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Panel 04-1
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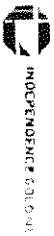
Rock Mechanics Paper 1 Model Answers

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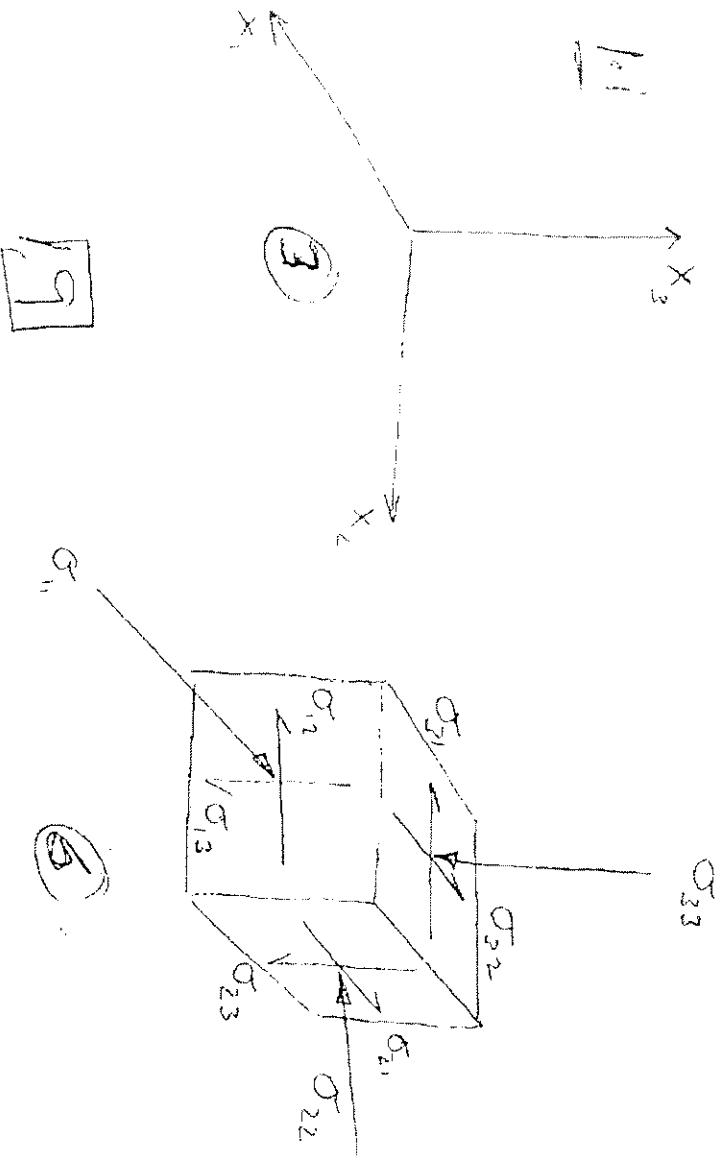


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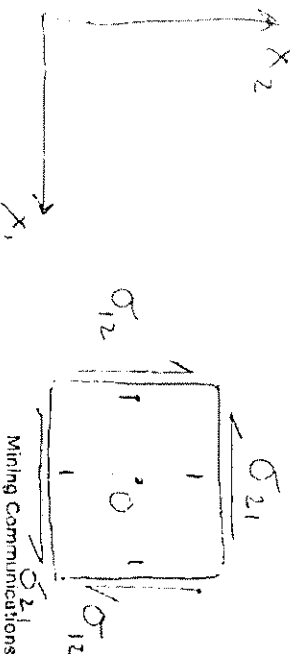
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Question 1.



1.2 On two dimensions the stress elements acting on the sides of a square element are as follows



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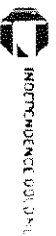
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Assuming the square element has centre O, the ~~element~~ ^{element} at each side of length l and unit thickness t moments about O:-

Clockwise moments:

$$0.5 \times \sigma_{12} \times l + 0.5 \times \sigma_{12} \times l = \sigma_{12} N - M_1 = M_c$$

Anticlockwise Moments

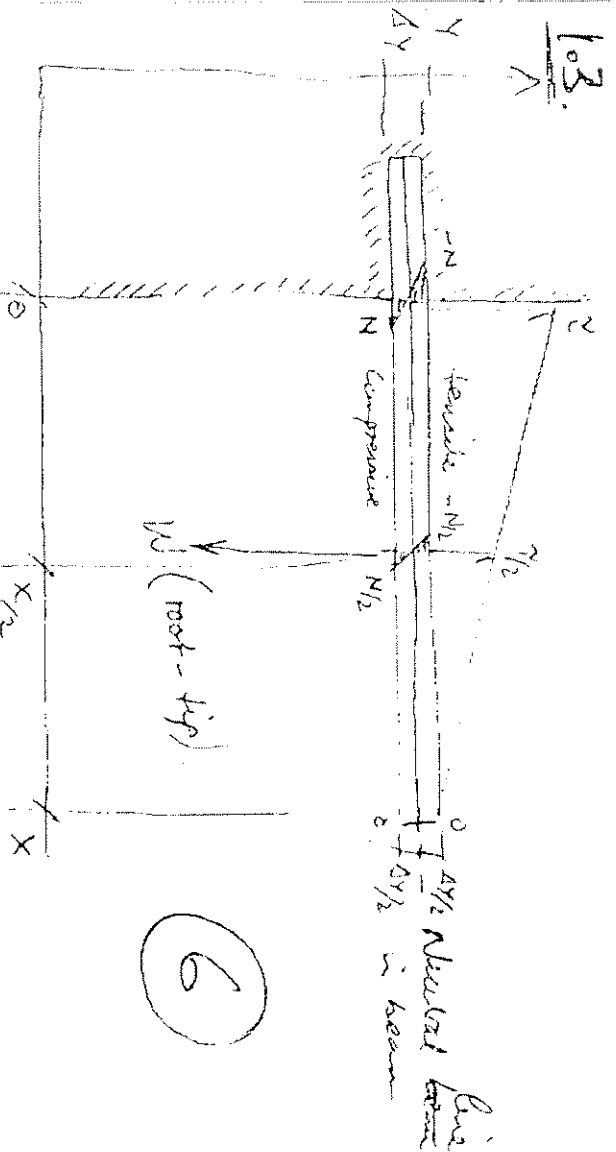
$$0.5 \times \sigma_{21} \times l + 0.5 \times \sigma_{21} \times l = \sigma_{21} N - M_1 = M_a$$

If the element is not to rotate, then

$$M_c = M_a$$

$$\Rightarrow \sigma_{12} = \sigma_{21}$$

(6)



(6)

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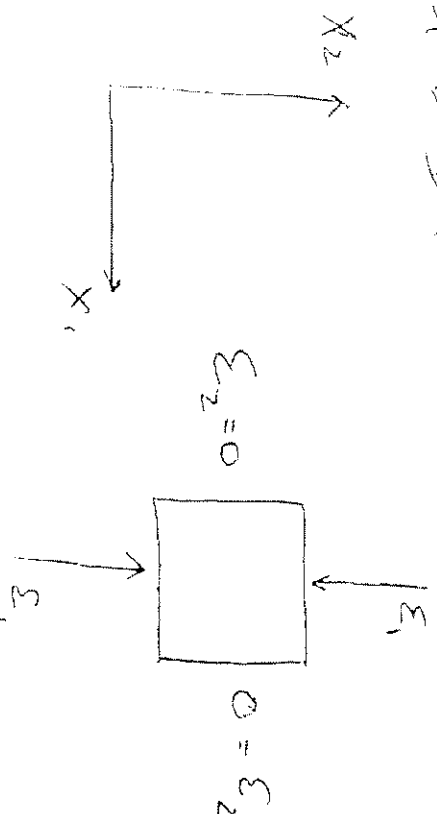
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1.4

Now again is that condition in which all the strains on the surface are zero. In 2-D :-



Condition is known where $\epsilon_2 = 0$, $\epsilon_1 = \epsilon_{comp}$ (RMS)

The expression of elasticity are as follows:-

$$\epsilon_1 = \frac{1}{E} (\sigma_1 - \nu \sigma_2)$$

$$\epsilon_2 = \frac{1}{E} (\sigma_2 - \nu \sigma_1) \Rightarrow \epsilon_2 = 0 = \sigma_2 - \nu \sigma_1$$

$$\Rightarrow \sigma_2 = \nu \sigma_1$$

$$\epsilon_1 = \frac{1 - \nu^2}{E} \sigma_1 \quad \epsilon_2 = 0$$

$$\sigma_1 = \frac{\epsilon_1 E}{1 - \nu^2} \quad \sigma_2 = \nu \sigma_1$$

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Quest 2

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2 (MPa)

2.1

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Co

$\sigma_0 \approx 2 \text{ MPa}$

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100

5 (MPa)

150



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2.2 ($\sigma_0 \approx 2 \text{ MPa}$) (4)
2.3 43° (East) (6)
2.4 σ_1 and σ_3 have a near linear relationship (3)

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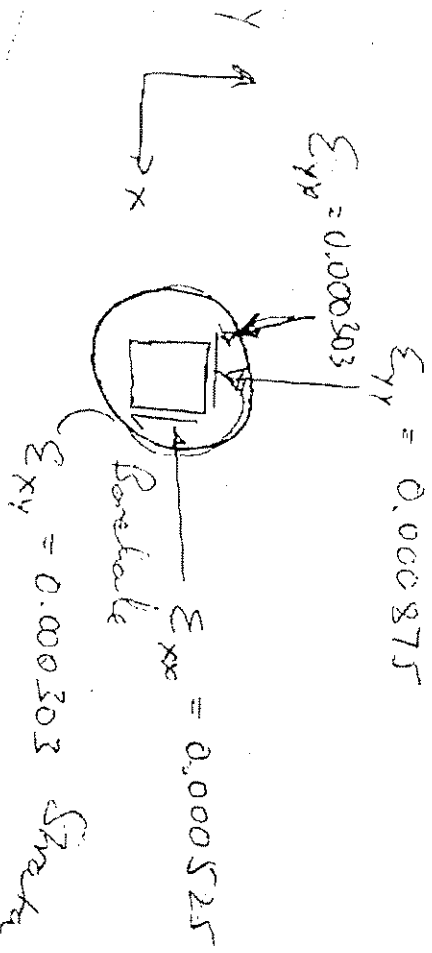
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2.5 at (100, 20) no failure
at (80, 10) failure ④

2.6 The data does not imply any failure model. Since the MCS and C_0 are relatively low 10Mk captures ~ MCS and 10Mk captures $> C_0$, hence I would expect a main capturing / show failure mode for the material. ④

Quasi 3



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$$3.1 \quad \Sigma_{xx} = \frac{1}{E} (\sigma_{xx} - \nu \sigma_{yy})$$

$$0.000525 = \frac{1}{60000} (\sigma_{xx} - 0.2 \sigma_{yy})$$

$$\sigma_{xx} - 0.2 \sigma_{yy} = 31.5 \quad \text{--- (1)}$$

$$\Sigma_{yy} = \frac{1}{60000} (\sigma_{yy} - 0.2 \sigma_{xx})$$

$$\Rightarrow -0.2 \sigma_{xx} + \sigma_{yy} = 52.5 \quad \text{--- (2)}$$

Multiplying (2) by 5 and adding to (1):

$$-0.2 \sigma_{yy} + 5 \sigma_{yy} = 31.5 + 262.5$$

$$\sigma_{yy} = \frac{294}{4.8} = 61.25 \text{ MPa}$$

hence $\sigma_{xx} = 31.5 + 0.2 \times 61.25$

$$\sigma_{xx} = 43.75 \text{ MPa}$$

$$\sigma_{xx} = \frac{1}{2\epsilon} \Sigma_{xy} = \frac{1+\nu}{E} \sigma_{xy}$$

$$= \frac{1.2}{60000}$$

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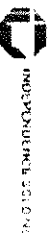
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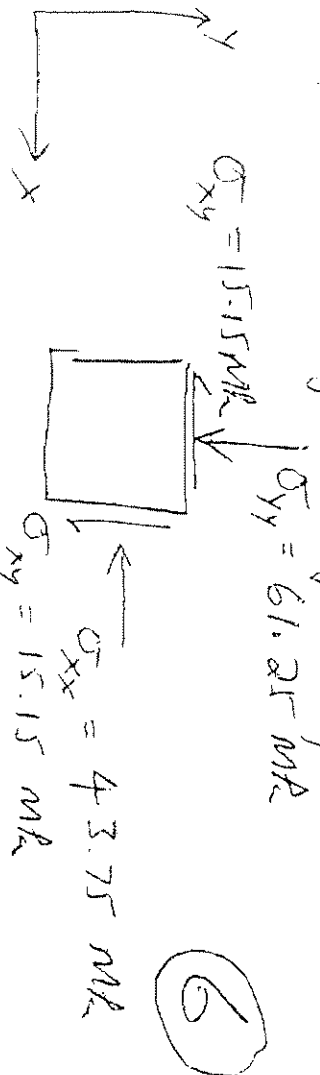
(8)

$$\sigma_{xy} = 2G \epsilon_{xy} = \frac{E}{1+\nu} \epsilon_{xy}$$

$$= \frac{60000}{1.2} \times 0.000303$$

$$= 15.15 \text{ MPa}$$

Tunnel is subjected to following stress state



(6)

$$3.2. \quad \sigma_v = \rho g h = 3018 \times 9.81 \times 2200$$

$$= 66 \text{ MPa}$$

(4)

The stress at 61.25 MPa is quite allowable/reasonable. Stress is not distributed uniformly through rock mass because of discontinuities, small movements, residual stresses locked in, and tectonics. The water pressure can affect the stress state, leading to variations. The average stress must be equal to the overburden weight but point stress can distort from this.

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$$3.3 \quad \sigma_{1,3} = \frac{1}{2}(\sigma_{yy} + \sigma_{xx}) \pm \sqrt{\frac{1}{4}(\sigma_{yy} - \sigma_{xx})^2 + \tau_{xy}^2}$$

$$= \frac{1}{2}(61.25 + 43.75) \pm \sqrt{\frac{1}{4}(61.25 - 43.75)^2 + 15.15^2}$$

(My mistake in dividing by 2)

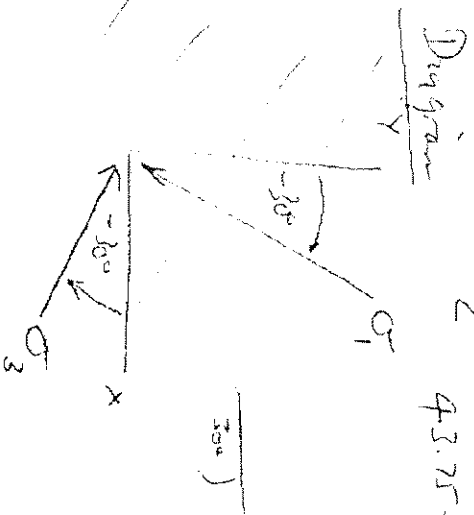
$$\Rightarrow \sigma_1 = \frac{12.94 \text{ MPa}}{1} \quad 69.999 = 70 \text{ MPa}$$

$$\Rightarrow \sigma_3 = \frac{32.94 \text{ MPa}}{1} \quad 35.004 = 35 \text{ MPa}$$

Check: $\sigma_1 + \sigma_3 = 105 \text{ MPa} = \sigma_{xx} + \sigma_{yy}$

$$\theta = \frac{1}{2} \arctan \left(\frac{2\tau_{xy}}{\sigma_{xx} - \sigma_{yy}} \right)$$

$$= \frac{1}{2} \frac{30.30}{43.75 - 61.25} = -30^\circ$$



Shear dip at 30° to right as seen from horizontal. Hence σ_1 is $\perp$ to strike and σ_3 is $\parallel$ to strike.

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3.4 No.

5 Reasons

1) Stress will change in vicinity of geological structures

2) Mining induced stresses (this handling will clearly serve mining, so it must be influenced by differing levels of mining induced stresses along its length).

This is not perfect - must be influenced by differing levels of mining induced stresses along its length.



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5) Topography (although the effect of it is typical SA condition is likely to be relatively small: hills are likely to be small in relative to type)

6) Residual stresses locked into the rock mass

over time

5) Rock mass structure will affect

to be more resistant.

4) Tectonic effect (although the trend

level (good rock = higher stress, poor rock = lower stress)

3) Non-homogeneity of stresses at various

2) Mining induced stresses (this handling

will clearly serve mining, so it must be influenced by differing levels of mining induced stresses along its length).

1) Stress will change in vicinity of geological structures

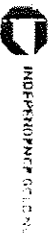
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Quest 4

4.1. Vertical Virgin Stress is coal before

$$\begin{aligned} \text{gold mining} &= 0.025h = 0.025 \times 180 \text{ MPa} \\ &= 4.5 \text{ MPa} = \sigma_h \quad (2) \end{aligned}$$

Vertical Virgin Stress is coal after
gold mining = $1.33 \times 0.025h$
 $= 1.33 \times 4.5$

$$\begin{aligned} \sigma_v &= 6 \text{ MPa} \\ \sigma_h &= 4.5 \text{ MPa} \quad (2) \end{aligned}$$

Stress condition in coal prior after
coal mining = $2 \times 1.33 \times 4.5 \text{ MPa}$

$$\begin{aligned} \sigma_v &= 12 \text{ MPa} \quad (2) \\ \sigma_h &= 4.5 \text{ MPa} \end{aligned}$$

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4.2 The radial and tangential
stress in the shaft barrel will
be essentially unchanged by the mining
(the numerical modelling shows this.)

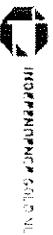
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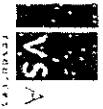


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The hanging steel screen is also the same in all directions and remains essentially so once all the mining has been completed.

$$\begin{aligned} \sigma_h (\text{base of Sandstone}) &= 0.025 h \text{ MPa} \\ &= 0.025 \times 177 \text{ MPa} \\ &= 4.43 \text{ MPa} \end{aligned}$$

$$\sigma_h (\text{base of lead}) = 4.50 \text{ MPa}$$

$$\begin{aligned} \sigma_h (\text{base of Sandstone}) &= 0.025 h \text{ MPa} \\ &= 5.00 \text{ MPa} \end{aligned}$$

Because the hanging steel screen is equal in all directions, σ has no meaning in the vertical direction because $\sigma_h - \sigma_v = 0$ ($k=1$).
Simplifying for $k=1$:
 $\Rightarrow \sigma_r = \sigma_t = \sigma \left(1 - \frac{R^2}{r^2}\right) = 0$ ($r=R$)

$$\sigma_{\theta\theta} = \sigma \left(1 + \frac{R^2}{r^2}\right) = 2\sigma \quad (r=R)$$

$$\sigma_{rr} = 0 \text{ for all } \theta$$

Strata	σ_r	$\sigma_{\theta\theta}$	σ_{rr}
Mudstone	0	8.86	0
Lead	0	9.00	0
Sandstone	0	10.00	0

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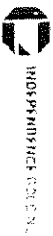
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4-3

② Mudstone - in siderite

$$(11+8) \quad \sigma_1 = \sigma_3 + \sqrt{11\sigma_1\sigma_3 + 5\sigma_1^2}$$

$$\sigma_c = 40 \text{ MPa}$$

$$\sigma_1 = 0 + \sqrt{0.01 \times 1600}$$

$$= 4 \text{ MPa}$$

This is much less than the 8.86 MPa that the mudstone is subjected to, so expect failure all around the shaft in rock:



Vertical fractures in
concentric rings

Shaft inspection shows that the shaft remains in good condition even at these stresses, and since they will change with cost mining, the rock mass condition will not change, excepting that the vertical stress will increase to 11.8 MPa vertical from 5.9 MPa vertical before mining. The stress change may induce fracture in the mudstone.

Comment: It appears that current

shaft condition suggest that the mudstone strength is underestimates.

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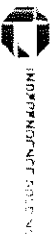
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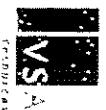


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$$O_1 = 0 + \sqrt{0.1 \times 400} = 6.32 MR$$

According to the average estimate, the coal should be in good condition in the shafts because after good mining. However, it may have to as O_1 increase to 12 MR from the current 6 MR, with concave mining of fracturing, developing because the shafts. Se fracture will be shown by O_1 , not O_2 , where because interbedded permeable stream.

(C) Sandstone (see base, vertical stream is highest here)

$$O_1 = 0 + \sqrt{0.1 \times 60^2} = 18.97 MR$$

At the base of the sandstone, it will be subject to 10 MR tensional stress, and 12.67 MR vertical stress after coal mining, no no fracture is expected in the sandstone.

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4.4 At distance above

(3)

Fracture in soft concave mining about shaft.

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