perimeter of the building to a depth of 1,5 times the widest foundation or to a suitable soil horizon and replace with material compacted to 93 % MOD AASHTO density at −1 % to +2 % of optimum moisture content Normal construction with lightly reinforced strip footings and light reinforcement in masonry
S2	>20	Stiffened strip footings, stiffened or cellular raft	Stiffened strip footings or stiffened or cellular raft with lightly reinforced or articulated masonry Bearing pressure not to exceed 50 kPa Mesh reinforcement in floor slabs Site drainage and service and plumbing precautions
		Deep strip foundations – Compaction of in-situ soils below individual footings	As for S1 but with mesh reinforcement in floor slabs
		Piled or pier foundations	Reinforced concrete ground beams or solid slabs on piled or pier foundations Ground slabs with fabric reinforcement. Good site drainage
		Soil raft	As for S1
NOTE 1 Differential settlement equals 50 % of total settlement. NOTE 2 The relaxation of some of these requirements, for example, the reduction or omission of reinforcement or articulation joints, might result in a category 2 of expected damage. NOTE 3 Account should be taken of sloping sites where differential fill heights might lead to greater differential settlements. NOTE 4 Settlements induced by loads imposed by deep filling beneath surface beds might necessitate the adoption of a construction type appropriate to a more severe site class.			

4.7 SANS 10400 Foundation Designs

According with the SANS 10400 Foundation recommendation for the site classified as “C2”, the following foundation designs are recommended in

Table 5: SANS 10400H Foundation design for 3 to 5 storey buildings

Table 6: SANS 10400H Foundation design for single storey buildings.

Table 5: SANS 10400H Foundation design for 3 to 5 storey buildings

FOUNDATION OPTIONS	CONSTRUCTION TYPE	FOUNDATION DESIGN AND BUILDING PROCEDURES (EXPECTED DAMAGE LIMITED TO CATEGORY 1 OF EXPECTED DAMAGEA)
Option 1	Reinforced concrete ground beams or solid slabs on piled or pier foundations	Pile is defined as “A reinforced concrete or steel column-shaped member in the ground designed to transfer structural loads to a suitable soil horizon” Pier foundations “Masonry, reinforced concrete or mass concrete column with or without a pad-footing, designed to transfer structural loads to a suitable founding horizon. ● Ground slabs with fabric reinforcement ● Good site drainage
Option 2	Deep strip foundations	Founding on a suitable founding horizon below the horizons within which relatively large movements might take place Normal construction with drainage precautions foundations

Table 6: SANS 10400H Foundation design for single storey buildings

FOUNDATION OPTIONS	CONSTRUCTION TYPE	FOUNDATION DESIGN AND BUILDING PROCEDURES (EXPECTED DAMAGE LIMITED TO CATEGORY 1 OF EXPECTED DAMAGEA)
Option 1	Stiffened concrete raft	A foundation system that comprises a grid of reinforced/post-tensioned concrete beams cast integrally with the floor slab and that, by virtue of its stiffness, a) enables a structure to tolerate differential movements or localized loss of support (soft spots), or b) reduces the differential movements due to heaving to a level that can be tolerated by the superstructure without significant damage occurring Stiffened or cellular raft of articulated lightly reinforced masonry Site drainage and plumbing and service precautions
Option 2	Compaction of insitu soils below individual footings	Remove in-situ material below foundations to a depth and width of 1,5 times the foundation width or to a suitable soil horizon and replace with material compacted to 93 % MOD AASHTO density at –1 % to +2 % of optimum moisture content Normal construction with light reinforcement in masonry Normal construction with drainage

5 Construction Machinery

Possible construction constrains are derived from the list of earthworks and construction related topics and the design level requirements stipulated by the South African Standards SABS 1200 LB, 1200 D etc. Each of the construction constrains have been explained in various sections here within the report.

The excavatability depends on the method used as well as the material properties.

Some of these are not mutually exclusive, i.e. strength may be affected by degree of weathering, and run direction is relevant mainly for large open excavations, and when dip direction is an issue.

The strength of the material is one of the key indicators in assessing the excavation requirements The blasting term as used here refers to the difficulty level and can include rock breakers, or expanding grouts.

The excavatability characteristics based on rock hardness and strength. The above is combined with its bulk properties (seismic velocity) and joint spacing.

Preliminary assessment of the likely excavation requirements.

Static weight for different roller types. The practical maximum layer thickness for compaction depends on the material to be compacted and equipment used.

5.1 Classes of excavation SABS 1200

For the purpose if this specification (SABS1200 D) the definitions and abbreviations given in SABS A or SABS 1200 AA (as applicable) and the following definitions shall apply;

5.1.1 Soft excavation

Soft excavation	Excavation Plant (i)	Excavation Plant (ii)	Excavation Plant (iii)
1. soft excavation, other than in restricted excavation, shall be excavation in material that can be efficiently removed or loaded, without prior ripping, by any of the following plant	A bulldozer of mass (including mass of ripper if fitted) approximately 22 t and flywheel power approximately 145 kW	A tractor-scraper unit of total mass approximately 28 t and flywheel power approximately 245 kW, pushed during loading by a bulldozer equivalent to that specified in (b)(1)	A track type front-end loader of mass approximately 22 t and flywheel power approximately 145 kW
2. soft excavation, in case of restricted excavation, soft excavation shall be excavation in material that can be efficiently removed by a back-acting excavator of flywheel power approximately 0,10 kW per millimetre of tined-bucket width, without the use of pneumatic tools such as paving breakers.			

5.1.2 Intermediate excavation

1) intermediate excavation, other than in restricted excavation, shall be excavation (excluding soft excavation) in material that can be efficiently ripped by a bulldozer of mass approximately 35 t, fitted with a single-tine ripper suitable for heavy ripping, and of flywheel power approximately 220 kW
2) in the case of restricted excavation, intermediate excavation shall be excavation (excluding soft excavation) in material that requires a back-acting excavator of flywheel power exceeding 0,10 kW per millimetre of tined-bucket width or the use of pneumatic tools before removal by equipment equivalent to that specified in (a)(2)

5.1.3 Hard rock excavations

1) Hard rock excavation, other than in restricted excavation, shall be excavation (excluding boulder excavation) in material that cannot, before removal, be efficiently ripped by a bulldozer equivalent to that specified in (b)(11). Note such excavation generally includes material such as formations of unweathered rock that can be removed only after blasting.
2) in the case of restricted excavation, hard rock excavation shall be excavation in material (excluding boulder excavation) that cannot be efficiently removed without blasting or without wedging and splitting.

5.1.4 Boulder excavations

1) Boulder excavation Class A	Boulder excavation Class A shall be excavation in material containing more than 40 % by volume of boulder of size in the range 0,03-20 m^3, in a matrix of soft material or smaller boulders.
	Excavation in dolomite formations other than solid dolomite will be classed as boulder excavation Class A if the formation contains more than 40 % by volume of lumps of hard dolomite of size in the range 0,03-20 m^3, in a matrix of soft material or smaller lumps of hard rock dolomite.
	Excavation of solid boulders or lumps of size exceeding 20 m^3 will be classed as hard rock excavation.
	Excavation of fissured or fractured rock will not be classed as boulder excavation but as hard rock or intermediate excavation, according to the nature of the material.

5.1.5 Boulder excavation Class B

Boulder excavation Class B shall be excavation of boulders only, which	1) are in a material containing 40 % or less by volume of boulders of size in the range of 0,03-20m^3, in a matrix of soft material or smaller boulders, and which
	2) require individual drilling and blasting in order to be loaded by a track type front-end loader or back-acting excavator, as the case may be, as specified in (a)(1) or (a)(2)
	The excavation of the rest of the material will be classed as soft or intermediate excavation, according to the nature of the material.

5.2 Ripping and blasting

The excavatability data shown are extracted from charts. It is therefore approximate values only Higher strengths combined with closer discontinuity spacing shifts the excavatability rating. Blast to loosen can be equated to using rock breaker. Ripping involves using a tine attached to the rear of the bulldozer.

The rock weathering term is another term incorporated in this table as well as the type of equipment i.e. backhoe, excavator etc.

The assessment of open excavations is difficult from excavation in limited space, such as trenches or drilled shafts.

Seismic Wave Velocity – SWV; Unconfined Compressive Strength – UCS

For drilled shafts: Limit of earth auger is 15 cm penetration in a 5 minute period – replace with Rock Auger. Rock auger to Down-the-hole hammers (Break).

Rippability rating chart derived from Weaver's charts combine concepts if strength, discontinuity, plant and joint characteristics.

Bulking Factors of 0% to 10% generally experienced in soils and soft rocks and Bulking Factor of 5% to 20% is experienced in hard rocks. Typical wastage is approximately 5%.

Rooling resistance = Force that must be overcome to pull a wheel load.

It depends on gradient of site and nature of trafficked area. Rolling resistance = rolling resistance factor x gross vehicle weight. Maintenance of haul road helps to reduce operational cost of plant. A surface with no maintenance is expected to have 5 to 10 times the operating cost of a good well maintained surface.

The compaction levels should be based in the type of application.

Compaction assumes a suitable material as well as adequate support from the underlying material.

A very high compaction on highly expansive clay can have an adverse effect in increasing swelling potential. The subgrade thickness is typically considered to be 1.0 m, but this varies depending on the application.

Earthworks and stability next to existing structures with specific reference to adjacent existing services and safety

Maximum size of equipment based on permissible vibration level.

Different from weight roller are required to buildings. This must be used with suitable offset distance.

Commercial and industrial buildings maybe able to tolerate a large vibration level 20 mm/second.

Conversely, historical buildings and buildings with existing cracks would typically be tolerate significant less vibration 2 to 4 mm/second.

Compaction required for different height of fill

The height of fill should also determine the level of compaction, and number of passes.

5.3 Stress stain curve – modulus.

The modulus is the ration of the stress versus strain (**Figure 9** – Stress strain graph) at a particular point or area under consideration. Materials with the same strength can have different stiffness values.

The applicable modulus is dependent in the strain range under consideration.

The long term and short term modulus is significantly different for fine grained soils, but slightly different for granular soils. The latter is considered approximately similar for all practical purposed.

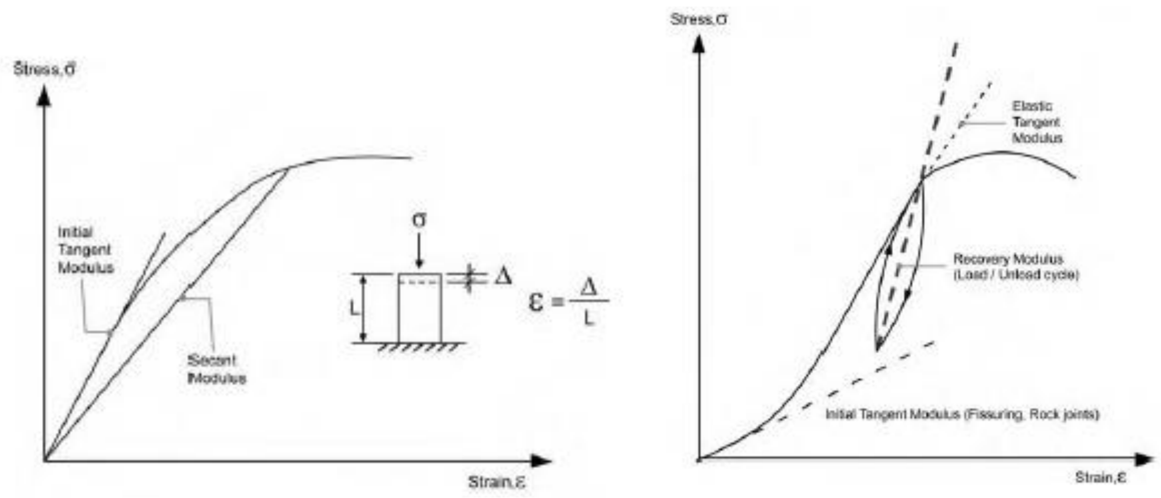

Figure 9: Stress strain curve - modulus

5.4 Strain shear modulus

Modulus usually derived from strength correlations. The two most common are secant modulus is usually quoted type for soil – structure interaction models. Resilient modulus applies for roads. strain – shear modulus (adapted after Sabatani *et al*., 2002) presented here below.

Shear modulus, G	**Small – strain shear modulus G_0 (MPa)**
Soft clays	3 to 15
Firm clays	7 to 35
Silty sands	30 to 140
Dense sands and gravels	70 to 350

Initial target modulus **–** slope of initial stress concave line, low strain. Fissured clays and Fills.

Elastic tangent modulus **–** slope of linear point (near linear), medium strain. Multi-storey buildings.

Deformation modulus – slope of line between zero and maximum or peak stress, medium to high strain. Also secant modulus. Applicable in Spread footing and pile tip.

Constrained modulus – slope of line between zero and constant volume stress, high strain. Values are lower than a secant modulus, and it is obtained from oedometer tests where the sample is prevented from failure. Applied in fills and embankments.

Recovery modulus – slope of unload line, high train, usually concave in shape. Heave in trenches.

Small strain shear modulus - The small strain modulus is significantly higher than at high strains

For large strains Gls = E/2.5 and For small strains Gss = 2E = 5Gls

5.5 Shear strain level

The shear strain levels (adapted after B, Look) have been presented here below for various applications i.e. Pavement design, Foundation design, in tunnels and retaining walls.

Application	Type	Strain level	Typical movement (mm)	Shear strain (%)	Applicable
Pavement	Rigid	Very small	5 – 10	<0.001	Dynamic method
	Flexible base	Large	5 – 30	>0.1	Dynamic methods/local gauges
	Sub base	Small/large	5 – 20	0.01 – 0.1	
	Subgrade	Small/very small	5 – 10	0.001 – 0.01	
	Haul/access	Very large	50 – 200	>0.5	Conventional soil testing
	Unpaved	Large	25 – 100	>0.1	
Foundations	Pipe shaft	Small	5 – 20	0.01 – 0.1	Local gauges
	Pile tip	Small/medium	10 – 40		
	Shallow	Small/large	10 – 50	0.05 – 0.5	Local gauge
	Embankments	Large/very large	>50	>0.1	Conventional soil testing
Retention systems	Retaining wall	Active - small	10. – 50	0.01 – 0.1	Local gauges
		Passive – large	>50	>0.1	
	Tunnel	Large	10 – 100	>0.1	Conventional soil testing

5.6 Young's modulus

The Young's modulus of various materials (adapted after Gordon, 1978) this includes soils such as soft and stiff clays and dense sands and weathered soft rock to hard rocks.

Classification	Material	Young's modulus, E (MPa)
Construction	Concrete	20,000
Soils	Soft clays	5
	Stiff clays, loose sands	20
	Dense sands	50
Rocks	Extremely weathered, soft	50
	Distinctly weathered, soft	200
	Slightly weathered, fresh, hard	50,000

5.7 Elastic parameters

Elastic parameters of various soils cohesive and granular soils have been (adapted after B. Look) for both short term soil strength and long term soil strength.

Type	**Strength of soil**	**Elastic modulus, E (MPa)**		
		Short term		**Long term**
		Cohesive soils	Granular soils	Cohesive soils
Gravel	Loose		25 - 50	
	Medium		50 - 100	
	Dense		100 - 200	
Medium to coarse sand	Very loose		<5	
	Loose		3 - 10	
	Medium dense		8 - 30	
	dense		25 - 50	
	Very dense		40 - 100	
Fine sand	Loose		5 – 10	
	Medium		10 – 25	
	dense		25 - 50	
Silt	Soft	<10		<8
	Stiff	10 – 20		8 - 15
	Hard	>20		>15
Clay	Very soft	<3		<2
	Soft	2 – 7		1 – 5
	Firm	5 – 12		4 – 8
	Stiff	10 – 25		7 – 20
	Very stiff	20 – 50		15 – 35
	hard	40 - 80		30 - 60

5.8 Coefficient of volume compressibility

Typical values for coefficient of volume compressibility presented within Typical values for coefficient of volume compressibility (adapted after Carter, 1983).

Type of clay	Descriptive term		Coefficient of volume compressibility m_v (10^{-3} kPa^{-1})	Constrained modulus l/m_v (MPa)
	Strength	Compressibility		
Heavily overconsolidated boulder clays, weathered mudstone	Hard	Very low	<0.05	>20
Boulder clays tropical red clays, moderately overconsolidated	Very stiff	Low	0.05 to 0.1	10 - 20
Glacial outwash clays, lake deposited, weathered mari, lightly to normally consolidated clays	Firm	Medium	0.1 – 0.3	3.3 - 10
Normally consolidated alluvial clays such as estuarine and delta deposits, and sensitive clays	Soft	High	0.3 – 1.0 (none sensitive) 0.5 – 2.0 (organic, sensitive)	0.7 – 3.3
Highly organic alluvial clays and peat	Very soft	Very high	>1.5	<0.7

The coefficient of volume compressibility (mv) is used to compute settlements for clay soils The mv value is obtained from the consolidation (oedometer) test.

This test is one dimensional with rigid boundaries, i.e. the Poisson Ration v' = 0 and E' = 1/mv.

The elastic modulus is referred to as the constrained modulus and is based on the assumption that negligible lateral strain occurs (in ordeometer), so that Poisson's ration is effectively zero. One dimensional settlement.

5.9 Rock deformation

Typical rock deformation parameters (adapted from Bell, 1992). The higher density rocks have a larger intact modulus.This need to be factored for the rock defects to obtain the in-situ modulus.

Rock density (kg/m^3)	Porosity (%)	Deformability (10^3 MPa)
<1800	>30	<5
1800 – 2200	30 – 15	5 - 15
2200 – 2550	15 – 5	15 - 30
2550 – 2750	5 – 1	30 - 60
>27520	<1	>60

5.10 Excavation characteristics

Excavation characteristics for soft to extremely hard rock (adapted after Bell, 1992) .

Rock hardness description	**Unconfined compressive strength (MPa)**	**Seismic wave velocity (m/s)**	**Spacing of joints (mm)**	**Excavation characteristics**
Very soft	1.7 – 3.0	450 – 1200	<50	Easy ripping
Soft	3.0 – 10.0	1200 – 1500	50 – 300	Hard ripping
Hard	10.0 – 20.0	1500 – 1850	300 – 1000	Very hard ripping
Very hard	20.0 – 70.0	1850 – 2150	1000 – 3000	Extremely hard ripping or blasting
Extremely hard	>70	>2150	>3000	Blasting

5.11 Digging parameters

Excavatability assessment (adapted after Franklin et al. 1971 with updates from Walton and Wong, 1993).

Parameter	Easy digging	Marginal digging without blasting	Blast to loosen	Blast to fracture
Strength, I_s (50) (MPa)	<0.1	<0.3	>0.3	>0.3
Discontinuity spacing (m)	<0.02	<0.2	0.23 to 0.6	>0.6
Rock Quality Designation (RQD)	<10%	<90%	>90%	>90%

5.12 Digging index

Diggability index rating (adapted from, Scoble and Muftuoglu, 1984) based on rock weathering, strength, joint spacing and bedding.

Parameter	Symbol	Ranking				
Weathering	W	Complete	High	Moderately	Slight	Fresh
	Rating	0	5	15	20	25
Strength (MPa): UCS	S	<20	20 – 50	40 – 60	60 – 100	>100
	I_s (50)	<0.5	0.5 – 1.5	1.5 – 2.0	2 – 3.5	3.5
	Rating	0	5	15	20	25
Joint spacing (m)	J	<0.3	0.3 – 0.6	0.6 – 1.5	1.5 - 2	>2
	Rating	5	15	30	45	50
Bedding spacing (m)	B	<0.1	0.1 – 0.3	0.3 – 0.6	0.6 – 1.5	>1.5
	Rating	0	5	10	20	30

5.13 Diggability classifications

Diggability classification for excavators (adapted from, Scoble and Muftuoglu, 1984) for very easy to extremely difficult excavations.

Class	Ease of digging	Index (W + S + J + B)	Typical plant which may be used without blasting	
			Type	Example
I	Very easy	<40	Hydraulic backhoe <3 m^3	CAT 253D
II	Easy	40 – 50	Hydraulic shovel or backhoe <3 m^3	CAT235FS, 235 ME
III	Moderately	50 – 60	Hydraulic shovel or backhoe >3 m^3	CAT245FS, 245 ME
IV	Difficult	60 – 70	Hydraulic shovel or backhoe >3 m^3 short boom of a backhoe	CAT245, O&K RH 40
V	Very difficult	70 – 95	Hydraulic shovel or backhoe >4 m^3	Hitachi EX 100
VI	Extremely	95 – 100	Hydraulic shovel or backhoe >7 m^3	Hitachi EX 1800

5.14 Rock Excavations parameters

Excavation in rock (part data from Smith, 2001) for Large open excavations to drilled shafts.

Type of excavation	**Parameter**	**Dig**	**Rip**	**Break/Blast**
	Relative cost	**1**	**2 to 5**	**5 to 25**
Large open excavations	N-Value	70<N>50		N = 100/100 mm, Use N = 300
	Rock Quality Designation (RQD)	<25%		>25%
	Seismic Wave Velocity – SWV	1500 m/s		1850 – 2750 m/s
Trench excavations	SWV	750 – 1200 m/s Using backhoe		1850 – 2750 m/s Excavators in large excavations, rock breakers
Drilled shafts	N-Value	N<100/75mm Use N<400		N>600
	Unconfined Compressive Strength (UCS)	<20 MPa		>28 MPa
	Seismic Wave Velocity – SWV	<1200 m/s		>1500 m/s

5.15 Rippability rating

Rippability rating chart (adapted after Weaver 1975) based on all rock descriptive parameters weathering, hardness, joint spacing and joint continuity.

Rock class	I	II	III	IV	V
Description	**Very good rock**	**Good rock**	**Fair rock**	**Poor rock**	**Very poor rock**
Seismic velocity (m/s)	>2150	2150 – 1850	1850 – 1500	1500 - 1200	1200 - 450
Rating	26	24	20	12	5
Rock hardness	Extremely hard rock	Very hard rock	Hard rock	Soft rock	Very soft rock
Rating	10	5	2	1	0
Rock weathering	Unweathered	Slightly weathered	Weathered	Highly weathered	Completely weathered
Rating	9	7	5	3	1
Joint spacing (mm)	>3000	3000 – 1000	1000 – 300	300 – 50	<50
Rating	30	25	20	10	5
Joint continuity	Non-continuous	Slightly continuous	Continuous – no gouge	Continuous – some gouge	Continuous – with gouge
Rating	5	5	3	0	0
Joint gouge	No separation	Slight separation	Separation <1 mm	Gouge <5 mm	Gouge >5 mm
Rating	5	5	4	3	1
Strike and dip orientation	Very unfavourable	Favourable	Slightly unfavourable	Favourable	Very favourable
Rating	15	13	10	5	3
Total rating	100 – 90	90 – 70	70- 50	50 – 25	<25
Rippability assessment	Blasting	Extremely hard ripping and blasting	Very hard ripping	Hard ripping	Easy ripping
Tractor selection		DD9G/D9G	D9/D8	D8/D7	D7
Horsepower		770/385	385/270	270/180	180
Kilowatts		575/290	290/200	200/135	135

6 Construction of foundation Earthworks

Static weight for different roller types (adapted after Forssblad, 1981) Roller type static weight drum module weight in brackets for various thickness of layers to be constructed. Thickness in confined areas should be 200 mm maximum thickness loose loft thickness

6.1 Different Roller Types

.For small sized equipment (<1.5 ton) the applicable thickness is ½ to 1/3 of the above.

Roller type static weight (drum module weight in brackets		**Construction material for Embankments**				**Construction material for Pavement**	
Type	Weight (ton)	Rock fill (m)	Sand/gravel (m)	Silt (m)	Clay (m)	Subbase	Base
Towed vibratory rollers	6	0.75	0.60	0.45	0.25	-0.4	0.5
	10	1.5	1.0	0.7	-0.35	-0.6	0.4
	15	2.0	1.5	1.0	-0.5	-0.8	-
	6 Padfoot	-	0.6	0.45	0.3	0.4	-
	10Padfoot	-	1.0	0.7	0.4	0.6	-
Self propelled roller	7 (3)	-	0.4	0.3	0.15	0.3	0.25
	10 (5)	0.75	0.5	0.4	0.2	0.4	0.3
	15 (10)	1.5	1.0	0.7	0.35	0.6	0.4
	8 (4) padfoot	-	0.4	0.3	0.2	0.3	-
	11 (7) padfoot	-	0.6	0.4	0.3	0.4	-
	15 (10) padfoot	-	1.0	0.7	0.4	0.6	-
Vibratory tandem rollers	2	-	0.3	0.2	0.1	0.2	0.15
	7	-	0.4	0.3	0.15	0.3	0.25
	10	-	0.5	0.35	0.2	0.4	0.3
	13	-	0.6	0.45	0.25	0.45	0.35
	18 padfoot	-	0.9	0.7	0.4	0.6	-

6.2 Rooling Resistance

Rooling resistance of wheeled plant (after Horner, 1988) for haul road conditions.

Haul road conditions		**Rooling resistance factor**	
Surface	Conditions	Kg/ton	An equipment gradient
Hard, smooth	Stabilized surface roadway, no penetration under load well maintained	20	2%
Firm, smooth	Rooling roadway with dirt or light surfacing, some flexing under load, periodically maintained	32.5	3%
With snow	Packed Loose	25 45	2.5% 4.5%
Dirt roadway	Rutted, flexing under load, little maintenance, 25 – 50mm tyre penetration	50	5%
Rutted dirt roadway	Rutted, soft under travel, no maintenance, 100 – 150 mm tyre penetration	75	7.5
Sand/gravel surface	Loose	100	10%
Clay surface	Soft muddy rutted, not maintenance	100 – 200	10 – 20%

6.3 Compaction Levels

Compaction requirements for various applications (adapted after B, Look) for various fills under buildings, pavements, small reservoirs and trench backfills.

Class	Application	Compaction level
Class 1	Pavements	Extremely high
	Upper 0.5m of subgrade under buildings	Extremely high
Class 2	Upper 1.5 m of subgrade under airport pavements	Very high
	Upper 1.0 m of subgrade under rail tracks	Very high
	Upper 0.75 m of subgrade under pavements	Very high
	Upper 3.0 m of fill supporting 1 or 2 story building	Very high
Class 3	Deeper parts to 3.0 m of fills under pavements	High
	Deeper parts of fills under buildings	High
	Lining for canal or smaller reservoir	High
	Earth dams	High
	Lining for fills	High
Class 4	All other fills requiring some degree of strength or incompressibility	Normal
	Backfill in pipe or utility trenches	Normal
	Drainage blanket or filter (Gravels only)	Normal
Class 5	Landscaping material	Normal
	Capping layers (not part of pavements)	Normal
	Immediately behind retaining walls (self-compacting material Drainage Gravel typical)	Normal

6.4 Distance for Vibrating Rollers

Minimum recommended distance from vibrating rollers (adapted after Tynan, 1973).

Roller class	Weight range	Minimum distance to nearest building
Very light	<1.25 tonne	Not restricted for normal road use, 3.0 m
Light	1 – 2 tonnes	Not restricted for normal road use, 5.0 m
Light to medium	2 – 4 tonnes	5 – 10 m
Medium to heavy	4 – 6 tonnes	Not advised for city and suburban streets 10 – 20m
Heavy	7 – 11 tonnes	Not advised for built up areas 20 – 40 m

6.5 Number of passes for compacted layers by Roller

Typical number of roller passes needed for 150 mm thick compacted layer (adapted after B. Look).

Height of fill (m)	Number of passes of roller for material type		
Material type and thicknesses	Clayey gravel (GC)	Sandy clay (CL) Clayey sand (SC)	Clay (CH)
<2.5 m	3	3	4
2.5 to 5.0 m	4	5	6
5.0 to 10.0 m	5	7	8

6.6 Excavations for general earthworks

a) after an area has been stripped, excavation shall be carried out first to any general level to which the ground has be reduced and then for foundations, footings, etc., to the depths indicated or to such greater depths as may be required by the Engineer to ensure a satisfactory foundation. The Engineer may order or authorize additional excavation for any stated purpose.

b) except where otherwise specified, shown on the drawings, ordered or dictated by the requirements for safeguarding, the excavation shall so carried out and so trimmed to the outline of the concrete work shown on the drawings that the excavated surface will act as forms for the concrete works.

c) except where provision for working space has been scheduled, each excavated surface on which or against which a permanent concrete structure will be placed shall be trimmed to ensure that there is no projection outside the specified tolerance into the excavation profile. Such surface shall be cleaned by hand or by air or other effective means to remove all loose material.

d) immediately before any permanent construction is commenced, the bottom of each excavation shall be cleaned of all loose material, and soft material shall be rammed or removed as required by the Engineer.

e) Excavated surfaces that will remain permanently exposes shall be finished off in a neat and workmanlike manner and hall be graded as shown on the drawings, to provide adequate drainage.

6.7 Preparation of Trench Bottom

The clause numbers given at the beginning or after the heading of a clause is / are, unless otherwise stated, the numbers of the relevant clauses of SABS 1200 DB.

Preparation of Trench Bottom (subclause 5.5). where the preliminary investigations reveal a risk of difficult conditions at the bottom of a trench in any section of the work, ensure that sufficient items have been scheduled, on a provisional basis, to deal with situation that are likely to occur.

The design engineer’s attention is drawn to the following main types of situations that arise:

a) where the trench bottom is coarse-grained, and reasonably dry, and variations in bearing qualities are insignificant, or where the bottom is fine-grained by dry, no problems are likely to arise and bedding can be constructed as specified.

b) where water is present the contractor is responsible, in terms of Subclause 5.1.2.1 of SABS 1200 DB, for ensuring by the sloping of the bottom, the provision of a channel on one side and the draining of water to low points, or the removal of water by pumping, that the bottom of the trench is always free from standing water. Where this has been achieved or is practicable, conditions on the trench bottom should be such that the situation given in (a) above is applicable.

c) where steps outlined in (b) above are impracticable because of the sloppy nature of the material in the bottom of the trench, it will be necessary to stabilize the trench bottom and to avoid disturbance and further softening of the trench bottom.

This situation will arise in wet fine-grained soils such as soft clays, silts, and fine sands. Suitable granular material, crushed stone, crusher-run, or ash should be placed as necessary on the trench bottom immediately the excavation has been completed.

Such a layer should become effective before its thickness exceeds 200 mm.

Where such steps are inadequate, a concrete raft should be constructed on top of the stabilizing layer.

Where the condition of the soil to depth exceeding 600 mm below the pipe invert level is poor, piles may be necessary to support a reinforced concrete raft constructed on the bottom of the trench.

Normal bedding as described in (a) above should be constructed on top of the concrete.

Attention is drawn to Subclause 3.1.4 of Section DB of Part 5 of the code, where further aspects of the problems are outlined.

The clause numbers given at the beginning or after the heading of a clause is / are, unless otherwise stated, the numbers of the relevant clauses of SABS 1200 DB.

Maximum width. The contractor can be held responsible only for the cost of strengthening a pipeline or its bedding to compensate for additional design loads attributed to any excess of trench width over the maximum trench width that is stated on the drawing or required in terms of the project specification, provided that a separate item has been scheduled for the particular section of the pipeline that is subject to the maximum trench width embargo.

Minimum width. Each minimum trench width specified has been determined in practice as providing the minimum width between the sides of the pipes and trench necessary for effective placing, working, ramming, and compaction of bedding under and around the pipes.

7 Embankments Excavations for general earthworks

Contractor to provide suitable equipment to excavate selectively (Subclause 3.2.1.2 of Section LB of Part 2 of the code). In areas where

a) homogenous materials occur in the trenches in one or more layers each exceeding 300 mm in thickness,

b) where trenches are relatively short as in a township or treatment works, and

c) in situations where sophisticated plant of high productivity is unlikely to be used for each excavation by the contractor, the engineer may, without great risk of incurring high prices, require the contractor to excavate selectively in terms of a clause such as PSLB 1.2 given in Subclause 3.2.1.22 of Section LB of Part 2 of the code.

7.1 Material Suitable for Embankments and Terraces.

For the purpose if this specification (SABS1200 D) the definitions and abbreviations given in SABS A or SABS 1200 AA (as applicable) and the following definitions shall apply;

7.2 Material Suitable for Embankments and Terraces.

The following materials are, in general, suitable for embankments and terraces:

a) Material having a CBR of at least 3% at the minimum specified density compacted at Optimum Moisture Content and a Plasticity Index not exceeding 18%;

b) hard or rock material having a maximum dimension of 300 mm;

c) both clay or clayey material of liquid limit exceeding 40 or Plasticity Index exceeding 18% or both, and rock or boulders having a maximum dimension greater than 300 mm, provided they

1) are not placed against structures, and

2) are placed in predetermined quantities and in specified parts of the fill, as directed.

7.3 Embankments Excavations for general earthworks

a) after an area has been stripped, excavation shall be carried out first to any general level to which the ground has be reduced and then for foundations, footings, etc., to the depths indicated or to such greater depths as may be required by the Engineer to ensure a satisfactory foundation. The Engineer may order or authorize additional excavation for any stated purpose.

b) except where otherwise specified, shown on the drawings, ordered or dictated by the requirements for safeguarding, the excavation shall so carried out and so trimmed to the outline of the concrete work shown on the drawings that the excavated surface will act as forms for the concrete works.

c) except where provision for working space has been scheduled, each excavated surface on which or against which a permanent concrete structure will be placed shall be trimmed to ensure that there is no projection outside the specified tolerance into the excavation profile. Such surface shall be cleaned by hand or by air or other effective means to remove all loose material.

d) immediately before any permanent construction is commenced, the bottom of each excavation shall be cleaned of all loose material, and soft material shall be rammed or removed as required by the Engineer.

e) Excavated surfaces that will remain permanently exposes shall be finished off in a neat and workmanlike manner and hall be graded as shown on the drawings, to provide adequate drainage.

7.4 Embankments placing and compaction

Where approved material from excavations is insufficient to form designated embankments, the Contractor shall, unless otherwise ordered, obtain the additional material, as directed, from borrow pits at sties approved by the Engineer.

Only material that;

a) has been obtained from excavations or borrow pits or both,

b) is free of stumps, trees, rubble and other deleterious materials, and

c) has been approved,

shall be places in the lower layer of embankment, and material of the same or better quality shall be placed in the upper portion of an embankment.

Where it is necessary to use clay or clayey material, the Engineer may direct that such material be places not less than 1.0 m and not more than 6.0 m below the finished surface.

Rock having a maximum dimension exceeding 600 mm shall not be placed at the base of the embankment.

The material of each embankment shall, unless otherwise approved, be deposited in layers of thickness, before compaction, not exceeding 300 mm. the material shall be spread to form a layer that is of approximately uniform thickness, and graded over the whole area of the embankment.

Each layer shall be compacted at Optimum Moisture to a density of at least 90 % of modified AASHTO maximum density in the case of cohesive soil or 98 % in the case of non-cohesive soil.

Should the material be too wet, owing to rain, or any other cause, it shall be harrowed and allowed to dry out to the correct moisture content before compaction is undertaken.

Where shown on the drawings or ordered, all trenches and excavations outside structures shall be carefully refilled with approved material in layers of thickness not exceeding 250 mm before compaction.

During the placing of each layer, the filling shall be well rolled and compacted, sufficient water being added uniformly to ensure that the density specified for the particular zone is achieved or, where a density in not specified, that the density achieved is at least that of the adjoining undisturbed material. Each layer shall be completed before the next is added.

Where the use of conventional compaction plant close to a structure is not possible, the material to be compacted hall be spread in loose layers of thickness not exceeding 250 mm and compacted by means of mechanical tampers to at least the density specified for that particular zone, or where a density is not specified, to at least the density of the adjoining undisturbed material.

On completion of earthworks to the finished level and of backfilling of all holes, trenches and the like, the whole surface shall be graded, shaped and compacted to final grades and levels. The surface shall be lightly watered as the Engineer may direct.

Where scheduled, topsoil shall be placed on level and slightly graded areas and shall be lightly compacted by wheels vehicles or by tamping, and trimmed neatly to the required lines, grades and levels. The final thickness of topsoil after compaction shall be at least 75 mm.

8 Backfill requirements in terms of SANS 1200 LB

Pipe backfill shall be in accordance with SANS 1200 LB (1983) concerning bedding requirements, buried pipelines may require two types of selected material. These selected materials are termed *"Selected Granular Material"*, *"Selected Fill Material"* and *"General Backfill".* Schematic drawing for Measurement of Bedding is presented in **Figure 10** – Pipe backfill SANS1200 LB.

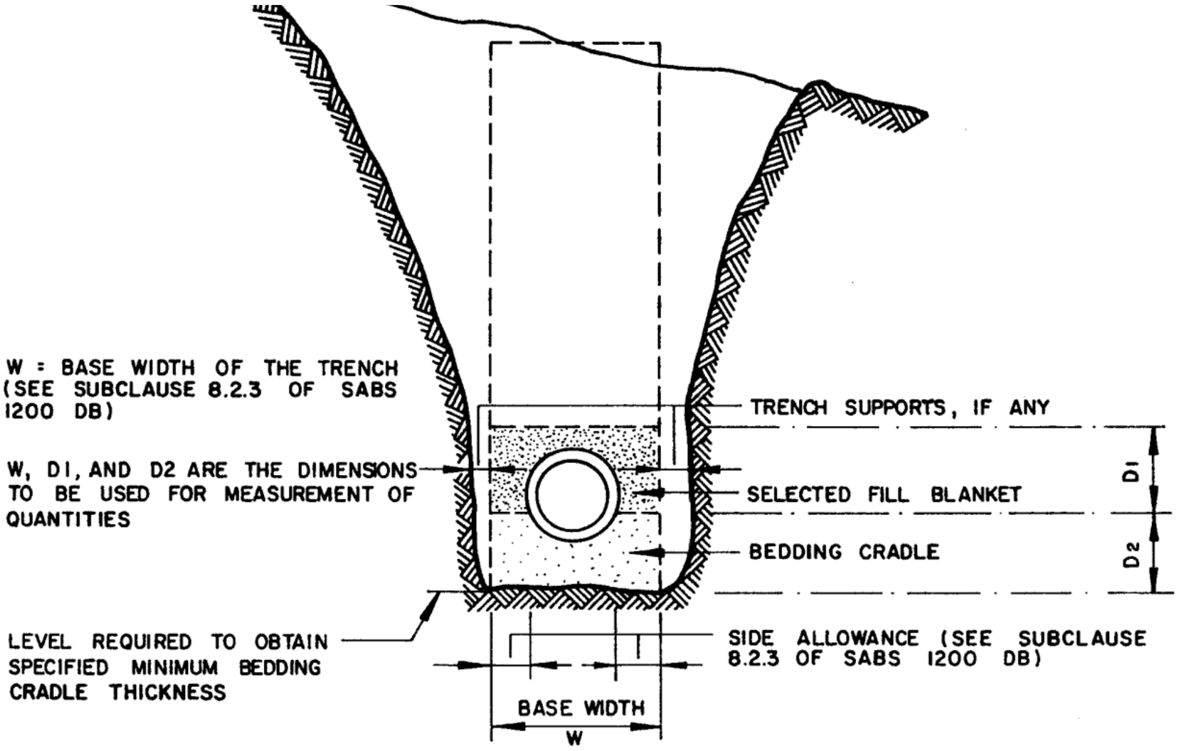

Figure 10: Pipe backfill SANS 1200 LB

8.1 Bedding Class for Rigid Pipes

For rigid pipes, four classes of bedding (designated A, B, C, and D) are required.

Bedding Class A. bedding of Class A is concrete bedding and is required for a pipeline designed for a bedding factor of 3.0. this bedding provides support for the pipe sides and spreads the retention load. A bedding factor of 3.4 can be used in the design where the concrete bedding is strengthened with reinforcement. Give details of the reinforcement. See also 2.2.4.

Bedding Class B. bedding of Class B is necessary for a pipeline designed for a bedding factor of 1.9. this bedding requires that bedding cradle supports the bottom half of the pipe barrel.

Bedding Class C. bedding Class C is necessary for a pipeline designed for a bedding factor of 1.5. this bedding requires that bedding cradle supports the bottom quarter of the pipe barrel.

Bedding Class D. Bedding of Class D is necessary for a pipeline designed for a bedding factor of 1.1. this bedding permits the pipe to be laid directly on the trench bottom and requires no bedding materials to be worked under the pipe. The pipe is therefore, in theory, subject to line loading. Such bedding conditions are generally acceptable for small diameter rigid pipes only, such as galvanized iron pipes of up to 100 mm and subsoil drain pipes.

Relating Class of Pipe to Class of Bedding

To meet the design load requirements, a particular pipe class and a bedding class to suit it must be specified. However, a change in the conditions at the trench bottom may necessitate a strengthening of the pipeline which should be achieved by changing the bedding class rather than the pipe class, as change in the pipe class usually involves the more costly delays. Therefore, where bedding of a high class is being contemplated, consider using, where possible, a higher strength (class) pipe on a lower class bedding so that, if required, the bedding class can be increased to provide improved support. See Subclause 3.2.1 of Section LB of Part 5 of the code.

Concrete Class A and Encasement (Subclause 5.4) where concrete encasement is required (see 2.2.4) schedule an item in terms of Subclause 8.2.4 of SABS 1200 LB. Where necessary because of substandard cover over a pipeline such as may occur where it crosses a road or where pipeline maybe subject to scour, for example, where it crosses a stream, consider concrete encasement of the pipeline.

8.2 Selection of bedding

The clause numbers at the beginning or after the heading of a clause is / are unless otherwise stated, the numbers of relevant clauses of SABS 1200 LB.

Using excavated materials (Subclause 3.4.1)

a) in preparing information required in terms of 1.3.1, take cognizance of the most trench excavations are carried out by means of backactors or various types of trenchers, each of which operate most economically if it excavates to the full final depth as the machine progresses along the trench.

b) it follows that the material excavated and placed alongside the trench by such machine will be a mixture of the various layers penetrated and that the material most readily and cheaply available for bedding will be that mixture.

c) thus, if it is required that particular strata be preserved for bedding, specify this requirement clearly and bear in mind that selective excavation and separate stockpiling on the side of the trench will necessitate a higher rate than would otherwise be quoted.

d) decide which materials available within an economic distance of the pipeline is most suitable before specifying the compactibility factor or varying the specified grading for the bedding cradle or the selected fill blanket

8.3 Bedding

Bedding is the material in the bedding cradle and fill blanket up to the underside of the main fill.

The operation of placing and compacting bedding in the manner specified.

8.4 Bedding cradle

Bedding cradle is the zone in which bedding is placed firmly and without voids under and up the sides of a pipe, a duct, or a cable in such a manner that for all practical purposes the pipe, duct, or cable cannot move or deflect.

8.5 Rigid pipe

Rigid pipe is a pipe of which the diameter is reduced by not more than 1% under an external radial force before the appearance of cracks.

8.6 Main fill

Main fill is the approved filling material placed in a pipeline trench after the pipe has been laid, bedded, and surrounded by selected fill blanket up to 150 mm or other specified cover above the top of the pipe.

8.7 Selected fill material

Selected fill material shall be material that has a Plasticity Index not exceeding 6 and that is free from vegetation and from lumps and stones of diameter exceeding 30 mm.

8.8 Selected backfill blanket

Selected backfill blanket is material placed and compacted to form a blanket on or from the top of the bedding cradle up the sides and over the top of a pipe, duct, or cable, in a manner that the barrel of the pipe, duct, or cable is supported continuously and firmly on the sides and protected over the top by a dense cushion of material.

8.9 Selected granular material

Selected granular material shall be material of a granular, non-cohesive nature that is singularly graded between 0.6 mm and 19.0 mm, is free-draining, and has a compactibility factor not exceeding 0.4 or such other value as is laid down in the project specifications.

The clause numbers at the beginning or after the heading of a clause is / are unless otherwise stated, the numbers of relevant clauses of SABS 1200 LB.

When searching for a material suitable for use as a selected granular material, bear in mind the following facts;

a) the main requirement for this material is that it should be free-running so that it can easily take up the shape of the pipe to form a sound support.

b) for this purpose a none-cohesive material that is neither too coarse nor too angular is best, a pea-gravel i.e. a gravel-like material consisting of particles similar in size and shape to a pea and most commonly found in river beds being ideal.

c) the function of the bed is to provide continuous uniform support to the lower segment of the barrel of the pipe, and also perhaps to allow some longitudinal drainage if the trench is situated in waterlogged ground.

d) select a local material or a blend of local materials such that it resembles as closely as possible a dry non-plastic singularly graded rounded fine gravel or medium sieved sand and, if such materials is not available, consider importing the material.

e) the terms fine gravel and medium sand have the meanings given in BS 5930, the grain sizes being between 0.6 mm – 6.0 mm for fine, 6.0 mm – 19.0 mm for medium sand (see Subclause 3.1. of SABS 1200 LB).

9 Report Conclusions

The property owner, Uvuko Civils Maintenance and Construction (Pty) Ltd, has appointed Nomfundo Exploration and Consulting (Pty) Ltd, a geotechnical and geological consulting company, in the month of July 2016, to undertake geotechnical investigation for the project: Portion on 26, 37, 40 & 41 of Paardeplaats 177 Munsieville Mogale City, West Rand District Municipality , proposed to be developed as Human Settlement Mixed Development.

According to the regional and site geology, the study area is underlined by shale, quartzite, conglomerate, diamictite of the Government Sub-group (Rg), West Rand Group, of the Witwatersrand Supergroup. Thus the conditions encountered are none-dolomitic.

Gradient along the north – south (south facing slope, thus area drains to the south) is 2.4 degrees (slope 1:14) and west – east (west facing slope, thus area drains to the west) the maximum slope is 11 degree and averaged slope from north-south is at 5.5 degrees (slope 1:6). Thus the terrain elevations are classified as Relief Class 2: Rolling and irregular plains – fairly low relief with moderate percentage of near-level land; low to moderate steep slopes.

The climatic N-value 2 – 5 nearest approximation to Thornthweite's climatic regions is Sub-humid warm. The residual soils derived from weathering of Government Sub-group (Rg), West Rand Group, of the Witwatersrand Supergroup giving rise to secondary minerals, resulting in weakly cemented grain structures, resulting in quartz minerals cemented by clayey-silty bridges, thus forming collapsible and compressible residual soils.

Thus the Munsieville Extension 10 is underlined by soil horizons subject to both consolidation and collapse settlement, the soil class designation is C2.

Foundations design solutions for this soil class designations C2 includes;

- Stiffened strip footings, stiffened or cellular raft
- Deep strip foundations compaction of insitu soils below individual footings
- Soil raft

Construction limitations, shear strength; unstable slopes; semi-pervious to impervious soil; poor to good compaction and workability. Rippability rating chart (adapted after Weaver 1975) based on all rock descriptive parameters weathering, hardness, joint spacing and joint continuity; our company's evaluation of the rock rippability has been estimated from the Tractor Loader Backhoe, we have concluded the following; Good rock (Rock Class II) - Fair rock (Rock Class III) Very hard ripping to blasting, Tractor selection DD9G/D9G (Horsepower 770/385 Kilowatts 575/290) - D9/D8 (Horsepower 385/270 Kilowatts 290/200.

10 Recommendations

10.1 Foundation designs

The geotechnical planning takes several stages to be accomplished i.e. Feasibility stage and Design Foot-print investigations. ***This geotechnical report is consider to be Phase 1 Feasibility Geotechnical Investigations, thus, we recommend a Phase 2 Foot-Print design level investigation***.

We recommend that we are involved in the design of the foundation for the various structures because we need to nominate the foundation design for each and every structure and ensure compliance with SANS10400 H Foundations and the National Housing requirements for the Enrolment of Subsidy scheme houses.

10.2 Foundation Excavations

Ground excavations have been assessed from the performance of Tractor Loader Backhoe, this is described as an excavator of flywheel power approximately 0,10 kW per millimetre of tined-bucket width, without the use of pneumatic tools such as paving breakers.

Intermediate excavation conditions other than in restricted excavation, shall be excavation (excluding soft excavation) in material that can be efficiently ripped by a bulldozer of mass approximately 35 t, fitted with a single-tine ripper suitable for heavy ripping, and of flywheel power approximately 220 kW. Intermediate excavation in the case of restricted excavation, intermediate excavation shall be excavation (excluding soft excavation) in material that requires a back-acting excavator of flywheel power exceeding 0,10 kW per millimetre of tined-bucket width or the use of pneumatic tools before removal by equipment equivalent to that specified in (a)(2)

Rippability rating chart (adapted after Weaver 1975) based on all rock descriptive parameters weathering, hardness, joint spacing and joint continuity; our company’s evaluation of the rock rippability has been estimated from the Tractor Loader Backhoe, we have concluded the following; Good rock (Rock Class II) - Fair rock (Rock Class III) Very hard ripping to blasting, Tractor selection DD9G/D9G (Horsepower 770/385 Kilowatts 575/290) - D9/D8 (Horsepower 385/270 Kilowatts 290/200.

10.3 Engineered Mattresses

The soils encountered on the site are suitable to be used for the construction of engineered platform also referred to as engineered mattresses.

For fills between 0m to 1.2m in height, the fill material should be placed in layers not exceeding placed in layers 150mm loose thickness, and compacted by impact roller to 95% Modified AASHTO density at 0% to +2% of optimum moisture content.

Roller type static weight drum module weight in brackets recommended for compaction of the engineered earth-mattresses is a Self propelled roller.

10.4 Slope Design

Sidewalls of excavations be either battered back to 1 (vertical) to 0.5 (horizontal)

Groundwater seepage encountered.

Sidewall seepage will necessitate battering of open trenches to 1 (vertical) to 2 (horizontal) to reduce possible block sliding due to groundwater uplift pressure.

De-watering mechanism will be required should earthwork construction commence within the summer rain seasons.

10.5 Road Construction

Inorganic clays low plasticity, **Drainage characteristics** Practically impervious **Shrinkage or swelling properties** Medium **Value as a road foundation** Fair to poor **Bulk density before excavation Dry or moist Mg/m^3** 1.6 to 1.8 **Coefficient of bulking %** 20 to 40.

The estimated COLTO designation for the subgrade is G8.

Subgrade potentially collapsible soils, requires rip and compact. The material has fair workability as road construction material.

Import subbase and base layer from commercial quarries.

REPORT ANNEXURES

ANNEXURE A – Soilkraft geotechnical report compiled 2007.

ANNEXURE B – Soil Profiles

ANNEXURE C – Laboratory soil tests

ANNEXURE D – Oedometer soil settlement (93% remoulded samples)

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