Minerals Council of South Africa

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS **PAPER 2:** BASIC ROCK MECHANICS PRACTICE **SUBJECT CODE:** COMRMC **DATE:** 13 MAY 2026 **TIME**: 14H00 TO 17H00 (3 HOURS)	**EXAMINER: N Netshivhazwaulu** **MODERATOR: GR Gainsford** **TOTAL MARKS:** 100 **PASS MARK:** 60%

NUMBER OF PAGES: 9 (Including this one)

EXAMINATION FORMAT: CLOSED BOOK. NO REFERENCES OTHER THAN WHAT ARE PROVIDED ARE ALLOWED.

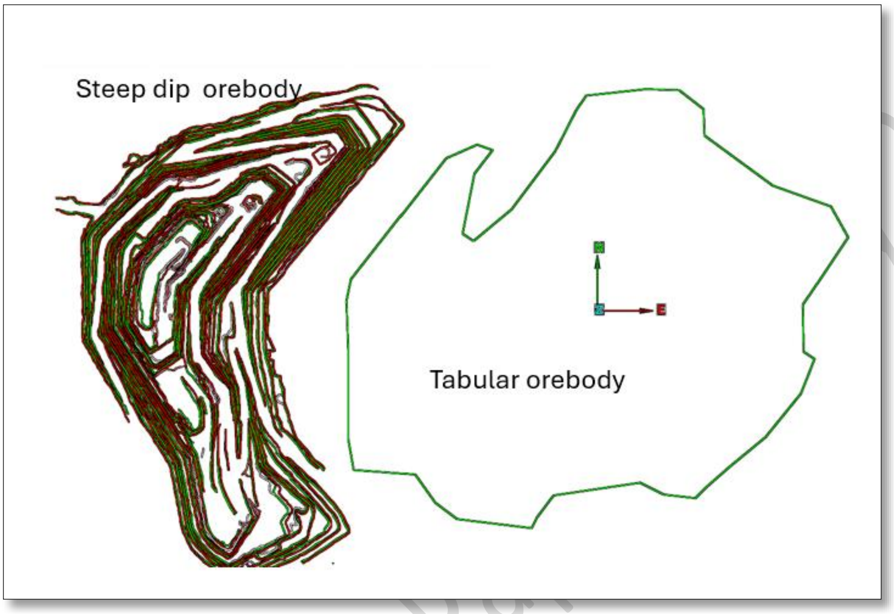
SPECIAL REQUIREMENTS:

1. Answer all the questions in legible English.
2. Write your ID number (no names) on the outside cover page of each script used and on any graph paper or other loose sheets handed in.
3. Show all calculations and check the calculations on which the answers are based.
4. Hand-held electronic calculators may be used for calculations. Reference notes may not be programmed into calculators.
5. Write legibly in black ink on the right-hand page only. Left-hand pages will not be marked.
6. Illustrate your answers using sketches or diagrams wherever possible.
7. Final answers must be given with accuracy typical of practical conditions; however, be careful not to use too few decimal places during your calculations, as rounding errors may result in incorrect answers.

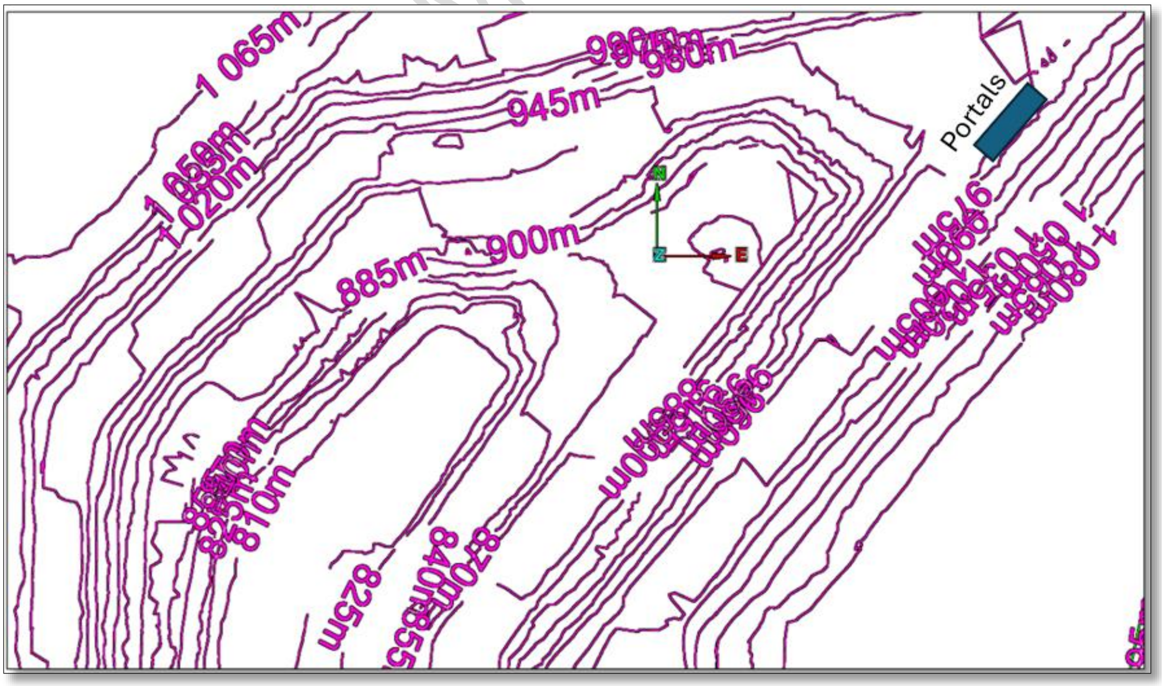
   NB: Ensure that the correct unit of measure (SI unit) is used as marks will be deducted if the incorrect unit is used even if the calculated value is correct.
8. In answering the questions, full advantage should be taken of your practical experience as well as the data given.
9. You are not allowed to contact your examiner or moderator regarding this examination.
10. Cell phones and other smart devices are not allowed on your person and must be handed to the invigilators or left in your vehicle.
11. You are encouraged to make use of the **CoMCert Tip-off Hotline** whenever you witness or suspect any wrongdoing related to the CoMCert Examinations on landline **0800 118 998** or alternatively you can use email **COMCert@tip-offs.com**. This tip-off hotline and tip-off email is managed anonymously and confidentially through an independent service provider.

QUESTION 1. PILLAR DESIGN

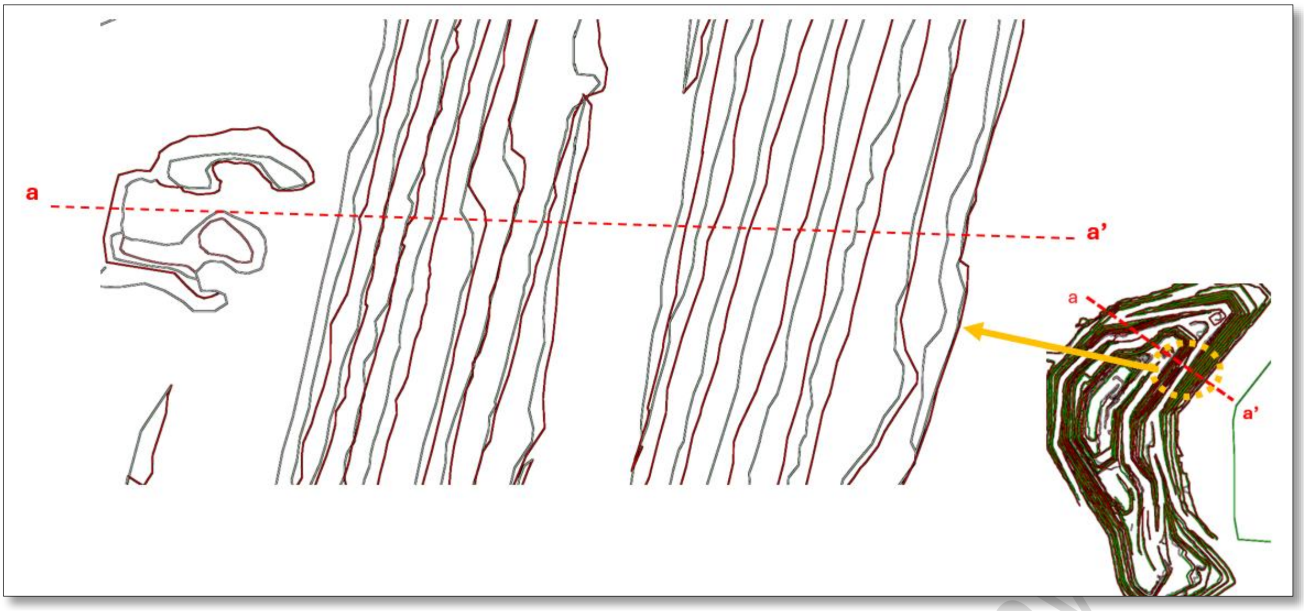
The Nwanedi Pit has been extracting ore from a massive, thick, and steeply dipping orebody and has now reached its maximum depth. Recent exploration efforts to extend the mine's life have uncovered a new PGE orebody adjacent to the pit. In contrast to the exhausted deposit, this discovery consists of a tabular deposit up to a depth of 650m below surface. Two Portals (6m x 6m) spaced 14m apart will be driven to access the orebody from the existing Nwanedi Pit walls.



Nwanedi Limit



Nwanedi topo contours

 *Nwanedi limit zoom-in* As a newly appointed rock engineer, you have joined a project team conducting a feasibility study on mining a tabular orebody. The rock mass classification within the portal area revealed good ground condition with an MRMR of 78 and rock type UCS of 233Mpa. It is said that the new ore body will be exploited by a bord and pillar mining method, where bords are 8.5m wide, mining height of 2.0m and rock mass density is 3100kg/m^3.	
1.1. What is the depth of the portal position and the bottom of Nwanedi pit?	(3)
1.2. Draw and label a cross-section view (not to scale) along lines a-a'?	(3)
1.3. Discuss the factors influencing pillar stability in a board and pillar layout.	(4)
1.4. Develop a board and pillar layout where you define the width and shape of pillars to archive a FOS of 1.6. State and substantiate all assumptions you make. $Strength = k\frac{w_e^{0.5}}{h^{0.75}}\text{MPa}$ Where k is 35MPa	(10)
1.5. Describe, in a summarized form, the Geotechnical Risk Management Framework which you would recommend for the underground operation?	(10)
	[30]

QUESTION 2. MINE SEISMICITY & LAYOUT

Discuss how regional mining layouts—for example, scattered breast mining and sequential grid mining—affect the energy release rate (ERR) and seismic hazard in South African deep-level tabular mining. Your answer should also incorporate the concepts of pre-conditioning, non or yielding and crush pillars, and backfill. Your response should:	
• Explain the mechanisms by which layout choices alter stress redistribution and ERR.	(10)
• Evaluate and contrast scattered and sequential mining layouts, highlighting their advantages, disadvantages, and practical underground constraints.	(10)
• Conclude with three evidence-based recommendations to reduce damaging seismicity while maintaining acceptable exposure.	(10)
	[25]

QUESTION 3. ROCK MASS CHARACTERISATION

3.1. Describe and explain how rock quality designation (RQD) may be determined from a winze development.	(2)
3.2. Based on the assessment of numerous underground excavation case histories, Nick Barton, R. Lien, and J. Lunde of the Norwegian Geotechnical Institute developed an index to evaluate the tunnelling quality of a rock mass. This index, known as the Q-system, is expressed as: $Q = (RQD / Jn) \times (Jr / Ja) \times (Jw / SRF)$ (i) What are the three quotients (in brackets) crude measures of? (3) (ii) What values of Q typically define Poor ground and Fair ground? (2) (iii) A relationship between the Rock Mass Rating and the Tunnelling Quality Index exists. Express this relationship mathematically (2)	 (3) (2) (2)
3.3 During the development of a winze, detailed geological mapping of the excavation walls is carried out in addition to core drilling. (i) Describe how the joint set number (Jn), joint roughness number (Jr), and joint alteration number (Ja) may be determined from such mapping. (ii) Explain the significance of the quotient (Jr / Ja) as a crude measure in the Q-system and why it is important for assessing rock mass stability in underground excavations. (iii) State the typical Q-value ranges that define Good ground and Very good ground.	 (3) (2) (1) **[15]**

QUESTION 4. NUMERICAL ANALYSIS

4.1. Limit equilibrium analysis (LE) is used efficiently during slope design to calculate the FoS & PoF related to the geotechnical model.

a) Briefly describe the theory behind limit equilibrium analysis (3) and also state why limit equilibrium may be favoured over Numerical Models (2). (5)

b) Various techniques / method of slices are used to solve limit equilibrium problems. Name and describe three common slice techniques other than the Janbu 1954/6. (6) (6)

4.2. The Mohr-Coulomb failure criterion (M-C) and Hoek-Brown failure criterion (H-B) are commonly used both used to describe the strength and failure behaviour during LE analysis. Provide a comparison of M-C and H-B failure criterion as applied in slope stability. (4) (4)

4.2. A small consortium, Mzamo, has been granted a Mining Permit to mine a coal deposit in the Waterberg near Lephalale using an open cut strip mining method. The director aims to prioritise the extraction of high-quality coal early in the project to achieve a rapid payback within the first year, which may influence slope design and mining sequence.

You have been appointed as a consulting rock engineer to assess the stability of the initial pit strip. Based on the provided pit geometry (Appendix 1), you developed two slope stability models and applied two limit equilibrium slice methods for comparison. The results obtained from these analyses are presented, and form the basis for evaluating slope stability, identifying potential failure mechanisms, and recommending any necessary design adjustments.

Category		Method	Overall Mean FoS	Overall PoF (%)	Critical FoS	Critical PoF (%)	Critical Failure Volume
H-B	Homo	A	1.4	0.0	1.4	0.0	0.0
		B	1.2	0.0	1.2	0.0	0.0
	Hetero	A	1.0	49.0	1.0	46.4	91.0
		B	0.9	61.6	1.0	46.9	91.0
M-C	Homo	A	1.6	0.4	1.6	0.3	1583.0
		B	1.3	0.8	1.6	0.6	1404.0
	Hetero	A	1.2	0.0	2.3	0.0	0.0
		B	0.0	100.0	0.1	100.0	52.0

4.2.1. Explain the importance of performing material property sensitivity analysis for stability analysis.	(2)
4.2.3. Appendix 1 shows the results of the sensitivity analysis done on M-C & H-B. Which two material properties are most positive?	(2)
4.2.2. Evaluate the results obtained from stability analysis as shown in table above and provide a concise interpretation. Your interpretation should focus on H-B to specifically address the following aspects: • Interpret the results from both slice methods and compare the calculated Factors of Safety • Comment on the stability of the initial pit slopes in relation to industry acceptable criteria • Identify the most likely failure mechanism based on the modelling outputs Your answer should demonstrate a clear understanding of slope stability principles, limit equilibrium methods, and the practical implications.	(11)
	[30]

Total Marks = [100]

FORMULA SHEET

$$\sigma_1 = \sigma_3 + \sqrt{(s\sigma_c^2 + m\sigma_c\sigma_3)}$$

$$\sigma_1 = \sigma_c + \beta_o\sigma_3$$

$$\varepsilon_3 = \frac{\left[\sigma_3 - \nu\left(\sigma_1 + \sigma_2\right)\right]}{E}$$

$$\sigma_1 = \sigma_3 + \sigma_{ci}\left(m_b \frac{\sigma_3}{\sigma_{ci}} + s\right)^a$$

$$\sigma_1 = \sigma_3 + \sigma_{ci}\sqrt{m_i \frac{\sigma_3}{\sigma_{ci}} + 1}$$

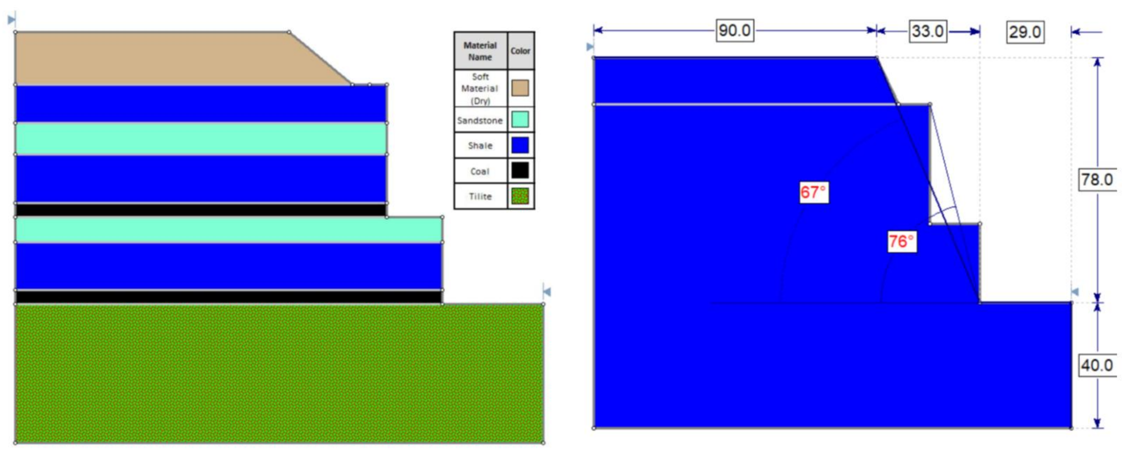
$$\tau = C_o + \mu\sigma_n$$

$$\tau_{max} = \frac{1}{2}(\sigma_1 - \sigma_2)$$

$$\tau = \sigma' \tan\left(\phi + \text{JRC} \log_{10}\left(\frac{\text{JCS}}{\sigma'}\right)\right)$$

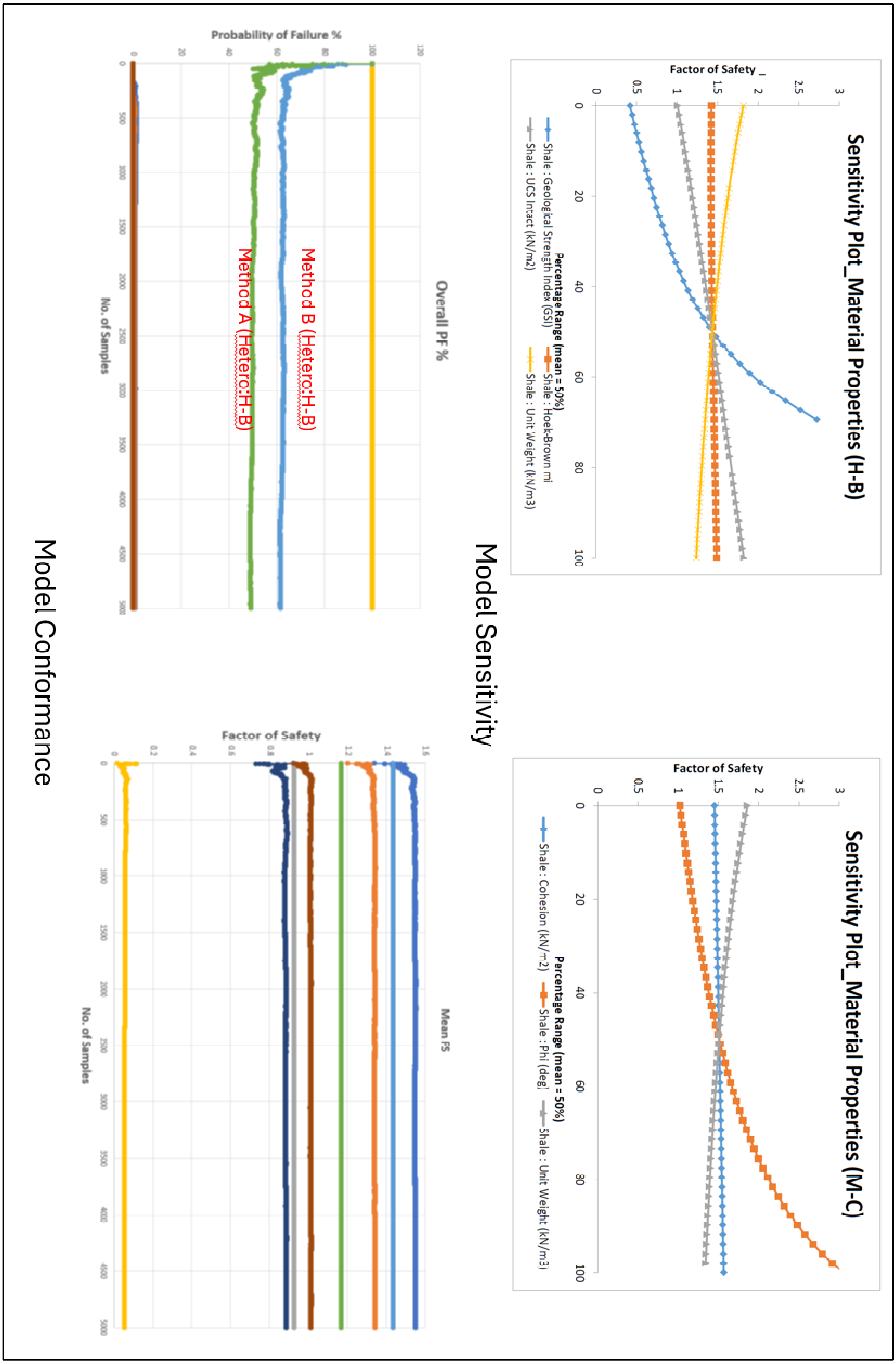
$$\phi_j \approx \tan^{-1}\left(\frac{J_r}{J_a}\right)$$

Appendix 1: Limit Equilibrium Model Geometry



a) Hypothetical heterogeneous slope model

b)Hypothetical homogeneous slope model


Sensitivity Plot_Material Properties (H-B)
Factor of Safety
Percentage Range (mean = 50%)
Shale : Geological Strength Index (GSI)
Shale : Hoek-Brown mi
Shale : UCS Intact (kN/m2)
Shale : Unit Weight (kN/m3)
Sensitivity Plot_Material Properties (M-C)
Factor of Safety
Percentage Range (mean = 50%)
Shale : Cohesion (kN/m2)
Shale : Phi (deg)
Shale : Unit Weight (kN/m3)
Model Sensitivity
Overall PF %
Probability of Failure %
Method B (Hetero:H-B)
Method A (Hetero:H-B)
No. of Samples
Mean FS
Factor of Safety
No. of Samples
Model Conformance