Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CERTIFICATE IN ROCK MECHANICS	**EXAMINER:** THOVHEDZO GCUDA
PAPER 1: ROCK MECHANICS THEORY	**MODERATOR:** DAVE ROBERTS
SUBJECT CODE: COMRMC	**TOTAL MARKS:** [100]
DATE: 08 OCTOBER 2024	**PASS MARK:** (60%)
TIME: **14H30 TO 17H30**	

NUMBER OF PAGES: 7

THIS IS NOT AN OPENBOOK EXAMINATION – ONLY REFERENCES PROVIDED ARE ALLOWED

SPECIAL REQUIREMENTS:

1. Answer all the questions in legible English.
2. Write your ID number on the outside cover of each script used and on any graph paper or other loose sheets handed in.

   NB: Your name must not appear on any answer book or loose sheets.
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 to an 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 recorded 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 in the examination room.

QUESTION 1. GENERAL QUESTIONS

1.1 Shear stress is always zero on the planes where the principal stresses act. True or False?	(1)
1.2 The directions of principal stresses are always aligned with the applied external forces. True or False?	(1)
1.3 Brittle rocks experience less deformation before rupture than ductile rocks. True or False?	(1)
1.4 Joint spacing does not influence joint strength. True or False?	(1)
1.5 A higher Rock Wall Condition Factor indicates a more stable rock mass. True or False?	(1)
1.6 Plastic deformation is reversible. True or False?	(1)
1.7 Griffith's equation calculates the critical stress needed for crack propagation based on the crack length and material properties. True or False?	(1)
1.8 The triaxial rock lab test is conducted without lateral confinement. True or False?	(1)
1.9 A higher Young's modulus indicates that a material is stiff and will deform less under applied stress. True or False?	(1)
1.10 A material with a Poisson's ratio of 0.5 is considered incompressible. True or False?	(1)
1.11 Briefly describe the following failure criteria including formulae. Describe typical underground conditions where the failure criteria is applicable. a) Hoek-Brown b) Mohr coulomb c) Barton	 (5) (5) (5)
	[25]

QUESTION 2. STRESS AND STRAIN

2.1 Explain each of the following terms by utilising sketches and formulae (where appropriate) and give examples of how and where they can impact on rock engineering design. a) Elastic modulus b) Shear stress c) Principal stress d) Poisson's ratio e) Plane strain	 (3) (3) (3) (3) (3)
2.2 If an element of an elastic material is to be subjected to the stresses as indicated below, σ_{xx} = 20 MPa σ_{xy} = -10 MPa σ_{yy} = 40MPa σ_{yx}= -10MPa Calculate the principal stress and direction and graphically plot your results on a labelled Mohr circle.	(10)
	[25]

QUESTION 3. ROCK STRENGTH

3.1 In a series of triaxial compression tests, the following represent the stresses obtained at peak load conditions:	

Table 1: Triaxial Strength Results

Sample Number	Confining Stress, MPa	Peak Stress, MPa
1	5.0	30.0
2	9.5	70.0
3	15.0	101.0
4	20.0	120.0
5	30.0	170.0

a) Derive the Mohr-Coulomb parameters and equation from the above triaxial test results	(15)
b) Numerical modelling results for a tunnel at your mine show major stress of 100MPa and minor stress of 20 MPa. Would you expect failure and why?	(5)
c) If the Mohr coulomb equation is $\tau = 25 + \sigma_n \tan 40^o$ would you expect failure from the tunnel in (b)?	(5)
	[25]

QUESTION 4. STRESS IN ROCK AND ROCKMASSES [25]`

4.1 A vertical shaft is 6 m in diameter and the k-ratio in y-direction, ky = 1.4 and in the x-direction, kx = 0.8 at the depth of 1200. The average host rock density is 2900 kg/m^3 , UCS = 180 MPa and the rock mass condition is generally good. Calculate the radial and tangential stresses in the shaft sidewall along the x axis at 0m, 0.5m, 1m, 1.5m, 2m.	(20)
4.2. Describe how you would use the hoek-brown failure criterion and the results obtained in 4.1 to determine the required tendon length to support the shaft?	(5)
	[25]

Total Marks = [100]

Formular Sheet

1. $\tau = c + \sigma_n \tan\phi$
2. $\sigma_1 = \sigma_c + \tan\psi\, \sigma_3$
3. $\tan\psi = (1 + \sin\phi)/(1 - \sin\phi)$
4. $\sigma_c = 2c\cos\phi/(1 - \sin\phi)$
5. $\phi = \sin^{-1}(\tan\psi - 1|\tan\psi + 1)$
6. $c = \sigma_c/2\sqrt{\tan\psi}$
7. $\sigma_n = \sigma_{xx}cos^2\theta + 2\tau_{xy}\sin\theta\cos\theta + \sigma_{yy}sin^2\theta$
8. $\tau_{nm} = \frac{1}{2}\left(\sigma_{yy} - \sigma_{xx}\right) sin2\theta + \tau_{xy}\cos 2\theta$
9. $\tan 2\theta = \frac{2\tau_{xy}}{(\sigma_{xx} - \sigma_{yy})}$
10. $\sigma_1 = \frac{1}{2}\left(\sigma_{xx} + \sigma_{yy}\right) + \frac{1}{2}\sqrt{(\sigma_{xx} - \sigma_{yy})^2 + 4\tau_{xy}^2}$
11. $\sigma_2 = \frac{1}{2}\left(\sigma_{xx} + \sigma_{yy}\right) - \frac{1}{2}\sqrt{(\sigma_{xx} - \sigma_{yy})^2 + 4\tau_{xy}^2}$
12. $\varepsilon_n = \epsilon_{xx}cos^2\theta + \gamma_{xy}sin\theta cos\theta + \varepsilon_{yy}sin^2\theta$
13. $\gamma_{nm} = \left(\varepsilon_y - \varepsilon_x\right)\sin 2\theta + \gamma_{xy}\cos 2\theta$
14. $\tan 2\theta = \frac{\gamma_{xy}}{(\varepsilon_{xx} - \varepsilon_{yy})}$
15. $\varepsilon_1 = \frac{1}{2}\left(\varepsilon_{xx} + \varepsilon_{yy}\right) + \frac{1}{2}\sqrt{\left(\varepsilon_{xx} - \varepsilon_{yy}\right)^2 + \gamma_{xy}^2}$
16. $\varepsilon_2 = \frac{1}{2}\left(\varepsilon_{xx} + \varepsilon_{yy}\right) - \frac{1}{2}\sqrt{\left(\varepsilon_{xx} - \varepsilon_{yy}\right)^2 + \gamma_{xy}^2}$
17. $\tan 2\theta = {}^{\gamma_{xy}}\!\big/_{(\varepsilon_{xx} - \varepsilon_{yy})}$
18. $W = \frac{1}{2}(\sigma_1\varepsilon_1 + \sigma_2\varepsilon_2 + \sigma_3\varepsilon_3)$
19. $\sigma_1 = \frac{E}{1-v^2}(\varepsilon_1 + v\varepsilon_2)$
20. $\sigma_2 = \frac{E}{1-v^2}(\varepsilon_2 + v\varepsilon_1)$
21. $\varepsilon_x = \frac{1}{E}\{\sigma_x - v(\sigma_y + \sigma_z)\}$
22. $\varepsilon_y = \frac{1}{E}\{\sigma_y - v(\sigma_x + \sigma_z)\}$
23. $\varepsilon_z = \frac{1}{E}\{\sigma_z - v(\sigma_x + \sigma_y)\}$
24. $\gamma_{xy} = \frac{1}{G}\tau_{xy}$, $\gamma_{yz} = \frac{1}{G}\tau_{yz}$, $\gamma_{zx} = \frac{1}{G}\tau_{zx}$

25. $\lambda = \frac{Ev}{(1+v)(1-2v)}$

26. $G = \frac{E}{2(1+v)}$

27. $\sigma_r = \frac{1}{2}q(1+k)(1-\frac{R^2}{r^2}) - \frac{1}{2}q(1-k)\ (1-\frac{4R^2}{r^2}+\frac{3R^4}{r^4})\cos 2\theta$

28. $\sigma_\theta = \frac{1}{2}q(1+k)(1+\frac{R^2}{r^2}) + \frac{1}{2}q(1-k)\ (1+\frac{3R^4}{r^4})\cos 2\theta$

29. $\tau_{r\theta} = \frac{1}{2}q(1-k)(1+\frac{2R^2}{r^2}-\frac{3R^4}{r^4})\sin 2\theta$

30. $\sigma_3 - \mathrm{I}_1\sigma^2 - \mathrm{I}_2\sigma - \mathrm{I}_3 = 0,$

31. $\mathrm{I}_1 = \sigma_{xx} + \sigma_{yy} + \sigma_{zz}$

32. $\mathrm{I}_2 = -(\sigma_{xx}\sigma_{yy} + \sigma_{yy}\sigma_{zz} + \sigma_{zz}\sigma_{xx}) + \tau_{xy}^2 + \tau_{yz}^2 + \tau_{zx}^2$

33. $\mathrm{I}_3 = \sigma_{xx}\sigma_{yy}\sigma_{zz} + 2\tau_{xy}\tau_{yz}\tau_{zx} - \sigma_{xx}\tau_{yz}^2 - \sigma_{yy}\tau_{zx}^2 - \sigma_{zz}\tau_{yx}^2$

34. $Q = (3I_2 + I_1^2)^{0.5}$

35. $\cos\phi = (9\mathrm{I}_1\mathrm{I}_2 + 27\mathrm{I}_3 + 2\mathrm{I}_1^3)/2Q^3$

36. $\sigma_p = \frac{1}{3}\left[2Q\cos\left(\frac{\phi}{3} + k.120°\right) + \mathrm{I}_1\right]$

37. $k = 0, 1, 2$

38. $\mathrm{I}_1 = \sigma_1 + \sigma_2 + \sigma_3 = \sigma_{xx} + \sigma_{yy} + \sigma_{zz}$

39. $\mathrm{I}_2 = (\sigma_1\sigma_2 + \sigma_2\sigma_3 + \sigma_3\sigma_1) = -\left(\sigma_{yy}\sigma_{zz} + \sigma_{zz}\sigma_{xx} + \sigma_{xx}\sigma_{yy}\right) + {\tau_{yz}}^2 + {\tau_{zx}}^2 + {\tau_{xy}}^2$

40. $\mathrm{I}_3 = \sigma_1\sigma_2\sigma_3 = \sigma_{xx}\sigma_{yy}\sigma_{zz} + 2\tau_{yz}\tau_{zx}\tau_{xy} - \sigma_{xx}{\tau_{yz}}^2 - \sigma_{yy}{\tau_{zx}}^2 - \sigma_{zz}{\tau_{xy}}^2$

41. $Q = \frac{RQD}{Jn}\ x\ \frac{Jr}{Ja}\ x\ \frac{Jw}{SRF}$

42. $\tau = \sigma_n \tan(\phi_r + \mathrm{JRC}\log_{10}(\mathrm{JCS}/\sigma_\mathrm{n}))$

43. $\tau = \sigma_n \tan(\phi_b + \mathrm{i})$

44. $\sigma_1 = \sigma_3 + \sigma_{ci}\left(m_b\, {}^{\sigma_3}/_{\sigma_{ci}} + s\right)^a$

45. $\sigma_1 = \sigma_3 + \sigma_{ci}\left(m_i\, {}^{\sigma_3}/_{\sigma_{ci}} + 1\right)^{0.5}$

46. $GSI = RMR_{89} - 5$

47. $m_b = m_i exp\left(\frac{GSI-100}{28}\right)$

48. $For\ GSI > 25, s = exp\left(\frac{GSI-100}{9}\right), and\ a = 0.5$

49. $For\ GSI < 25, s = 0, and\ a = 0.65 - {}^{GSI}/_{200}$

50. $When\ \sigma_{ci} > 100\ MPa,\ E_m = 10^{\left(\frac{GSI-10}{40}\right)}$ (GPa)

51. $When\ \sigma_{ci} < 100\ MPa,\ E_m = \sqrt{{}^{\sigma_{ci}}/_{100}}\, 10^{\left(\frac{GSI-10}{40}\right)}$ (GPa)