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An appraisal of the pillar support system at the St. Helena gold mine

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APPENDIX II

THE RESISTANCE ANALOGUE

Calculation of Closure:

This was achieved by equating the voltage obtained at the centre of a parallel slit modelled on the Analogue, with the closure in inches obtained analytically for the same slit. The equation is that derived by Muskelishvili and modified by Ortlepp, (Ref. 1).

$$- w = \frac{PL\, w_1}{4u}$$

L is the half span equal to 175 ft.

u is the modulus of rigidity equal to 5.3×10^6

w is the Closure

w_1 is the normalized closure at the mid span equal to 3.36, (Ref. 1).

P is the overburden stress of 2323 Stope, equals 5860 lbs./ins.^{2}

$\therefore$ Total Closure w = 3.88 ins.

This is equivalent to the voltage of 1.81 obtained on the Resistance Analogue, i.e., 3.88 ins. = 1.81v.

Calculation of Stress:

The residual voltage on the Analogue was equal to .0069 volts and this was taken to be equivalent to the overburden stress of 5860 lbs./ins.^{2}

MEASUREMENT OF STRESS

Photo-elastic Gauge for "In-Situ" Stress Measurements:

The photo-elastic gauge consists of a 1¾ ins. diameter bi-refringent plastic disc, with a quarter inch diameter central hole. The disc is backed by a reflective coating and a non-stick plastic coating, except for the periphery of the disc which is stuck to the rock surface. This disc size is used with an N.X. hole which is about 2 and 1/8th ins. outside diameter. The hole at the centre of the disc concentrates the strain and appears as a fringe pattern when viewed with polarized light. This pattern is then compared with a set of standard patterns, some of which are shown in FIG. 32 (a) and (b).

The Direction of the Principal Stresses is obtained from the orientation and the axes of symmetry of the pattern. These axes are clearly seen when the fringe order is greater than unity, (FIG. 32 (a) and (b)). When the strains are small rotation of the scale of the hand viewer causes two dark coloured patches to appear. These are the iso-tropic points, and the line joining these two points and the line at right-angles to it, indicate the directions of the principal strains.

The Magnitude of the major principal strain is obtained by comparison with the whole number standard fringe patterns. A fraction of a fringe is determined by holding the handle of the viewer in line with the minor principal strain and rotating the scale clockwise to shrink the fringe on to the collar of the hole. The scale reading is then added to the whole number reading.

The Magnitude of the Minor Principal Strain is obtained from a measurement of the distance y between the iso-tropic points, since the distance compared with the gauge diameter is a constant for any given stress field. The ratio of strains is then equal to :-

$$\frac{y - 0.68}{.63}$$ for a 2 ins. disc.

The Magnitude / .....

The Magnitude of the strains is obtained by multiplying the gauge sensitivity by the fringe order. The gauge sensitivity is 440 Micro inches per inch per fringe.

The sensitivity of the gauge is not affected by a change in temperature, but large errors can be caused due to the different coefficient of expansion of the gauge and the rock. Hence the gauge must be read with the core temperature within $3^{\circ}F$ of the temperature of the back of the hole.

The classical equations for the relationship between stress and strain at a point in an elastic medium are :-

$$6_x = \frac{E \quad (e_x + ue_y)}{I - u^2} \quad \text{and Actual stress} = \frac{6_x}{1.5}$$

The relationship between actual and measured stress is due to stress concentration at the end of the borehole.

CALCULATION OF "IN-SITU" STRESS MEASUREMENTS BY OVERCORING

2436 Stope:

Depth of Stope	-	5,200 ft. - Place of measurement - Bottom North Internal Pillar.
Depth of overcoring	-	7 ft. 6 ins. Hole rising 20° drilled at rightangles to face of pillar.
Gauge - Thickness		0.12 ins. Diameter - 1.75 ins.
Sensitivity		440×10^6 ins. per inch.
Diamond Coring Bit		N.X.

Results:

Initial Gauge Reading	-	0.00 Final Gauge Reading - 0.50 fringes.
Temperature inside hole	-	$86^{\circ}F$.
Major Principal Stress Direction	-	28° clockwise from vertical.
Isotropic Point Spacing	-	0.49 ins.

Calculations: / .....

Calculations:

Major Principal Strain = Fringe order x gauge sensitivity

= 0.5 x 440 = 220 micro ins./ins.

Minor principal strain factor = $\frac{.49 \times 2}{\frac{1.75}{.63}} - .68 = .2$

Minor principal strain = .2 x 220 = 44 micro ins./ins.

Major principal stress = $\left(\frac{E}{1-u^2}\right) \frac{(e_x + u\ e_y)}{1.55}$

$\therefore$ Major principal stress = $\left(\frac{11.5 \times 10^6}{1 - .142^2}\right) \frac{(220 + .142 \times 44)}{10^6 \times 1.55}$

= <u>1710 lbs./ins.^{2}</u>

Minor principal stress = 7.56 (44 + .142 x 220)

= <u>566 lbs./ins.^{2}</u>

THE CALCULATIONS OF MATPACK SPACING FOR NO. 8 SHAFT

A. Depth below surface = 6,500 ft.

Maximum stoping span = 800 ft.

Ratio = $\frac{6,500}{800}$ = 8.13

Height of Tensile Zone, (FIG. 12) = .13 x 800 = 104 ft.

Matpack spacing = x

The weight of rock on each matpack = $\frac{\text{Cos. } 40^\circ \; 104 \times 170 \times X^2}{2,000}$ tons

The elastic closure at the mid-point of an 800 ft. span at a depth of 6,500 ft. from Muskelishvili's equation, = 11·8 ins.

Assume 1 ins. of closure before matpack is installed.

Matpack compression = $\frac{10·8 \text{ ins.}}{36 \text{ ins.}}$ = 30%

The loading on a timber concrete composite matpack pre-stressed to 50 tons = 500 tons for 30 per cent compression, (FIG. 11).

Matpack Spacing

$$\therefore \quad 500 = \frac{104 \times 170 \times X^2 \times .77}{2,000}$$

$$\therefore \quad X^2 = \frac{2,000 \times 500}{104 \times 170 \times .77} = \frac{100}{1.04 \times 1.7 \times .77} = 8.6 \text{ ft.}$$

B. At 50 ft. from face - closure = 3 ins.

Assuming 1 ins. closure lost - compression = 2 ins.

Matpack loading for $\frac{2}{36}$ = 6 per cent compression

= 200 tons for composite matpack.

The height of the separated hangingwall 50 ft. back from the face is taken to be 50 ft.

Weight of rock at x ft. spacing = $\frac{50 \times 170 \times X^2 \times \text{Cos. } 40^\circ}{2,000}$

$$\therefore \quad x = 8 \text{ ft.}$$

VOUSSOIR ARCHES - SUBTENDED BY MATPACKS

1. $L = 1.5 (\tan 45 - \frac{\phi}{2}) \sqrt{Idz}$

I = Loading Index z = depth = 1,000 ft.

d = 5 ft. = depth of Voussoir

$$\therefore \quad I = \frac{\text{Matpack Load}}{\text{Overburden Stress}}$$

For a closure of 4 ins. the matpack generates 200 tons load.

Matpack size is 2 ft. x 2 ft.

$$\therefore \quad I = \frac{200 \times 2{,}000}{2 \times 2 \times 144 \times 1{,}200} = .58$$

If ϕ = friction angle = 50° then

$$L = 1.5 \tan 20^\circ \sqrt{0.58 \times 1{,}000 \times 5}$$

$$\therefore \quad L = 1.5 \times .364 \times 10 \sqrt{29}$$

$$\therefore \quad L = 30 \text{ ft.}$$

2. If matpack generates 10 tons load :-

Load = 10 tons

I = .029

$$\therefore \quad L = 1.5 \times .364 \times 10 \sqrt{.029 \times 5 \times 10}$$

$$= \underline{6.5 \text{ ft.}}$$

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