# Minerals Council South Africa

**EXAMINATION PAPER**

| **SUBJECT:**<br>CHAMBER OF MINES OF SOUTH AFRICA -<br>CERTIFICATE IN ROCK MECHANICS:<br>PAPER 3.4 OPEN PIT<br>**SUBJECT CODE: COMRMC3.4**<br><br>**EXAMINATION DATE: 10 October 2019**<br><br>**TIME: 14:30 – 17:30** | **EXAMINER:**<br>Des Mossop<br><br>**MODERATOR:**<br>Peter Terbrugge<br><br>**TOTAL MARKS:** [100]<br><br>**PASS MARK:** 60% |
|---|---|

NUMBER OF PAGES: 6

SPECIAL REQUIREMENTS

1. Answer **<u>all five</u>** questions;
2. References other than those provided are not permitted;
3. Hand-held scientific calculators may be used, but programmable electronic calculators are not permitted;
4. Put your examination number on the outside cover of each book used and on any graph paper, sketch or other loose sheets handed in;
   **NB: Your name must not appear on any answer book or loose sheets;**
5. **<u>Write in ink on the right hand side of the paper only (only the right hand pages will be marked). Request as many answer books as needed;</u>**
6. Show all calculations on which your answers are based;
7. Illustrate your answers by sketches and/or diagrams wherever possible;
8. In answering these questions, full advantage should be taken wherever possible of your practical experience as well as of the given data; and
9. Answers must be given to an accuracy that is typical of practical conditions.
10. NO cell phones will be allowed in the examination room

**QUESTION 1**

A 12m high rock slope has been excavated at an angle of 60°. There is persistent foliation dipping at 35° into the excavation. A 4.35m deep tension crack has developed 4m behind the crest, and is filled with water to a height of 3m above the sliding surface (Figure 1). The strength parameters of the sliding surface have been determined as:

Cohesion (c) = 25 kPa
Friction (ϕ) = 37°

The unit weight of the rock is 26 kN/m$^3$, and the unit weight of water is 9.81 kN/m$^3$.

The formula for FoS for a planar failure is given as:

$$FS = \frac{cA + (W\cos\psi_p - U - V\sin\psi_p)\tan\phi}{W\sin\psi_p + V\cos\psi_p}$$

$$A = (H + b\tan\psi_s - z)\ \mathrm{cosec}\,\psi_p$$

$$U = \tfrac{1}{2}\gamma_w z_w (H + b\tan\psi_s - z)\ \mathrm{cosec}\,\psi_p$$

$$V = \tfrac{1}{2}\gamma_w z_w^2$$

$$W = \gamma_r\left[(1 - \cot\psi_f\tan\psi_p)\left(bH + \tfrac{1}{2}H^2\cot\psi_f\right) + \tfrac{1}{2}b^2(\tan\psi_s - \tan\psi_p)\right]$$

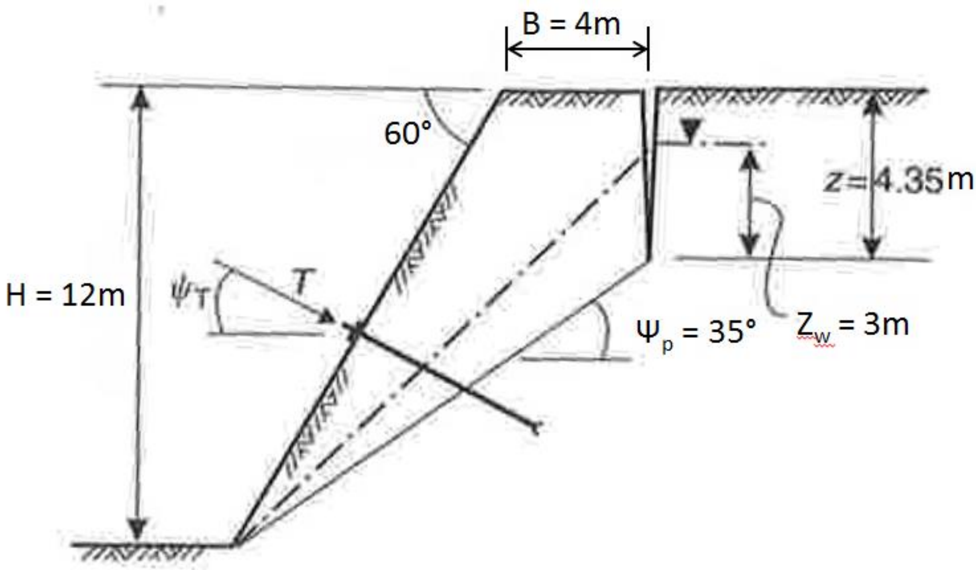



**Figure 1: Plane failure geometry**

Assuming that a planar failure is the most likely mechanism, and that the sliding block has a weight (W) of 1241 kN/m and the area (A) of the sliding plane is 13.34m$^2$/m, using the formulae provided, analyse the following stability condition:

a.) Calculate and comment on the factor of safety (FoS) for the condition given in Figure 1.

**[4]**

b.) Determine and comment on the FoS for the tension crack being completely water filled.

**[4]**

c.) Determine and comment on the FoS for the slope being completely drained.

**[4]**

d.) Determine and comment on the FoS for cohesion reduced to zero due to nearby blasting activities, assuming that the slope is still completely drained.

**[4]**

e.) Assuming the total load per linear metre of the slope is 400 kN, calculate the number of rock bolts required per vertical row to achieve a FoS of 1.3 for bolts with a load capacity of 250 kN each. Assume that the bolts can be installed perpendicularly to the sliding plane, i.e. $\Psi_T$ = 55°. The formula for FoS of a reinforced slope is given below:

$$FoS = \frac{cA + (W \cos \Psi_p - U - V \sin \Psi_p + T \sin (\Psi_T + \Psi_p)) \tan \phi}{W \sin \Psi_p + V \cos \Psi_p - T \cos (\Psi_T + \Psi_p)}$$

Where:
T = anchor tension at an angle $\Psi_T$ below the horizontal.

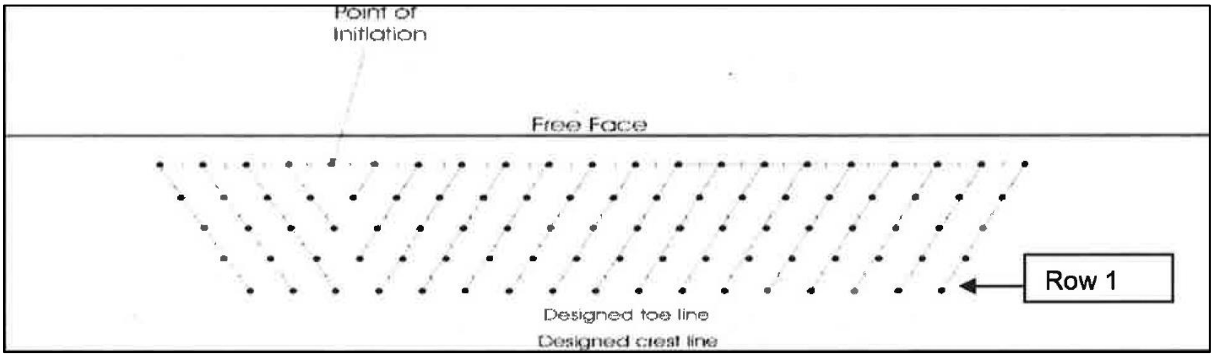
**[4]**

**(20)**

**QUESTION 2**

The following blast design is being utilised against the final pit limits of a hardrock open pit mining operation.

| | **Normal production blast** | **Final wall blast** |
|---|---|---|
| Hole diameter | 310 | 310 |
| Hole length (excl. sub-drill) | 11m | 11m |
| Sub-drill | 3.5m | 2.5m |
| Drilled rows | 8 | 5 |
| Explosives | ANFO<br>700kg/hole | ANFO<br>700kg/hole<br>Row 1 – 610kg/hole |
| Initiation | Shock tube | Shock tube |
| Burden & spacing | 8.4 x 9.2m | 8.4 x 9.2m |
| Stemming | Yes | Yes, but not in last row against the final limit |
| Row 1 stand-off | N/A | 3m |




Considering that the above blast design has been optimised for fragmentation at the request of the General Manager, motivate the following:

a.) Discuss the likely damage mechanism in a brittle, moderately strong to strong rock mass with bedding and sub-vertical joint sets striking across the pit, and how the current blast design is likely to contribute to slope instability.
**[** **[10]**

b.) Discuss the potential financial impact on the mining operation and motivate the need for improved wall control. **[5]**

c.) Discuss the pre-split mechanism and explain which rock mass parameters influence pre-split design. **[5]**

**(20)**

**QUESTION 3**

Numerous factors affect the stability of rock slopes. Discuss the importance and influence that each of the following factors have on the stability of a slope:

a.) Geology and geological structure **[4]**

b.) Groundwater **[4]**

c.) Blasting **[4]**

d.) Slope geometry **[4]**

e.) Mine to design/plan vs. actual performance **[4]**

**(20)**

**Question 4**

Discuss the main geotechnical risk items that you would consider in an open pit to underground transition where the underground mining method being considered is a caving method. Consider how you would monitor the effect that the underground mining will have on pit slope and surface stability using both surface and sub-surface methods.

**(20)**

**Question 5**

a.) Discuss the difference between deterministic and probabilistic design, giving advantages and disadvantages of both methodologies, and the suitability of each to anisotropic design analysis.

**[15]**

b.) Discuss the application of Hoek-Brown vs. Mohr-Coulomb failure criteria.

**[5]**

**(20)**

**(Total 100 marks)**