NAMIBIA UNIVERSITY
OF SCIENCE AND TECHNOLOGY

FACULTY OF ENGINEERING AND THE BUILT ENVIRONMENT
DEPARTMENT OF CIVIL MINING AND PROCESS ENGINEERING

QUALIFICATION : BACHELORS OF ENGINEERING IN MINING ENGINEERING	
QUALIFICATION CODE: 08BMIN	LEVEL: 7
COURSE CODE: REE720S	COURSE NAME: ROCK ENGINEERING
SESSION: NOVEMBER 2022	PAPER: THEORY
DURATION: 3 HOURS	MARKS: 100

FRIST OPPORTUNITY QUESTION PAPER	
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MODERATOR:	Prof. Mapani Benjamin

INSTRUCTIONS

1. Answer all questions.
2. Read all the questions carefully before answering.
3. Marks for each question are indicated at the end of each question.
4. Please ensure that your writing is legible, neat and presentable.

PERMISSIBLE MATERIALS

1. Examination paper.
2. Tracing paper
3. Mathematical Instruments

THIS QUESTION PAPER CONSISTS OF 08 PAGES (Including this front page)

Instructions: Answer Question I and any 4 other questions. Excess questions will not be marked.

Question I is compulsory.

Time allowed: 3 hours

Question I (20)

(Short answer questions)

a) Expand the CHILE properties of rockmass? [1]

b) What kind of roof failure can a truss bolt can prevent? [1]

c) How do the tangential and radial stresses vary as you move away from the boundary of a circular opening [1]

d) Under low stress environment what kind of support stiffness is required? provide an example [2]

e) What is the function of sill pillar? [1]

f) How are the tangential and radial stresses influenced by the internal pressure applied to a circular opening? [1]

g) When k>0.3 what is the nature stress at the crest of the circular opening? [1]

h) Two openings are made in the underground adjacent to each other and tunnel 1 is under the influence of tunnel 2, while tunnel 2 is not under the influence of tunnel 1. Which one should be opened first for safe excavation? [1]

i) What kind of mesh are used for shotcrete? [1]

j) What is active support and give an example [2]

k) What is critical support pressure? [1]

l) What are the limitations of resign bolts? [2]

m) What is the function of barrier pillars in mines? [1]

n) What are the assumptions behind the pillar design according to tributary theory? [2]

o) What are the conditions for planar slope failure? [2]

Question II

a) A tunnel of 4 m diameter driven at a depth of 500 m in stresses field with k = 0.25. The rock mass compressive and tensile strengths found from laboratory test are 30 MPa and 2 MPa respectively. The average density of overburden rock is 27 kN/m^3. Determine the extent of boundary failure. (20)

Question III

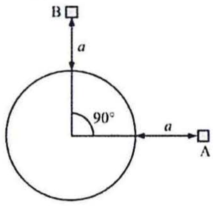
a) A tunnel of radius 2.0 excavated in a rock having modulus of elasticity 5 GPa and Poisson's ratio 0f 0.25. The tunnel is subjected to initial hydrostatic stress field of 10 MPa. Assuming c and ϕ of intact rock 3 MPa and 20° and those of broken rock is 1 MPa and 15° respectively. (20)

i) Determine critical support pressure

ii) Calculate inward displacement of the tunnel when internal support pressure is 5 MPa and 3 MPa

Question IV

a) A circular tunnel of radius a is constructed in prevailing far-filed stress of σ_v and σ_h. Tangential stress at point B (a units distance from boundary of the opening) is twice than that of at point A (a units distance from boundary of the opening). Determine the value of k. (10)



b) Discuss the support reinforcement principles used to support underground mine openings [10]

Question V

a) A horizontal stratiform orebody at a depth of 150 m below ground surface is planned for extraction using 4.0 m room spans and pillars 7.0 m square in plan. The full stratigraphic thickness of 3 m is to be mined. The unit weight of the overburden rock is 22.5 kN/m^3. Analysis of pillar failures in the orebody indicates that pillar strength is defined by (14)

$$s = 10.44h^{-0.7}w_p^{0.5}$$

Where s is in MPa and pillar height h and width w_p are in m

i. Determine the factor of safety against compressive failure of pillars in the planned layout.

ii. The orebody described above is underlain by a clay shale, for which c = 5 MPa, ϕ = 28°, and γ = 22 kN/m^3. Determine the factor of safety against bearing capacity failure of the floor rock.

b) State the advantages of rock bolts (6)

Question VI

a) What are the different types of backfill considered in mining operations and briefly describe about the crushed waste fill (10)

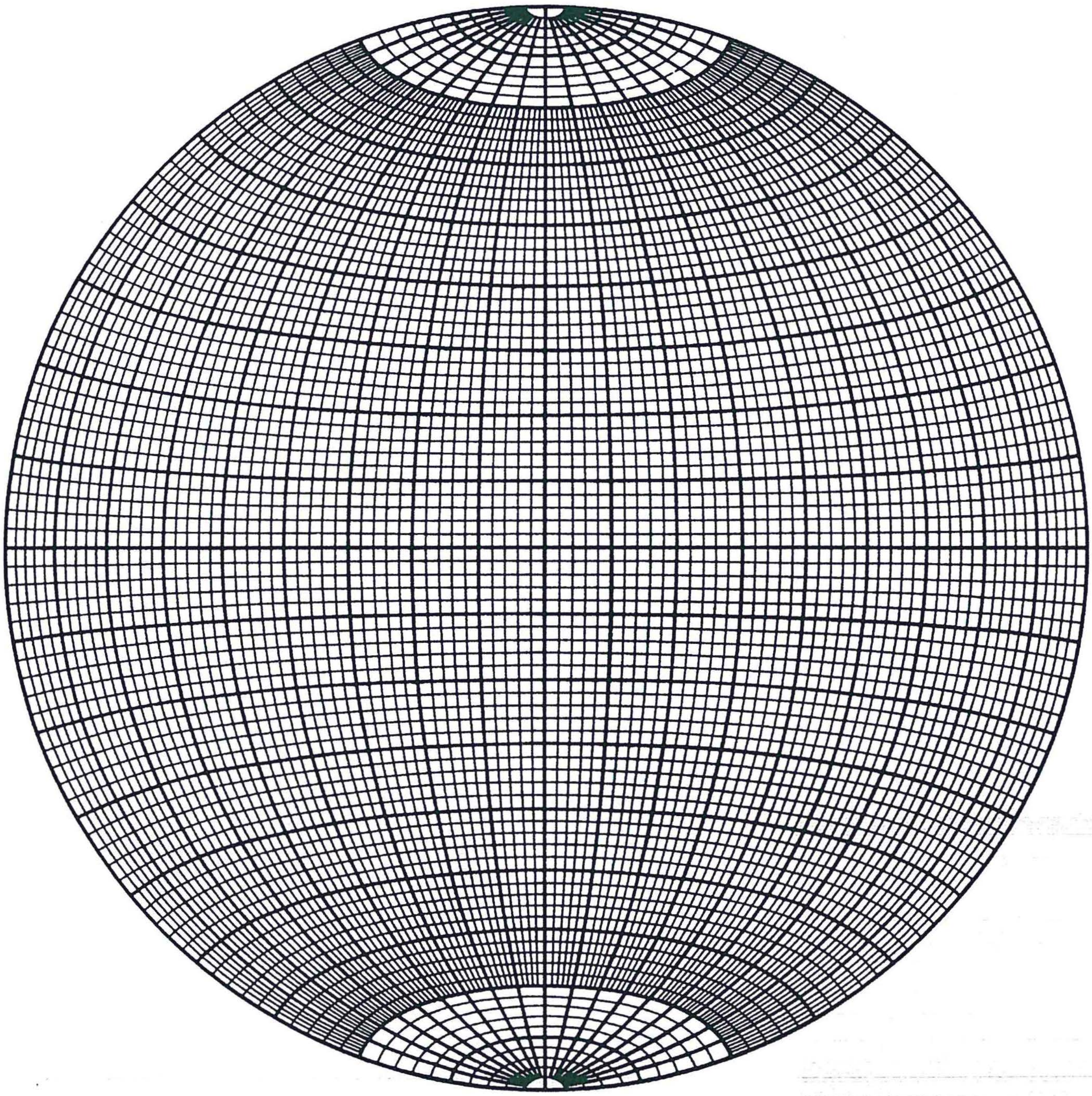
b) Data for a potential wedge failure by sliding down the line of intersection are given below (10)

Plane	Dip direction	Dip	Cohesion (kPa)	Friction angle (ϕ)
Plane A	-30	60	70	29
Plane B	120	60	35	23
Slope Face	45	60		
Upper slope	100	10		
Height of wedge = 30 m				

i. Determine dip and azimuth of the line of intersection of joint plane A and B [6]

ii. Check whether basic conditions for wedge failure are satisfied [4]

Equal Area Net
(Schmidt Net)



Additional Information

Exam (REE720S-2022)

Stresses around circular openings

$$\sigma_{rr} = \frac{p_0}{2}\left\{(1+k)\left(1-\frac{a^2}{r^2}\right) - (1-k)\left(1-4\frac{a^2}{r^2}+3\frac{a^4}{r^4}\right)\cos 2\theta\right\}$$

$$\sigma_{\theta\theta} = \frac{p_0}{2}\left\{(1+k)\left(1+\frac{a^2}{r^2}\right) + (1-k)\left(1+3\frac{a^4}{r^4}\right)\cos 2\theta\right\}$$

$$\tau_{r\theta} = \frac{p_0}{2}\left\{(1-k)\left(1+2\frac{a^2}{r^2}-3\frac{a^4}{r^4}\right)\sin 2\theta\right\}$$

Displacement around circular openings

$$u_r = \frac{p_0 a^2}{4Gr}\left\{(1+k) - (1-k)\left(4(1-\nu)-\frac{a^2}{r^2}\right)\cos 2\theta\right\}$$

$$u_\theta = \frac{p_0 a^2}{4Gr}\left\{(1-k)\left(2(1-2\nu)+\frac{a^2}{r^2}\right)\sin 2\theta\right\}$$

Stresses around circular openings with internal pressure

$$\sigma_{rr} = p_i + \frac{(p_o - p_i)}{2}\left\{(1+k')\left(1-\frac{a^2}{r^2}\right) - (1-k')\left(1-\frac{4a^2}{r^2}+3\frac{a^4}{r^4}\right)\cos 2\theta\right\}$$

$$\sigma_{\theta\theta} = p_i + \frac{(p_o - p_i)}{2}\left\{(1+k')\left(1+\frac{a^2}{r^2}\right) + (1-k')\left(1+3\frac{a^4}{r^4}\right)\cos 2\theta\right\}$$

$$\tau_{r\theta} = \frac{(p_o - p_i)}{2}\left\{(1-k')\left(1+\frac{2a^2}{r^2}-3\frac{a^4}{r^4}\right)\sin 2\theta\right\}$$

$$k' = \frac{kp_0 - p_i}{p_0 - p_i}$$

Stresses around circular openings **at infinite distance**

$$\sigma_{\theta\theta} = p_0[1+k+2(1-k)\cos 2\theta]$$

Stress transformation

$$\sigma_n = \frac{1}{2}(\sigma_{rr}+\sigma_{\theta\theta}) + \frac{1}{2}(\sigma_{rr}-\sigma_{\theta\theta})\cos 2\alpha + \tau_{r\theta}\sin 2\alpha$$

$$\tau_n = \tau_{r\theta}\cos 2\alpha - \frac{1}{2}(\sigma_{rr}-\sigma_{\theta\theta})\sin 2\alpha$$

Support System Characteristics

$$\sigma_c = \frac{2c\cos\emptyset}{1-\sin\emptyset} \quad k = \frac{1+\sin\emptyset}{1-\sin\emptyset}$$

$$p_{cr} = \frac{2p_0 - \sigma_c}{1+k}$$

Inward elastic displacement

$$u_{ie} = \frac{r_0(1+v)}{E}(p_0 - p_i)$$

Radius of plastic zone around the tunnel

$$r_p = r_0\left[\frac{2(p_0(k-1)+\sigma_c)}{(1+k)\left((k-1)p_i+\sigma_c\right)}\right]^{\frac{1}{(k-1)}}$$

Total inward displacement

$$u_{ip} = \frac{r_0(1+v)}{E}\left[2(1-v)(p_0-p_{cr})\left(\frac{r_p}{r_0}\right)^2 - (1-2v)(p_0-p_i)\right]$$

Longitudinal displacement

Ratio of maximum plastic zone radius to tunnel radius

$$\frac{r_p}{r_0} = \left[\frac{2(p_0(k-1)+\sigma_c)}{(1+k)\sigma_c}\right]^{\frac{1}{(k-1)}}$$

Displacement at tunnel face

$$u_{if} = \left(\frac{u_{im}}{3}\right)e^{-0.15\left(\frac{r_p}{r_0}\right)}$$

Maximum displacement

$$u_{im} = \frac{r_0(1+v)}{E}\left[2(1-v)(p_0-p_{cr})\left(\frac{r_p}{r_0}\right)^2 - (1-2v)p_0\right]$$

The tunnel wall displacement ahead of the face (x < 0) is

$$u_i = u_{if}\, e^{x/r_0}$$

The tunnel wall displacement behind the face (x > 0) is

$$u_i = u_{im} - (u_{im} - u_{if})e^{\frac{(-3x/r_0)}{(2r_p/r_0)}}$$

<u>Rock Support Interaction</u>

The displacement of the tunnel at support yield is given by

$$u_{iy} = u_{io} + \frac{p_{smax}}{K_s}$$

The factor of safety (FS) of the support

$$FS = \frac{p_{smax}}{p_{se}}$$

Steel Support

$$p_{ssmax} = \frac{A_s\sigma_{ys}}{s_l r_0};\ K_{ss} = \frac{A_s E_s}{s_l r_0^2}$$

Shotcrete support

$$p_{scmax} = \frac{\sigma_{cc}}{2}\left[1 - \frac{(r_0 - t_c)^2}{r_0^2}\right];\ K_{sc} = \frac{E_c(r_0^2 - (r_0 - t_c)^2)}{2(1 - \upsilon^2)(r_0 - t_c)r_0^2}$$

Rock bolts

$$p_{sbmax} = \frac{T_{bf}}{s_l s_c};\ K_{sb} = \frac{E_s \pi d_b^2}{4 l s_l s_c}$$

Pillar design

Average pillar stress

$$\sigma_p = \frac{\sigma_{zz}(w_0 + w_p)^2}{w_p^2}$$

Bearing capacity of **roof/floor with square pillar**

$$q_b = \frac{1}{2}\gamma w_p N_\gamma + cN_c$$

$$N_c = (N_q - 1)\cot\phi;\ N_\gamma = 1.5(N_q - 1)\tan\phi;\ N_q = e^{\pi \tan\phi}\tan^2\left[\left(\frac{\pi}{4}\right) + \left(\frac{\phi}{2}\right)\right]$$

Bearing capacity of roof/floor with rib pillar

$$q_b = \frac{1}{2}\gamma w_p N_\gamma S_\gamma + c\cot\phi\, N_q S_q - c\cot\phi$$

$$S_\gamma = 1 - 0.4\left({}^{w_p}/_{l_p}\right);\ S_q = 1 + \sin\phi\left({}^{w_p}/_{l_p}\right)$$

Subsidence

Maximum subsidence

$$s_m = 0.39h\left(\frac{W}{H}\right)^{0.32}$$

Subsidence at a distance *x* from the rib side

$$S_x = 0.5S_m\left[\tanh\left(\frac{7x}{W} - 1.645\right) + 1\right]$$

Slope Stability

Planar slope failure

$$FoS = \frac{\mathrm{cA} + w\cos\psi_p\tan\phi}{w\sin\psi_p}$$

Slope with Tension Crack in upper slope surface **(From equations)**

$$FoS = \frac{\mathrm{cA} + (w.\cos\psi_p - U - V.\sin\psi_p)\tan\phi}{\mathrm{w.}\ \sin\psi_p + V.\cos\psi_p}$$

$$A = \frac{(H - z)}{\sin\psi_p};\ U = \frac{\frac{1}{2}\gamma_W z_w(H - z)}{\sin\psi_p};\ V = \frac{1}{2}\gamma_W z_W^2$$

Weight of sliding block (Slope with Tension Crack in upper slope surface)

$$W = \frac{1}{2}\gamma H^2 \left\{\left(1 - \left({}^{z}/_{H}\right)^2\right)\cos\psi_p - \cos\psi_f\right\}$$

Weight of sliding block (Slope with Tension Crack in a slope face)

$$W = \frac{1}{2}\gamma H^2 \left\{\left(1 - \left({}^{z}/_{H}\right)^2\right)\cos\psi_p\left(\cot\psi_p . \tan\psi_f - 1\right)\right\}$$

Factor of safety of the slope in dimensionless form **(from Figures)**

$$\mathrm{F} = \frac{\left({}^{2c}/_{\gamma H}\right).P + \left(Q.\cot\psi_p - R\,(P+S)\right)\tan\phi}{Q + R.S\cot\psi_p}$$

$$P = \frac{\left(1 - {}^{z}/_{H}\right)}{\sin\psi_p};\ R = \frac{\gamma_w}{\gamma}.\frac{z_w}{z}.\frac{z}{H};\ S = \frac{z_w}{z}.\frac{z}{H}.\sin\psi_p$$

Slope with Tension Crack in the upper slope surface

$$Q = \left\{\left(1 - \left({}^{z}/_{H}\right)^2\right)\cos\psi_p - \cos\psi_f\right\}\sin\psi_p$$

Slope with Tension Crack in the slope face

$$Q = \left\{\left(1 - \left({}^{z}/_{H}\right)^2\right)\cos\psi_p\left(\cot\psi_p . \tan\psi_f - 1\right)\right\}$$