STRUCTURAL DESIGN REPORT FOR THE RELOCATION OF DWELLERS AT INGULA PUMPED STORAGE SCHEME

PREPARED FOR: ESKOM (INGULA PUMPED STORAGE SCHEME)

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1.General

This is the summary of the structural design considerations implemented as part of the design and construction of homesteads to relocate dwellers at Ingula Power Station. Ingula Power Station, a pumped storage facility situated about 23 km northeast of Van Reenen, spans the Little Drakensberg escarpment, which delineates the boundary between the Free State and KwaZulu-Natal Provinces. The construction of this power station necessitated the relocation of local residents by Eskom, leading to the need for six new homesteads.

Project Overview

The project is situated on a Site Class C1 area, characterized by soil with a pH of less than 6, indicating high corrosive potential. Additionally, the site presents significant excavation challenges due to hard dig conditions, which require specialized methods for site preparation. The absence of groundwater seepage simplifies certain aspects of the design but necessitates other precautionary measures to ensure the longevity and structural integrity of the project.

2.0Design Philosophy

The load is transferred from the roof through the load bearing walls into the strip footing. The selection of the type of footing is guided by the geotechnical investigations and the width of the footings is designed to distribute the weight so that the maximum allowable bearing capacity of the soil is not exceeded. A simple approach is used to establish if the chosen parameters comply with SANS 10400 prescribed approaches. The "deemed-to-satisfy" approach in the South African National Standards (SANS 10400) provides prescriptive guidelines for building elements, ensuring structures meet safety and performance requirements without the need for extensive calculations.

The foundation design method focuses on the direct bearing demand on the soil, primarily assessing whether the footing’s pressure remains below the soil’s ultimate bearing capacity. It assumes that the soil beneath the footing does not significantly deform under load and does not require modelling the soil-structure interaction as in elastic approaches.

The outcomes are as shown in Annexure A, for the structural design and in Annexure B for the wind load analysis.

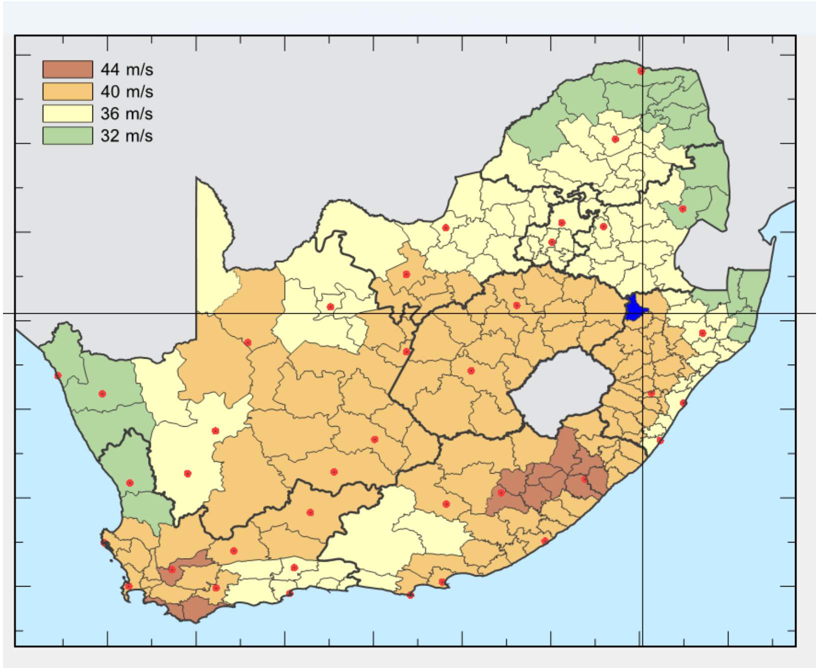


Table 1-Map indicating wind speed applied in analysis , in the area location of the site

Codes applied

Code	Description	Summary
SANS 10400-A	General principles and requirements	Provides fundamental building requirements for safety and compliance.
SANS 10400-B	Structural Design	Outlines structural design criteria to ensure building stability and safety.
SANS 10400-H	Foundations	Specifies requirements for safe and effective foundation design.
SANS 10400-K	Walls	Details standards for wall construction, stability, and insulation.
SANS 10160-1	Structural design	Establishes guidelines for structural design, considering load actions.
SANS 10160-2	Self-weight and imposed load	Defines requirements for calculating self-weight and imposed loads on structures.
SANS 10160-3	Wind loading	Sets standards for wind load calculations on building structures.
National Home Builders Registration Council Manual	Home Building Guide	A practical guide for safe, compliant home construction practices.

SANS 10100-1	The Structural use of Concrete	Provides guidelines for the design of concrete structures, focusing on safety, durability, and serviceability.

Soil Bearing Capacity

Geotechnical findings suggest that soil bearing pressure should not exceed 50 kPa, the foundation design ensures effective load distribution. In accordance with SANS 10400-H and the NHBRC Home Building Manual, the design will utilize strip footings to manage the bearing capacity and prevent structural failure.

Soil Corrosion Potential

The soil's corrosive nature (pH < 6) necessitates specific measures to protect structural components. Reinforcement will be covered with a minimum of 50 mm of concrete, and Grade 20 concrete will be used to enhance durability and resist corrosion. The contractor will be instructed to install plastic membranes below the footing to prevent moisture rise, which will accelerate oxidation and eventually corrosion of rebar.

Excavation Conditions

Hard digging conditions require soft to intermediate excavation techniques to facilitate proper site preparation. SANS 10400 Part F (Site Preparation and Demolition) and the NHBRC Home Building Manual stipulate practices for safe and effective excavation. The excavation strategy will address the removal of colluvium and residual sandstone while ensuring stable foundation placement. Scarifying will be important especially if heavy machinery will be utilised.

Foundation Design

The selection of strip footings addresses the reduced soil bearing capacity and corrosion risks. Both SANS 10400 Part H and the NHBRC Home Building Manual specify requirements for foundation design, including the use of aprons and plastic membranes to prevent water ingress and protect against potential moisture-related deterioration. Detailed outlay is shown in Annexure-A.

3. Structural Analysis

Load Distribution and Bearing Capacity

Structural calculations in Annexure-A consider the soil bearing capacity. The design will ensure that loads are distributed effectively across the foundation. Compliance with SANS 10160 (Basis of Structural Design) and the NHBRC Home Building Manual will guide load calculations and structural safety to prevent overloading and maintain stability. Due to high wind speeds, wind considerations have been considered at high values.

4. Construction Considerations

Techniques

Given the hard dig conditions, excavation will use soft to intermediate techniques. This approach, in line with SANS 10400 Part F and the NHBRC Home Building Manual, ensures effective site preparation and stability of foundation placement. Techniques will include mechanical and manual methods to address the challenges of hard dig conditions.

The sloping terrain will be managed with careful grading and stepping in footings as necessary, in line with SANS 10400 Part K and NHBRC guidelines. This ensures that the foundation adapts to the slope and maintains stability. Accurate setting out by a qualified surveyor is crucial. This involves correct alignment and placement of foundations and structural elements.

Foundation Construction

The foundation design will incorporate strip footings, following specifications in SANS 10400 Part H and NHBRC guidelines. Aprons and plastic membranes will be installed to prevent moisture ingress, and concrete will be properly mixed, placed, and cured to meet quality standards.

Reinforcement

Reinforcement in walls and footings will adhere to SANS 10100 and SANS 2001-CM2, with additional compliance to the NHBRC Home Building Manual. Reinforcement will be placed with a minimum cover of 50 mm to protect against corrosion and ensure structural integrity.

5. Quality Control

All material to be used to comply/be SANS approved. Concrete quality will be monitored through regular testing to ensure compliance with Grade 20 specifications and SANS 2001-CM2. Testing will include Compressive Strength Testing using cubes is a requirement. Method statements and Quality control plans will be submitted before the commencement of work. Maintenance procedures will enhance structural performance, especially towards the design service timeline. This includes Regular Inspections and assessments e.g. cracking extents and implementing preventative maintenance to reduce the rate of deterioration.

6. Conclusion

This design philosophy comprehensively addresses the unique challenges posed by the site through the integration of SANS 10400, the NHBRC Home Building Manual, and best practices in structural engineering and construction. By applying rigorous structural analysis, adopting appropriate construction techniques, and implementing robust quality control measures, the design ensures that the project will be stable, durable, and compliant with all relevant standards and regulations.

Recommendations

The proposed design follows a modified normal construction approach, which involves adapting standard methods to address specific site conditions. This includes soft to intermediate excavation to remove colluvium material and residual sandstone, as the soil bearing capacity is less than 50kPa. The foundation will use a strip footing or slab-on-the-ground system, with aprons and plastic membranes provided to prevent water ingress. Light reinforcement will be used in the walls, and additional reinforcement will be included in the footings. Grade 20 concrete will be used in the footings, with a minimum cover of 50mm to the reinforcement. This modified approach ensures the foundation is structurally stable, protected from moisture, and adequately reinforced, meeting the required design criteria.

At the construction stage, any adjustments will require prior instruction or approval from the design engineer to ensure alignment with the design intent and adherence to safety standards. Modifications will only be permitted within allowable tolerances and shall not exceed limits that could affect the structural integrity of the foundation or the safe bearing capacity of the soil. Authorization by the design engineer is mandatory for all such adjustments to safeguard compliance and stability.

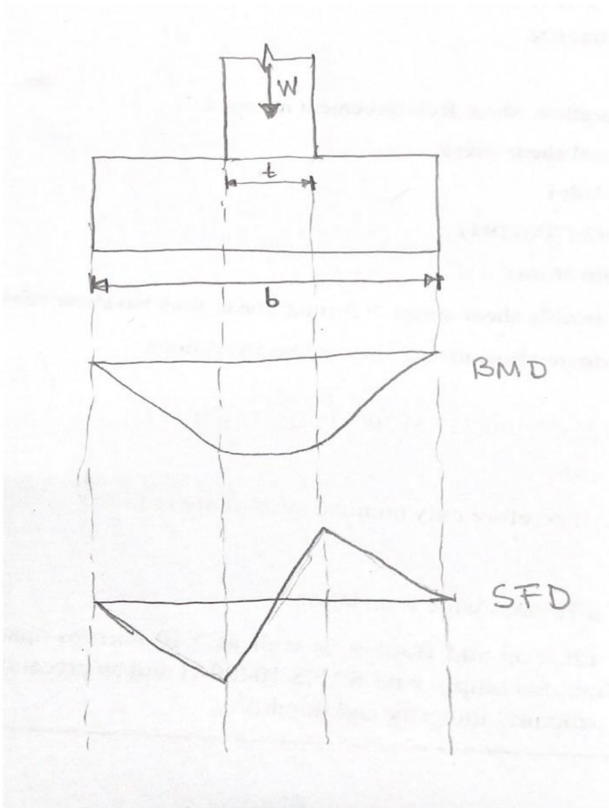
Annexure A – Calculations Summary

Code	**FOUNDATIONS & WALLS**
SANS 10400-H	**Geotechnical report findings summary:** - Site Class C1 - Ground water seepage not encountered - Test Pits terminated due to Hard dig - Highly Corrosion Potential Soil (Soil PH<6) Action - Modified Normal Construction - Utilise soft to intermediate excavation to remove a layer of colluvium material and residual sandstone - Soil Bearing to be less than 50kPa - Strip Footing / Slab on the ground - Provision of Aprons and Plastic Membranes on the foundations to prevent water ingress into the foundation - Light reinforcement in the walls - Provision of reinforcement in the footings Concrete in the footings will be Grade 20 concrete Minimum cover to reinforcement to be 50mm
SANS 10160-1 SANS 10160-2 SANS 10160-3	**LOAD TAKEDOWNS AND MAX ALLOWABLE BEARING PRESSURE CHECK.** **Permanent Action** *ROOF* Per metre span, assuming approx. 2 trusses Members assumed to have a total of 18m including purlins etc. Volume = 0.152m x 0.038m x 18m =0.104m^3 Weight = Volume x Unit weight (timber) = 0.51984 KN Per 4m width = 0.51984 KN 0.51984 KN / 1m length = *0.51984 KN/m*

	Sheeting/ covering $78 KN/m^3$ x 0.0006m = $0.0468 KN/m^2$ 0.0468 x4 m length = *0.1872 KN/m* Total Roof Load (Dead)= **0.7 KN/m** *WALL* Burnt clay plastered ϒ (KN/m^3) x H x T 19 x 2.6x 0.23 **= 11.362 KN/m** *FOUNDATION* Below footing to ground level = 0.7m (Max allowable) (Excavation width- brick wall) x Height of trench Backfill = (0.7m-0.230m) x 0.7m x 1m = $0.329 m^3$ 0.329x 23 KN/m^3 = 7.567KN Per metre length= **7.567 KN/m** Concrete Area = 0.25 m x0.7m= $0.175 m^2$ =0.175x $25KN/m^3$ =**4.375 KN/m** **Total Permanent Action = 23.97048 KN/m** **Variable Action** Roof accessible only for maintenance – (Class H2)

SANS 10160-1	*Rondavel has no access to the roof and will not be subjected to live loads Action= 0.25+ $(\frac{15-A}{48})$ = 0.25+ $(\frac{15-(4X1)}{48})$ 0.479 KN/m^2 = 0.5KN/m^2 0.5KN/m^2 x 4m = 2 KN/m **Serviceability Limit State Design** CASE1: Variable Action Dominant 1.1 Permanent Action(PA) + 1.0 Variable Action (VA) 1.1(23.9078) + 1.0 (2) = 28.29858 KN/m CASE 2: Wind Action Dominant *-wind analysis (Annexure B)* 1.1 Permanent Action(PA) + 0.3 Variable Action (VA) + 0.6 Wind Action (WA) 1.1(23.9078) + 0.3 (2) +0.6(0.84) = 25.0118 KN/m Therefore, Case 1 wcs Load = 28.3 KN/m x 1m length = 28.3 **Load = 28.3 KN** Gross Bearing Pressure = $\frac{\text{Total Load on foundation per metre}}{\text{Area of Foundation per metre}}$ Q=$\frac{P+wf+Ws}{A}$

	P- Total load transferred to foundation W_f- Weight of footing W_s- Weight of Soil Backfill Assuming a width of 0.7m for the load bearing walls Gross Bearing pressure $=\frac{28.3}{0.7m x 1m}$= 40.887 KN/m^2 <50Kpa therefore satisfactory **Therefore, bearing pressure on the Foundation is OK** **Sizing the footings** Width of the footing Load / Bearing Capacity 28.3/50= 0.566 m Therefore, a 0.7 m width will be OK Effective Depth Slab –Cover-(Bottom bar midpoint) 250-50-(12/2) = 194mm **Max moment at the centre of the wall**

SANS 10100-1	 Moment at the centre of the wall: $\frac{W}{b} * \frac{b}{2} * \frac{b}{4} - \frac{Wt}{t} * \frac{t}{2} * \frac{t}{4} = \frac{W}{8}(b - t)$ W- Load carried by the footing t- thickness of the wall seating on the foot b- width of the footing Maximum Shear force $\frac{W}{2}(b-t)$ Ultimate moment of a section M_u= 0,156$f_{cu}bd^2$ K= M/$f_{cu}bd^2$ Max BM

	$\frac{40.887\ KN}{8}(0.7\text{-}0.23) = 2.402$ KNm Ultimate (M_u)= 0.156 (20x 10^3) (0.7)(0.194^2)= 86.939 KNm K=0.0054 < 0.156 Compression OK Z= d(0.5+ sqrt(0.25- $\frac{K}{0.9}$) =< 0.95d Z=0.78d 0.95d A_s=M/(0.87f_yZ) A_s=2.29125x10^6/(0.87x450x151) A_s= 38.68 mm^2 Min A_s for a section = 0.13% BH $\frac{0.13}{100}$(700x25)= 227.5 mm^2 Shear Stress Allowable shear: 0.8$(f_{cu})^{0.5}$= 0.8$(20)^{0.5}$ 3.577 N/mm^2 or 5N/mm^2 Therefore 3.577 N/mm^2 Shear Force at the face of the wall V= q_{ult}(B/2 –(t_w/2)) V= 28.3 (0.7/2 – 0.23/2) =6.6505 KN Therefore, Shear Reinforcement required.

Actual shear stress

U= V/bd

6.6505 /(700x194)

$=0.049\ N/mm^2$

Allowable shear stress > Actual Shear thus No shear rebar .

Ultimate allowan=ble shear stress in sections

$V_c = 0.75/1.4\ (20/25)^{0.5}(100(227.5)/700x194))^{(1/3)}(400/194)^{(1/4)}$

=0.3208

$v<v_c$ Therefore only nominal stirrups are required

For a 700mm wide foundation:

3Y 12s Top and Bottom as well as Y10 stirrups spaced at 300mm to comply with SANS 10400-H and as precautionary for structural integrity and durability.

For a 500 mm wide footing carrying only a single-width masonry wall:

Provide 2 Y 12 Top and Bottom with stirrups Y10 spaced at 300mm.

*Rondavel will have minimal reinforcement (2 Y 12 Top and Bottom)

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