Minerals Council South Africa

EXAMINATION PAPER

SUBJECT: CHAMBER OF MINES OF SOUTH AFRICA - CERTIFICATE IN ROCK MECHANICS PAPER 3.3 : MASSIVE UNDERGROUND MINING (HARD AND SOFT ROCK) **SUBJECT CODE: COMRME 3.3** **EXAMINATION DATE: 10 OCTOBER 2019** **TIME**: 14:30 – 17:30	**EXAMINER:** DR PJ LE ROUX **MODERATOR:** J WALLS **TOTAL MARKS:** [100] **PASS MARK:** (60%)

NUMBER OF PAGES: 11

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

SPECIAL REQUIREMENTS:

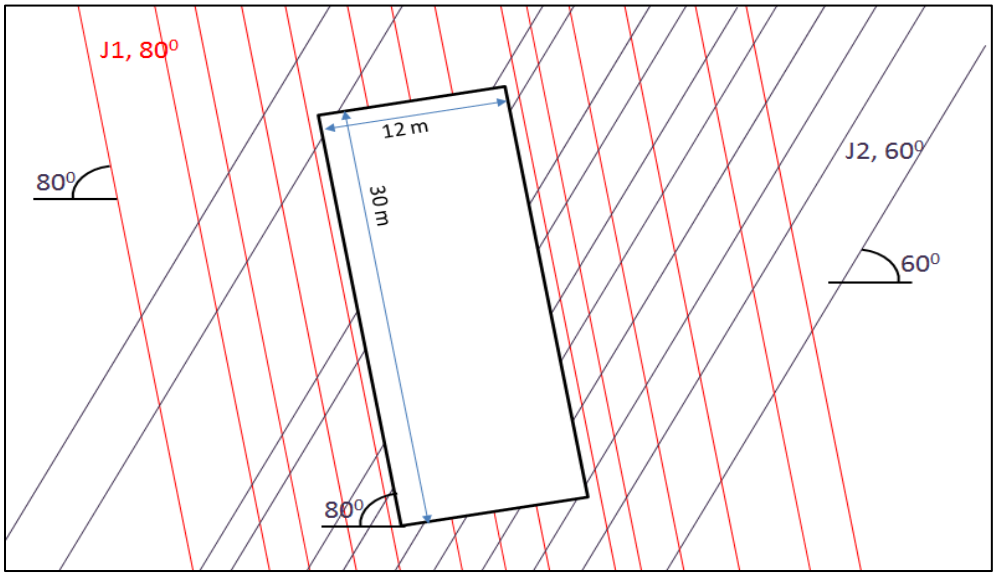
1. Answer **all questions**. Answer the questions **legibly** in English.
2. Write your **ID Number** on the outside cover of each book used and on any graph paper or other loose sheets handed in.

   NB: Your name **must not** appear on any answer book or loose sheets.
3. Show all calculations **and check calculations on which the answers are based.**
4. Hand-held electronic calculators may be used for this exam.
5. **No** programmable calculators may be used.
6. Write **legibly** in ink on the **right hand page** only – **left hand pages will not be marked**.
7. Illustrate your answers by means of sketches or diagrams wherever possible.
8. **Final answers** must be given to an accuracy which is 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) are recorded as marks will be deducted from answers if the incorrect unit is used. (even if the calculated value is correct).
9. In answering the questions, full advantage should be taken of your practical experience as well as data given.
10. Please note that you are not allowed to contact your examiner or moderator regarding this examination.
11. Cell phones are **NOT** allowed in the examination room.

QUESTION 1

Longhole open stoping is used to mine a 12 m wide orebody, dipping at 80^0 to the west with a known strike length of 600 m. Mining will commence at a depth of 150 m below surface. The individual stopes will be 40 m long and 30 m high. Elastic modelling has been carried out to determine the stress distribution around the stope (results are included with the tables of information). A geotechnical investigation has revealed that the rock mass quality is quite good (Q' = 14) and the intact rock strength is 120 MPa. Two major joint sets, striking roughly parallel to the strike of the orebody, influence the rock mass surrounding the excavation, illustrated below.



1.1 Calculate the modified stability number (N') for the stope crown and each of the side-walls. Present your answer in a table and list the stress values, strength to stress ratio, critical joint set, relevant angles, failure mechanism and the values of the A, B and C parameters. **[12]**

1.2 Calculate the hydraulic radius for the crown and walls. Determine whether the stope crown and walls are stable, transitional or caving and estimate the ELOS. Plot these values on the modified stability and ELOS graphs and hand in the annotated graphs with your script. **[7]**

1.3 Calculate the percentage dilution and indicate what action is required, if any. Present your results and comments in a table. **[6]**

[25]

QUESTION 2

In open stoping backfill forms an integral part of the mining process.

2.1 With the aid of a sketch discuss the application of backfill and what you would consider as important with reference to placement in an open stope, curing time as well as why stand-up height would be important. **[5]**

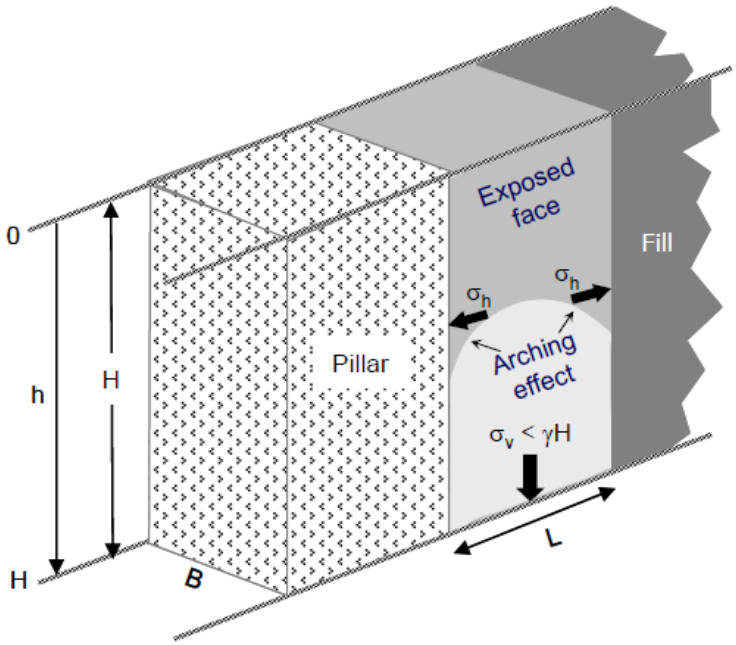
2.2 Briefly describe the key points to consider when designing a bulkhead. **[4]**

2.3 Using the following equations calculate the required Uniaxial Compressive Strength (UCS) in kPa for a given stand-up height of the backfill as shown in the Table below:

Table 1. Required stand up heights for open stopes

Height	5m	10m	15m	20m	25m	30m	35m	40m	45m

The open stope width is 20m and the backfill internal friction angle and cohesive strength is 25° and 20 kPa respectively. The backfill bulk unit weight is 22 kN/m^3 and a minimum safety factor of 1.5 is required.



Make use of the given table (Table 1) and graph in the question paper to show your results. Plot the UCS results on the graph and discuss the obtained results.

$$UCS_{design} = \frac{1.25B}{2K\tan\phi}\left(\gamma - \frac{2c}{B}\right)\times\left[1-\exp\left(-\frac{2HK\tan\phi}{B}\right)\right]FS$$

Where

$$K = \frac{1+\sin^2\phi}{\cos^2\phi + 4\tan^2\phi} = \frac{1}{1+2\tan^2\phi}$$

B = stope width

K = Backfill pressure coefficient

c = Backfill cohesive strength (kPa)

$\emptyset$ = Backfill internal friction angle in degree

γ = backfill bulk unit weight (kN/m^3)

H = Backfill height (m)

FS = Factor of safety **[16]**

[25]

QUESTION 3

With reference to the research project for the evaluation of the performance of shotcrete with and without fibre reinforcement under dynamic and quasi-static loading conditions (SIM 040204):

3.1 Name the steps in the process to determine the inputs required for the design of shotcrete.

[8]

3.2 What inputs are required for elastic modelling. **[4]**

3.3 The rock mass characteristics should be determined for the geotechnical domain or ground control district in which the tunnel is situated. Name the important aspects to consider. **[8]**

3.4 It is important to consider not only the size of excavations, but the function and importance of an excavation. Name the important aspects to consider.

[5]

[25]

QUESTION 4

In massive underground operations, broken ore first undergoes gravity flow before being extracted. The processes governing rock fragmentation and drawpoint control are therefore essential to the successful beneficiation of the ore.

4.1 Discuss the conditions that govern the process of fragmentation in a caving operation, beginning with natural fragmentation through to the fragmentation processes that takes place in the draw column. **[10]**

4.2 With the aid of an annotated sketch, explain the following gravity flow concepts for broken material being discharged from a bin or bunker:

4.1.1. Ellipsoid of motion

4.1.2. Limit ellipsoid

4.1.3. Draw cone **[5]**

4.3 Discuss how particle size distribution affects the shape of the ellipsoid of motion.

[2]

4.4 Ore is usually extracted from multiple drawpoints. With the aid of a sketch, show the different drilling patterns in sub-level caving that result in independent and interactive draw respectively. Explain the benefit of interactive vs independent draw zones. **[5]**

4.5 Briefly discuss the rock properties which govern fragmentation by blasting. Give an example of explosive type suited to strong, massive rock.

[3]

[25]

TOTAL MARKS: [100]

REFERENCE SHEET

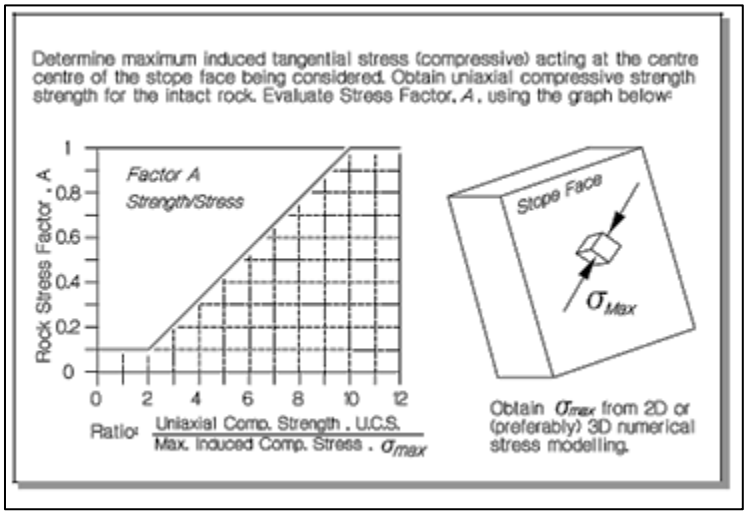
Cave angle and failure zone (Laubscher 1990)

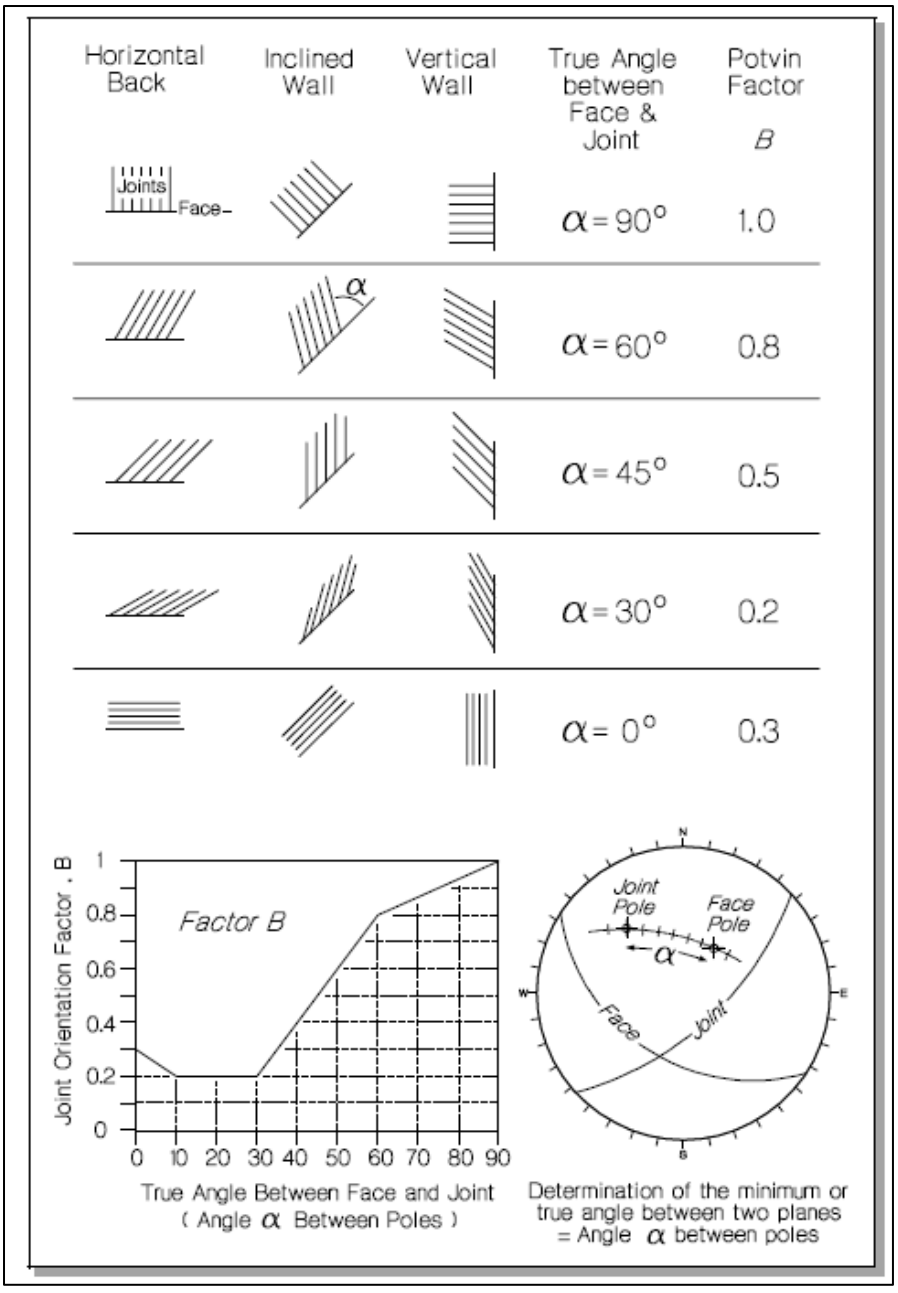
	Condition	Depth (m)	Adjusted *MRMR* 100-81	80-61	60-41	40-21	20-0
Cave angle	No lateral restraint	100	80	70	60	50	40
		500	70	60	50	40	30
	Lateral restraint from caved material	100	90	80	70	60	50
		500	80	70	60	50	40
Extent of failure zone	Surface	100	10 m	20 m	30 m	50 m	75 m
		500	10 m	20 m	30 m	50 m	75 m
	Underground	100	10 m	20 m	30 m	50 m	100 m
		500	20 m	30 m	50 m	100 m	200 m

TABLE XIII
MINING METHOD RELATED TO MRMR

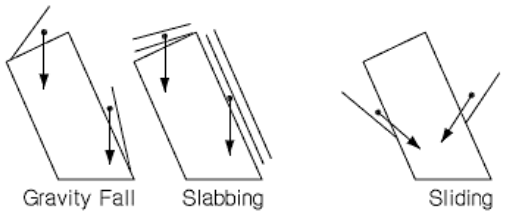
Class rating	5 0–20	4 21–40	3 41–60	2 61–80	1 80–100
Block Caving					
Undercut SI, m	1–8	8–18	18–32	32–50	+50
Cavability	Very good	Good	Fair	Poor	Very poor
Fragmentation, m	0,01–0,3	0,1–2,0	0,4–5	1,5–9	3–20
2nd lay-on blast/drill, g/t	0–50 0–20	50–150 20–60	150–400 60–150	400–700 150–250	+700 +250
Hangups as % of tonnage	0	15	30	45	>60
Dia. of draw zone, m	6–7	8–9	10–11,5	12–13,5	15
Drawpoint span, m					
Grizzly	5–7	7–10	9–12		
Slusher	5–7	7–10	9–12		
LHD, m	9	9–13	11–15	13–18	
Brow support	Steel and concrete Reinf. concrete		Concrete	Blast protection	
Drift support	Lining, rock reinf., repair techniques		Lining, reinf.	Rock reinf.	
Width of point, m	1,5–2,4	2,4–3,5	2,4–4	4	
Direction of advance	Towards low stress		Towards high stress		
Comments	Fine fragmentation, poor ground, heavy support, repairs	Medium fragmentation, good ground, fair support	Medium coarse fragmentation, good drill hangups	Coarse fragmentation, large LHDs, drill hangups	
Sub-level Caving					
Loss of holes	Excessive	Fair	Negligible	Nil	Nil
Brow wear	Excessive	Fair	Low	Nil	Nil
Support	Heavy	Medium	Low	Localized	Nil
Dilution	Very high	High	Medium	Low	Very low
Cave SI, m	1–8	8–18	18–32	32–50	+50
Comments	Not practicable	Applicable	Suitable	Suitable	Suitable, large HW cave area
Sub-level Open Stoping					
Minimum span, m	1–5	5–20	20–30	30–80	100
Stable area, i.e. SI, m	N/A	1–8	8–16	16–35	+35

N/A = Not available

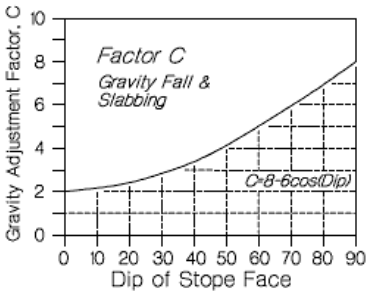


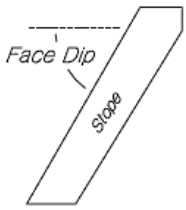

Horizontal Back
Inclined Wall
Vertical Wall
True Angle between Face & Joint
Potvin Factor
B
Joints
Face
α = 90°
1.0
α
α = 60°
0.8
α = 45°
0.5
α = 30°
0.2
α = 0°
0.3
Joint Orientation Factor , B
Factor B
1
0.8
0.6
0.4
0.2
0
0 10 20 30 40 50 60 70 80 90
True Angle Between Face and Joint
(Angle α Between Poles)
N
E
S
W
Joint Pole
Face Pole
α
Face
Joint
Determination of the minimum or true angle between two planes = Angle α between poles

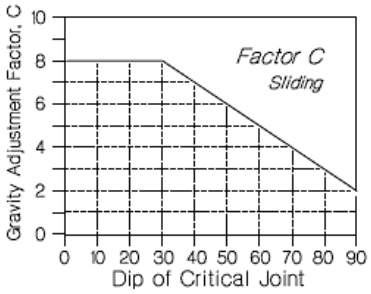
1) Determine the most likely mode of structural failure in case study using the figures below:

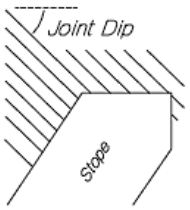


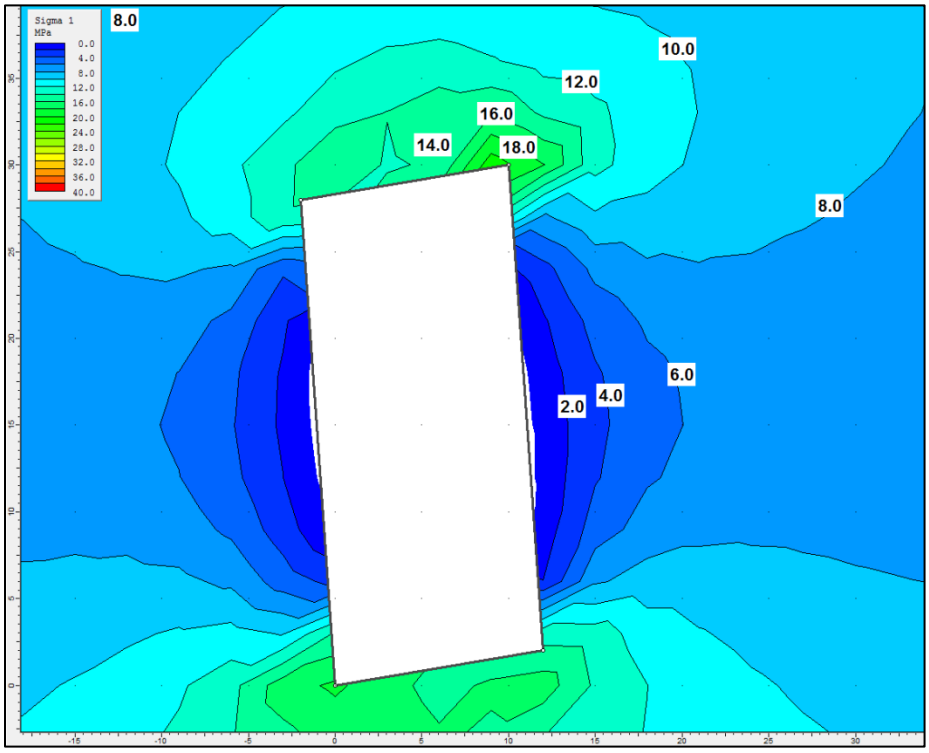
2) Next determine the gravity adjustment factor, C, based on the failure mode using the appropriate chart below.











SHEET TO BE HANDED IN WITH ANSWER PAPER

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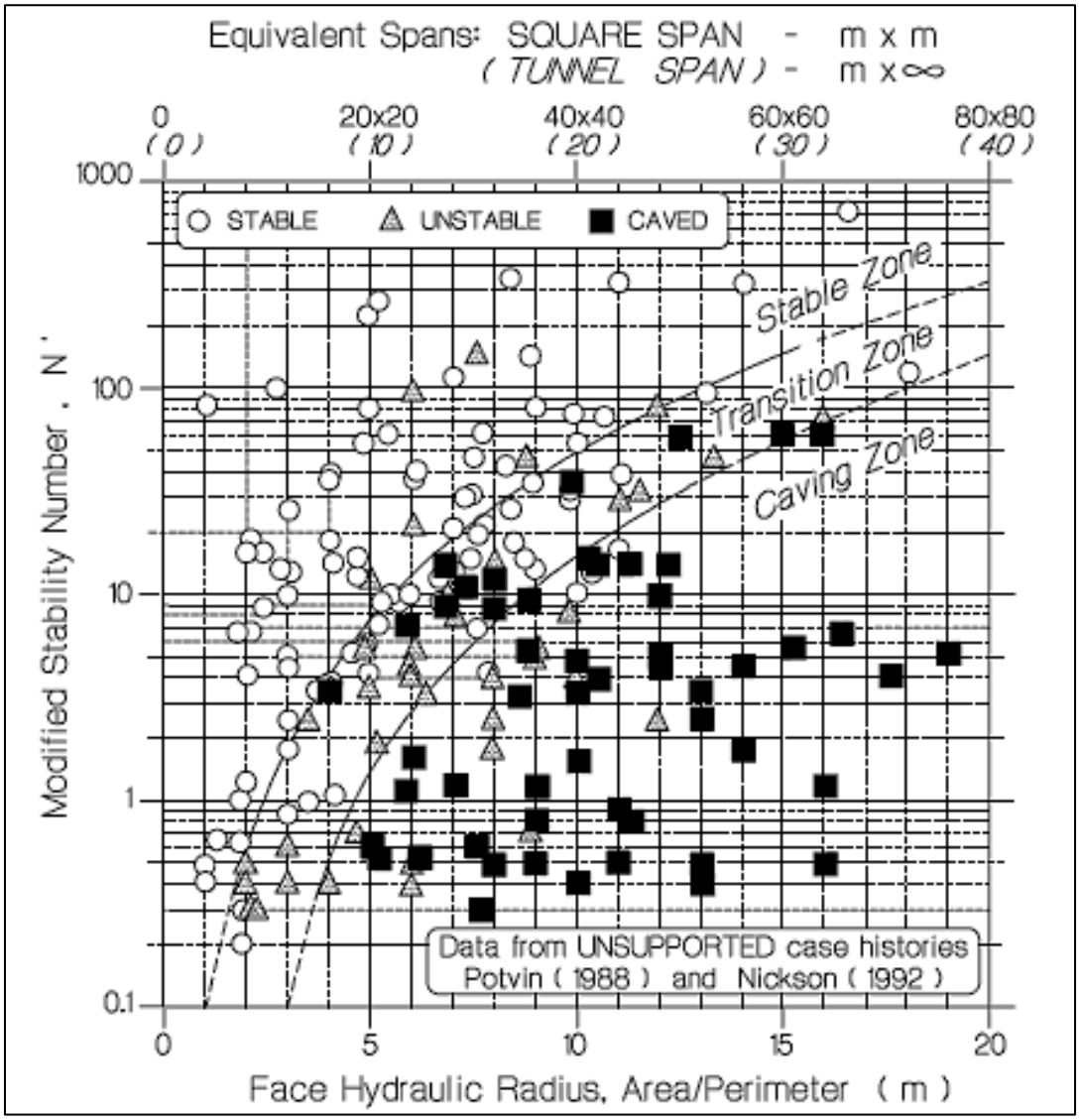

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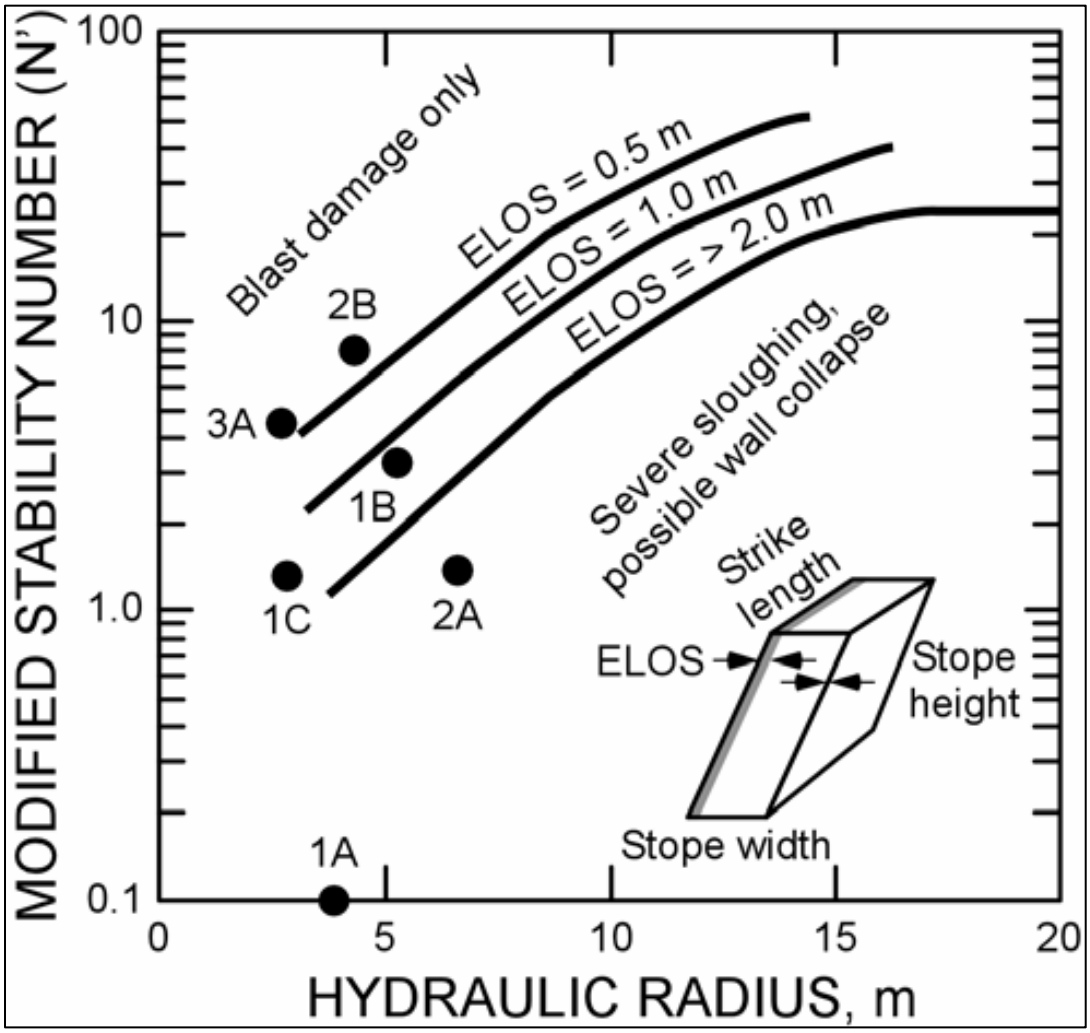

Equivalent Linear Overbreak / Slough