<table>
<tr><th colspan="2"><u>EXAMINATION PAPER</u></th></tr>
<tr><td>SUBJECT:
CHAMBER OF MINES OF SOUTH AFRICA EXAMINATION FOR CERTIFICATE IN ROCK MACHANICS PAPER 3.2 (COAL OPTION)

SUBJECT CODE

EXAMINATION DATE:

TIME:09H00 – 12H00</td><td>Examiner:

G Makusha

Moderator:

B Madden</td></tr>
<tr><td colspan="2">Number of pages 12 (including formula sheet)</td></tr>
</table>

SPECIAL REQUIREMENTS:

1. **Answer all questions.**
2. References, other than those specified below, are not permitted
3. Put your examination number on the outside cover of each book used, and on any graph paper or other loose sheets handed in.

N.B Your name must not appear on any answer book or loose sheets

4. Show all calculations on which your answers are based.
5. Hand-held electronic calculators may be used.
6. Write on the right hand page only.
7. Illustrate your answers by sketches or diagrams wherever possible.
8. Answers must be given to an accuracy which is typical of practical conditions.
9. In answering the questions, state any assumptions made.
10. A list of formula and any other essential charts and tables will be issued at the time of the examination.
11. Contacting of examiners and moderators is forbidden.

Question 1 roof support design (30 Marks)

Given a typical Stratigraphy tabulated below:

Strata type	Thickness (m)	Density (kg/m3)	Modulus (Mpa)
Sandstone	5.0	2000	8500
Coal	0.5	1650	1700
Sandstone(Jointed)	0.8	2100	1000
Siltstone (laminated)	0.3	2175	600
Coal	2.2	1630	1750

1) Calculate deflections of the individual strata which will form the immediate roof to the economically viable seam if the bord width is likely to be 7.5m. (5)

$$\eta = \frac{\gamma B^4}{32Et^2} = \frac{0.021*7^4}{32*600*0.3^2} =$$ (2)

				n
Sandstone	5	2000	8500	0.0
Coal	0.5	1650	1700	2.9
Sandstone	0.8	2100	1000	2.5
Siltstone(laminated)	0.3	2175	600	30.2
Coal	2.2	1630	1750	

(3)

2) Which strata are likely to influence other strata deflections once the coal seam is mined (2)

3) Test the nether sandstone beam given that it is jointed and tensile strength reduced to 1 MPa: (6)

$B_{max} = 6.389t_s\sqrt{\frac{\sigma_t}{(t_s+t_l+0.6t_c)}} = 3.5m \text{ will fail}$ (6)

4) Use the dead weight suspension method on 7.5m wide roads to design a suitable roof bolting pattern if the shear resistance of the resin /rock contact plane is 2000kPa and the hole diameter of 28mm with 20mm bolts are used for support. The yield strength of steel used is 500MPa. Allow a safety factor of 1.5 (13)

Weight of the beam per unit length to be suspended = (0.0165*0.5+0.021*0.8+0.02175*0.3)*7.5=237kn/m (3)

$$l_a = \frac{1.2 * F_T}{\pi d_h \tau_c} = 237 * 1.2/(3.142 * 0.028 * 2000) = 1.6m$$ (4)

Force per bolts $$F_b = \frac{\sigma_s \pi d_s^2}{4 * 1.5} = 450000 * \pi * 0.02\text{^}2/1.5 * 4 = 2.5$$ say 3(4)

Anchor lenth per bolt = 1.6/3=0.53m (1)

Required bolt length = 1.6+0.53=2.1m (1)

Required support pattern is 3 bolts per row, 2.1m long with row spacing of 1.0m.

5) Determine the length of a single twin speed resin that will provide full column grouting. State any assumptions you make (4)

Resin diameter =23mm (1)
Formula (2)
Lr=1.5m (1)

$$l_c = \frac{l_a\left(d_h^2 - d_b^2\right)}{(dr)\text{^}2}$$

Question 2 Total Extraction (20 Marks)

A panel with seven roads and pillar widths of 18 m is to be considered for increased extraction. The manager has requested you to consider three options.

- Option 1, take a 7,2 m split in the middle of each pillar,
- Option 2, Pillar Extraction taking diagonal cuts into the pillar leaving three triangular snooks with two sides of 6,0,
- Option 3, Checkerboard Extraction using the same method in Option 2.

The immediate roof consists of 10 m of competent Sandstone, bord width is 7,2 m, mining height is 4,0 m and depth is 130 m. In your report to the manager include the advantages and disadvantages of each Option including the potential extraction percentage and tons and which you would recommend.

Pillars are not squat, SF continuous adj is 1,85, w/h ratio is 4,5, both are acceptable for pillar extraction & checkerboarding
Option 1 leaves fender with low w/h ratio of 1,35, danger of violent collapse,
Option 2 gives best e% and tons but would have difficulties with goafing, could consider leaving row of pillars every ? rows, that's the difficulty,
Option 3 probably safest, could increase e% & tons by reducing pillar to 16 m x 16 m by taking a 2,0 m slype from two sides, w/h ratio would then be an acceptable 4,0.

Question 3 Pillar design and time to failure (30 Marks)

You have been appointed to oversee a new project in the vaal basin area. Preliminary borehole information have indicated the select mining horizon to be fairly flat at an average mining depth of 137. A 40m thick dolerite sill occurs 20m below surface. Literature review of the area revealed that the coal in that part of South Africa is considerably weaker than the Witbank coal seam.

a) The project surveyor requested you to evaluate a mining layout with square pillars, extracting 2.4m thick select horizon on 24.4m pillar center distance and 6.7m wide bords. (6)

w/h=17.7/2.4 (squat) (1)

$$\sigma = 4.5\frac{w^{0,46}}{h^{0,66}}$$ (2)

$$Load = \frac{[.025(H-T)+.03T]C_1C_2}{w_1w_2}$$ (2)

FOS=strength /load (1)

b) Assuming progressive scaling is possible, calculate the potential life of the pillars. (6)

$$d = w - \left[0,00714 S_{\min} HhC^2\right]^{0,333}$$ (2)

$$S_{\min} = 0.4$$ (1)

$$T = \left[\frac{d}{mh^x}\right]^{\frac{1}{1-x}}$$ (3)

Region	m	x
Vaal Basin, Klip River and South Rand	1,3888	0,804
Witbank No 2 and 4 Seams	0,1624	0,8135
Witbank No 5 Seam	0,105	-0,3061

d	h^x	1/1-x	T
9.479326526	2.02157491	5.10204082	496.7787years

c) In the event of the panel pillars failing determine maximum vertical subsidence, maximum tilt, maximum tensile and compressive strain on surface (6)

$S_{m,pf} = 0.1\_0.5h_e = 0.11376\_0.5688m$ (1)

$h_e = he = 0.47 * 2.4 = 1.1376$ (2)

$T_m = 21.6S_m + 7 = 9.5mm/m$ (1)

$\varepsilon_{m+} = 4.2S_m + 1.7 = 2.18mm/m$ (1)

$\varepsilon_{m-} = -9.1S_m - 2.8 = -3.83mm/m$ (1)

d) where total extraction methods are applied use the method developed by Van derMerwe to determine the barrier pillar spacing required to prevent failure of the dolerite sill (6)

$$L_c = 2T\sqrt{k + \frac{\beta}{D}} + 2(H - D)\tan\theta = 218m$$ (3)

$$\beta = \frac{1.53}{\gamma_m} - 0.8 = 57$$ (1)

$$\gamma_m = 0.025\frac{D-T}{D} + 0.03\frac{T}{D} = 0.02646$$ (2)

e) In (d) above use a clearly annotated diagram to describe a method you would use to monitor the height of caving and the integrity of the dolerite sill . (6)

Question 4 Miscellaneous (20 marks)

Detach the table attached to the back of this paper and use to fill in your answers, by clearly marking the "True" or " false" column opposite each question number.

Remember to fill in you examination number on the sheet.

Marks will be deducted for incorrect answers.

a) The formula, $S_m = 0.39h\left(\frac{w}{h}\right)^{0.32}$, pertaining surface subsidence
1) only applies to total extraction panels (T)
2) also applies to collapsed bord and pillar workings (F)
3) both 1 & 2 incorrect (F)
4) both 1 & 2 correct (F)

b) When fixed beams are loaded they deflect and stress are induced as follows:
1) Maximum tensile stresses are induced at both ends on top of the beam (T)
2) Compressive stresses of the same magnitude as tensile stresses are also set up at both ends at the bottom of the beam (T)
3) In the middle the stresses are compressive on to and tensile at the bottom and ½ the magnitude at the ends. (T)
4) Introducing a joint across the beam could increase the induced maximum stresses 6 fold. (T)

c) The post failure behavior of a coal pillar is
1) depended on modulus of elasticity of the coal (F)
2) only depend on the bulk modulus of coal (F)
3) is independent of pillar shape (F)
4) is only influenced by the stiffness of overburden material (F)

d) Strength of Rock materials
1) in compression is typically 1/8 to 1/12 of that in tension (F)
2) in tension is typically 1/8 to 1/12 of that in compression (T)
3) can be estimated from core in the field by using the point load test (T)
4) the shear strength is around ¼ to 1/10 of the compressive strength. (T)

e) Bord width
1) Doubling the bord width, increases the amount of roof sag 16 times (T)
2) Doubling the bord width, increases the maximum tensile stresses in the roof beam 4 times. (T)
3) The roof sag in an intersection is potentially 3.8 times that in the normal road way (T)
4) The amount of roof sag is inversely proportional to the 4th power of road width. (F)

Answer sheet question 2:

***Exam number:*____________________________**

	QUESTION	TRUE	FALSE
A			
1			
2			
3			
4			
B			
1			
2			
3			
4			
C			
1			
2			
3			
4			
D			
1			
2			
3			
4			
E			
1			
2			
3			
4			

Equation Sheet

Candidates may find some of the following equations useful, although other equations may also be used.

Pillars

$$\sigma = 7{,}2\frac{w^{0{,}46}}{h^{0{,}66}}$$

$$\sigma = 4.5\frac{w^{0{,}46}}{h^{0{,}66}}$$

$$\sigma = 4{,}3\left(0{,}64 + 0{,}36\frac{w}{h}\right)$$

$$\sigma = 3.5\frac{w}{h}$$

$$\sigma = k\frac{R_0^b}{V^a}\left\{\frac{b}{\varepsilon}\left[\left(\frac{R}{R_0}\right)^{\varepsilon} - 1\right] + 1\right\}$$

$$\sigma = \frac{.0786}{V^{0.0067}}\left\{R^{2.5} + 181.6\right\}$$

$$w_e = \frac{4A}{C}$$

$$SF_{cm} = SF\left(1 + \frac{0.6}{w}\right)^{2.46} \qquad SF_{cm} = SF\left(1 + \frac{0.6}{w}\right)^{3}$$

$$SF^{/} = SF\left(\frac{w - \Delta w}{w}\right)^{2.46} \qquad SF^{/} = SF\left(\frac{w - \Delta w}{w}\right)^{3}$$

$$SF^{//} = \left(\frac{h}{h + \Delta h}\right)^{0.66} \qquad SF^{//} = \left(\frac{h}{h + \Delta h}\right)$$

$$Load = \frac{[.025(H-T)+.03T]C_1C_2}{w_1w_2}$$

$$e\% = 100\left[\frac{h_m}{h_s}\left(1-\frac{w^2}{C^2}\right)\right]\frac{W}{W+P}$$

$$E_{cp} = \frac{0{,}562w_e}{h} - 2{,}293$$

$$R = m\left[\frac{h}{T}\right]^x$$

$$d \ = w - \left[0{,}00714 S_{\min} HhC^2\right]^{0{,}333}$$

$$S_{\min} \ = 0.4$$

$$T = \left[\frac{d}{mh^x}\right]^{\frac{1}{1-x}}$$

Region	m	x
Vaal Basin, Klip River and South Rand	1,3888	0,804
Witbank No 2 and 4 Seams	0,1624	0,8135
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Roof Support

$$\sigma_t = \frac{qB^2}{2t^2}$$

$$q = \rho g(t_s + t_w)$$

$$\sigma_t = \frac{fq_c s^2}{2t^2}$$

$$s = 1.414 t_{\min} \sqrt{\frac{\sigma_{tm}}{fq_c}}$$

$$q_c = q_l + \frac{q_u E_l - q_l E_u}{E_l + E_u}$$

$$l_a = \frac{\rho g s^2 t_w}{\tau_c \pi d_h} + .05$$

$$\eta = \frac{SF\rho gt}{P_d}$$

$$\sigma_{ts} = \frac{4W_b}{\pi d_b^2}$$

$$l_c = \frac{l_a\left(d_h^2 - d_b^2\right)}{\left(d_h - .002\right)}$$

$$t_{sb} = \frac{fk\rho gB^2}{2\sigma_{tm}}$$

$$\tau_b = \frac{3k\rho gB}{4}$$

$$\tau = C_c + C_b + \frac{F_b}{s_b^2}\tan\phi$$

$$F_b = \frac{s}{\tan\phi}\left[\frac{3\rho gkBs}{4} - \sigma_r d_h\right]$$

$$F_T = F_b \rho gkt_{sb} s^2$$

$$l_a = \frac{F_T}{\pi d_h \tau_c}$$

$$\eta = \frac{\gamma B^4}{32Et^2}$$

$$\sigma_s = \frac{4F_T}{\pi d_s^2}$$

$$\beta = \arctan\left(\frac{L/2}{\eta}\right) - \arctan\left(\frac{\eta}{L/2}\right)$$

$$R = \frac{L/2}{Cos\beta}$$

$$d\theta = \frac{\pi}{2} - \arctan\left(\frac{R-\eta-h_l}{L/2 - d}\right)$$

$$S = t_l d\theta$$

$$\sigma_r = \frac{\tau_l S_b}{d_b}$$

$$\varepsilon_r = \frac{\sigma_r}{E_r}$$

$$S_r = \varepsilon_r (d_h - d_b) + R_s$$

$$SSF = \frac{S}{S_r}$$

Subsidence

$$S_{m,he} = 0{,}39h\left(\frac{W}{H}\right)^{0{,}32}$$

$$S_{m,pf} = 0.1h_e$$

$$h_e = he$$

$$S_x = \frac{S_{\max}}{2}\left[\tanh\left(\frac{7x}{W} - 1{,}645\right) + 1\right]$$

$$L_c = 2T\sqrt{k + \frac{\beta}{D}} + 2(H - D)\tan\theta$$

$$\beta = \frac{c - b\gamma d}{\gamma_m \tan\phi} - \frac{kl}{2}$$

$$\beta = \frac{1.53}{\gamma_m} - 0.8$$

$$\gamma_m = \gamma_s \frac{D - T}{D} + \gamma_d \frac{T}{D}$$

$$\gamma_m = 0.025\frac{D - T}{D} + 0.03\frac{T}{D}$$

$$T_m = 21.6S_m + 7$$

$$\varepsilon_{m+} = 4.2S_m + 1.7$$

$$\varepsilon_{m-} = -9.1S_m - 2.8$$

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