Question 1:

A vertically dipping orebody with a circular shape (radius 100 m) is to be mined to a depth of 200 m in the rockmass depicted in Photo 1.

Using the Laubscher method of calculating a Rock Mass Rating, calculate (figure 1) the value for the outcrop in Photo 1. (4 marks)

Estimate using the supplied information in Figure 2 the angles to which the bench, stack and overall angles can be mined. Assume good quality blasting can be achieved. Justify any other assumptions you make. (10 marks)

Make comments on the limitations of using such a rock mass classification methodology to evaluate slopes planned to this height. (6 marks)

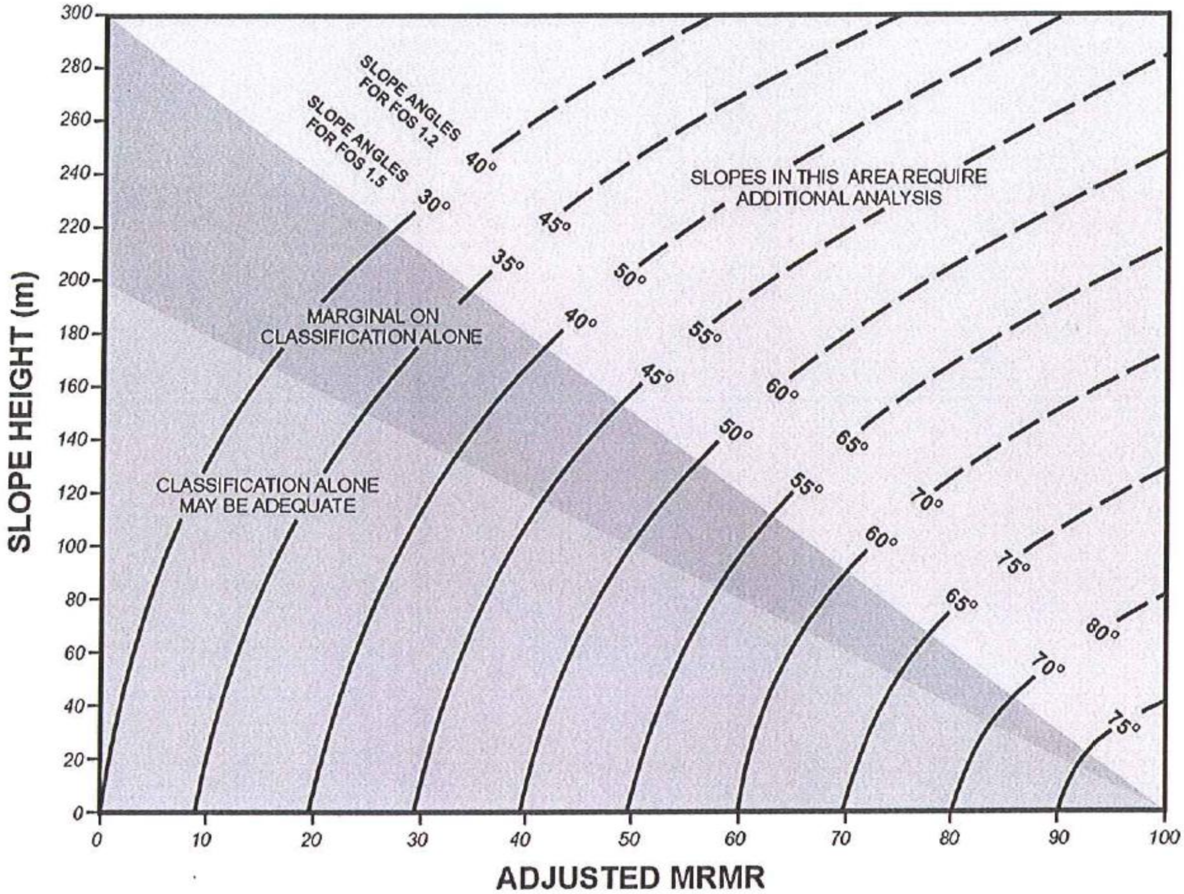
Total (20 marks)

Figure 1. Laubscher Classification System

IRS		Fracture Frequency				Joint Condition (max rating =40) % Adjsutment			
Value	Rating		Rating					Dry	Moist
		Av /Metre	1 set	2 set	3 set		Multi - Wavy Directional	100	100
> 185	20	0.1	40	40	40	Large Scale	Uni _Directional	95	90
165-185	18	0.15	40	40	40		Curved	85	80
145- 164	16	0.2	40	40	38		Slight Undulation	80	75
125-144	14	0.25	40	38	36		Straight	75	70
105-124	12	0.3	38	36	34	Small Scale 20cm *20cm	Rough stepped irregular	95	90
85-104	10	0.5	36	34	31		Smooth stepped	90	85
65-84	8	0.8	34	31	28		Slikensidded stepped	85	80
45-64	6	1	31	28	26		Rough Undulating	80	75
35-44	5	1.5	29	26	24		Smooth undulating	75	70
25-34	4	2	26	24	21		Slikensided undulating	70	65
12-24	3	3	24	21	18		Rough Planar	65	60
5-11	2	5	21	18	15		Smooth Planar	60	55
1-4	1	7	18	15	12		Polished	55	50
		10	15	12	10	Joint Filling	Clean	100	90
		15	12	10	7		Non - Softening	85	80
		20	10	7	5		Soft Sheared	60	55
		30	7	5	2		Gouge	45	40
		40	5	2	0				

Additional Adjustments		
	negative	positive
Weathering	30	100
Induced Stresses	60	120
Blasting	80	100

Figure 2 – Haines / Terbrugge Design chart.



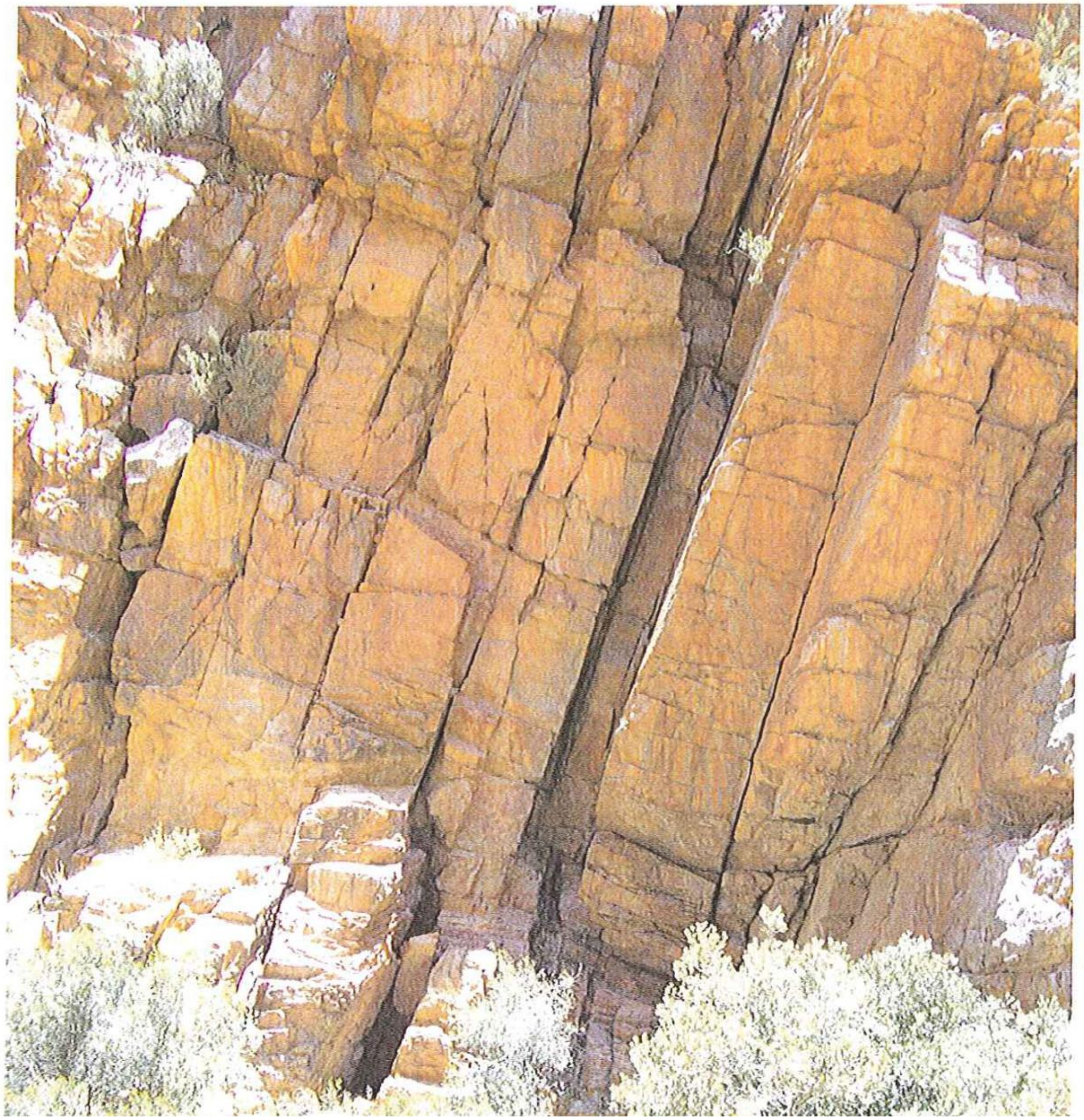


Photo 1

Scale 1 cm = 50 cm

Photograph Direction – Looking directly North

Rock Type – Sedimenatary with a UCS of 120 MPa

Joints are generally clean with no infill.

Water Table at 120 m.

Question 1 : Model answer.

Part A:

The elements of MRMR that are included in carrying out a determination are:

Strength,

Number of joint sets and their spacings

Nature of joints large scale, small scale and infill nature

From the photograph the average spacing of the shallow easterly dipping joints +/- 23 deg is 1.25 per meter , and the average spacing of the steeply easterly dipping joints (+/- 68 deg) = 0.625 per metre. The combined fracture frequency is approximately 1 per meter. The large scale expression of the joints is slightly undulating with a small scale expression of rough planar and a clean nature.

Thus using the tables:

120 MPa Sandstone = IRS Rating of 12 , No allowance for mis-interpretation

A fracture frequency rating of 1 for 2 joints gives a rating of 28: Ave increment 3

The nature of the joints dry gives a rating of 40 * 0.8 * 0.65 * 1 = 21: Ave increment .05 *.05 * 40 = 0.1

The nature of the joints moist i.e. below 120 m level is 40 * 0.75 * 0.6 * 0.9 = 16

Thus the total rating should be Dry +/- 61 & Wet +/- 56. Given the nature of the measurements values

+/- 4 either side of these will be acceptable.

Part B

Water table is at 120 m, unless a statement was made about dewatering two sets of angles are required.

The adjustments that need to be applied to take the RMR to an MRMR are as follows:

Weathering = 0.9 (fresh rock and clean joints)

Induced stresses 1.1 – shape of pit sharp radius circular

Blasting = good quality =0.9

Total adjustment = 0.9.

Thus the MRMR range accepted for further calculations dry is 51 to 59 & wet 47 to 54.

Using the supplied chart the following angles can be derived:

Configuration	Dry	Wet
Bench	Not from charts – to suit discontinuities	Not from charts – to suit discontinuities
IRSA	64 deg to 69 deg FOS 1.2 – 60 m high	61 deg to 66 deg FOS 1.2 60 m high
Overall	41 deg to 44 deg FOS 1.5	39 to 43 deg FOS 1.5

Comments made:

Haines and Terbrugge is a rock mass failure criterion and is not suited for design of benches where stability will be dictated by local kinematics. Thus bench angles should not be stated, however depending on the orientation of the wall angles between +/- 70 degrees and 90 degrees should be used

IRSA angles because of lower height can be designed with FOS of 1.2 and for global angles a FOS of 1.5 should be selected , permanent in nature

Part C

No acknowledgement of distinct structures made, thus no kinematic analysis possible.

No adjustments for angle of joints with respect to pit orientation

Water pressure not handled

Limited range for full slope heights – extra analysis required for these MRMR over 160 m

Deterministic – no probability calculations possible.

Interpolation difficult between boundaries

Insensitive at low fracture frequencies.

Question 2:

Support in the form of 2000 kN tensioned cable anchors in a single row are to be installed in a bench to combat plane failure. The anchors are to be installed in upwards holes inclined at 10 degrees. The bench has a height of 15 m and is vertical. The potential failure plane is formed by a major joint set and dips at 45 degrees out of the bench. The planes are dry and no tension crack is present. The angle of friction is 43 degrees on the joint set and it has zero cohesion. Derive the equation for the factor of safety and calculate the required number of bolts to ensure a factor of safety of 1.2. The specific weight of the rock is 30 kN /m^3

(20 Marks)

Question 2 Model Answer:

Derive Equation:

Specific weight is 30 KN /m3 i.e. g already accounted for.

Assume unit thickness

At equilibrium

Disturbing Forces = Resisting Forces. And or FOS = Resisting Forces / Disturbing Forces

As there is no tension crack, cohesion and Uplift pressures due to water this can be written as :

DF = Weight of Block * sin (angle joint plane) – Cable tension *Cos (angle between bolt and joint plane)

RF = (Weight of Block * cos (angle Joint plane) + cable tension * Cos (angle between bolt and joint)) * Tan (friction angle on plane)

FOS = (W cos(alpha)+T sin(beta))*tan phi) / (W sin (alpha) – Tcos(Beta))

FOS =1.2

W = 10(g) *0.5 * 15 * 15 * 1 *30 kN = 33750 KN

Beta = 45 -10 = 35 degrees

Alpha = 45 degree

Phi = 43 degree

1.2 *(3375.0 sin(45) – T cos (35) = (3375.0 * cos (45) + T sin(35)) * tan 43

1.2 * (2386.5 – 0.82T) = (2386.5 + 0.57 T) *0.93

2863.8 – 0.98T = 2219.5 +0. 53T

2863.8 -2219.5 = 0.53T +0.98T

T= 426.7 kN

Cable capacity = 2000 KN

Therefore 1 cable is required every 4.7 m of slope

Question 3

What are the most important factors of influence on the stability of rock slopes? Identify which factors you, as the slope designer, have control over, and those over which you have no control. What would you do to improve the stability of a slope that was showing signs of instability.

(10 marks)

Discuss the concept of a limit equilibrium analysis approach for a circular type failure and the method of slices used in the evaluation of the stability of a slope (No equations are required, but you must use sketches to assist with your answer)

(10 marks)

Total (20 marks)

Model Answer Question 3

What are the most important factors of influence on the stability of rock slopes? Identify which factors you, as the slope designer, have control over, and those over which you have no control. What would you do to improve the stability of a slope that was showing signs of instability.

Geological factors:

Lithology, Major Structures, Minor Structure – joints etc, Weathering Profile , Presence of Water / pressure

Rock Mass Factors:

Intact Rock Strengths, Joint / Structure Strengths, Overall Rock Mass Strength

Mining Parameters

Blasting Performance, Slope angles, Stack Heights, Bench catch capacity, Strike direction of slopes with respect to structural features

Design Factors

Choice of acceptable limits of performance, Analysis method, data availability

Control,

Obviously there is no control over natural elements, however, all other aspects can be controlled by the geotechnical engineer.

Improve Stability,

This question is not about monitoring, it is about techniques to improve stability, these could involve:

Dewatering, Improve blasting – reduce damage, Buffer blocks, change pit design below unstable area,

Leave a standoff.

Depending on size and type of failure look at active support measures, bolting cabling etc.

Improve passive safety measures, fencing / meshing for rockfall.

Question 4:

List five monitoring systems used on Open pit mines that are used to measure movement occurring on or in open pit slopes. (5 marks)

For the systems listed above discuss two advantages and one disadvantage of each system. (15 marks)

Total (20 Marks)

Model Answer –Question 4

<u>Visual Monitoring</u>

Cheap and quick to set up,

No equipment to set up / supplies available.

Not viable at night , low accuracy, usually not possible over the complete slope.

<u>Extensometers</u>

Can be cheap and quick to set up,

Low to high accuracy – fit for purpose , used across active cracks. Can be remote read.

Depending on type – subject to environmental conditions, relatively narrow zone of influence, point type measurement.

<u>Inclinometers</u>

Accurate & very sensitive, can be remote read, good for soft slopes and deep movements.

Linear, point type measurement at one place on slope – idea required of failure mode.

Borehole required

Expensive –not value for money in mining environment.

<u>Prism – Geomos based systems</u>

Accurate – true x.y.z measurements, can be continuous monitoring, easily expanded

Environmental factors- atmospherics, point measurements, theft of prisms, base station stability,

<u>Laser Scanning</u>

Aerial coverage of slopes, rapid scan of large volumes, scanner can be moved, reflector-less system, continuous monitoring

Set up of system /calibration, atmospherics, data volume / processing, lower accuracy

<u>Radar</u>

Aerial coverage of slopes, rapid scan of large volumes, scanner can be moved, reflector-less system, continuous monitoring, sensitive

Not true vectors, geo-referencing poor ,expensive, Question 5

Discuss the value of good geotechnical data and a good database in the context of open pit rock slope design and management

Question 5 model Answer

This question revolves around the value of data,

Topics that need to be mentioned are:

Data availability and quantity versus reliability statements made for PoF calculations.

Strength test data required for rock mass descriptions to determine overall angles

Carry out statistical analysis

Structural data required for kinematic analysis to design benches

Movement data required to calibrate designs

Movement data required to monitor slope movements

Movement data provides warning

Database is required to store data so relational queries can be established.

Database required to maintain data in case of staff movements

Database require to integrate different data sources