KURSUS PENSIJILAN CERUN TAHAP 2

GEOLOGY PART 2:

ROCK MASS DESCRIPTION & CHARACTERISATION, ROCK SLOPE STABILITY ANALYSIS & STABILIZATION AND PROTECTION METHODS





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16 MARCH 2020 (MONDAY) Pusat Kecemerlangan Kejuruteraan dan Teknologi JKR (CREaTE)

OUTLINE

- 1. Rock Mass Description & Characterization
- 2. Rock Mass Rating (RMR)
- 3. Rock slope stability analysis
- 4. Rock Slope Stabilization & Protection





DESCRIPTION OF ROCK MASS OUTCROP FLOW CHART

General Description of the outcrop (e.g. rock, soils, areas with water, dominant discontinuities)

Division into zones based on lithological and structural criteria Detailed description of each zone -Intact rock -Discontinuities - Rock mass

Global Characterization and Rock Mass Geomechanical classification



GEOLOGY AND ROCK PROFORMA

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OA.	300	TAMAN		ROAD NAME			ROUTE NO		SECTION NO.	C	SECTION NO		
_	LEFT RIGHT	DISTANCE FR	3M	AGE		(year built if any)	SLOPE ID						
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2	SECTION NO:]	2.2 DISTANCE		(m from km post)	2.3	SLOPE FACE / FI	EATURE ASPECT	Dip / Dip direction		Date for store of
2.	COORDINATE	NOR	тн		EAST]					
	P 3 GEOLO	OCY AND STRU	CTURAL										
3.	ROCK TYPE			1					WEATHER	NG GRADE			1
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			Becking (Bd)	Folded (Fd)	Chavage (Cl)	Overhang (Oh)	Tension crack (Tc)	Revelling (wavely junited & hage	ke matterial) (Filv).	Finans (F)	9	1
3/	ADVERSE G	EQLOGICAL FEA	TURES EVIDENCE OF	DISTRESS			3.5 EVIDENCE	OF PAST FAI	LURE		·		_
	1 No evis	dence of surficial	loosening				1	No recorded	or observed evide	ince of past inst	ability		
	2 Locals	ed sufficial loose	ming, or small over	hanging blocks	an initial or formals		2	Observed av fragments ac	dence of past inst cumulated at foe	tability (rock bloc of slope)	ks and		
	3 cracks	exist along crest	of slope.	veries, sayights	g parts of tension		3	(volume < 50	m ²)	matabality - Mino	n nan harte en an		-
	4 Surficia	al loosening and	small overhanging I	blocks in severa	i areas of slope		4	(50m3 ≤ Volume ≤ 500m3) Documented evidence of past instability - Major failure					-
	5 Large o	overhanging bloc	ks with potential rel	ease surfaces v	ISIERS	Please use these		(volume a SO	(* m)				Di 1s Iber
3	pacing size inters	Persistence (m)		Ternitution		Ra	uptoweil			Seque			telline .
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	damps with the	H 10-20	Dupe			ĸ	Sickersided	4	Danşi			On	Carnetted
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N .	200-600	VH >20	P	Second Photo			Water Manhattan		((round (Linema)				
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W	200-600 2000-6000 -6000 P-6 DISCO		P S U RMATION (30 read	Several Plane ImgularWaay	e længth)	8 8	* note : please ind	6 licate Chainag	ing (horizontal d	istance from Si	ope ID Marker)	-UN	
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GEOLOGY PROFORMA

DIVISION INTO ZONES AND GENERAL DESCRIPTION OF EACH ZONE

PHOTO







DETAILED INVESTIGATION BY GEOLOGICAL MAPPING AND DISCONTINUITY SURVEYS



OUTPUTS FROM GEOLOGICAL MAPPING & DISCONTINUITY SURVEY



- The strength of a large piece of rock is usually weaker than the strength of the small pieces of rock tested in the lab
- This is due to the presence of <u>large scale</u> <u>discontinuities</u>







• Foliation



Discontinuities



Bedding Plane & Joints

-





Major fault



Shear Zone



DESCRIPTION OF DISCONTINUITIES

GEOMETRY	SHEAR STRENGTH
1.Orientation	4.Roughness
	5. Aperture
2.Spacing	6. Filling
3.Persistence	7.Seepage (water)

1. ORIENTATION

- Using compass
- Dip and dip direction of the plane
- Plot using Kinematic
 stereonet analyses for rock
 slope stability 'ROCKPACK III'
- Enable the number of joint sets
- Mean orientation



DIP AND DIP DIRECTION



2.SPACING

(how far apart the discontinuities are)

• The perpendicular distance between adjacent discontinuities



Description	Spacing
Extremely narrow spacing	< 2 cm
Very close spacing	2-6 cm
Narrow spacing	6-20 cm
Moderate spacing	20-60 cm
Wide spacing	60-200 cm
Very wide spacing	200-600 cm
Extremely large spacing	> 600 cm

ISRM classification according to the spacing

3. PERSISTENCE (how continuous are they)

- A measure of the areal extent of a discontinuity
 - Inception to termination in solid rock
 or against another discontinuity
- Major joints;
 - the plane may extend beyond the limits of the exposure
 - Measure the maximum trace length



Description	Persistence
Very low persistence	<1 m
Low persistence	1-3 m
Average persistence	3-10 m
High persistence	10-20 m
Very high persistence	>20 m

ISRM classification according to the persistence

4. ROUGHNESS (rough to smooth)

- Discontinuity surface
 - Stepped
 - Undulating
 - Planar
- Based on two scales:-
 - Small scale: several centimeters
 - Large scale: several meters
- The roughness gives indications for the <u>evaluation of the</u> <u>shear strength</u> of not filled discontinuities



5.APERTURE

(is the discontinuity open or closed)

- The mean perpendicular distance between adjacent walls of a discontinuity.
- Space between walls that is filled with air or water

Aperture	Description	Discontinuity			
<0.1 mm	Very narrow				
0.1-0.25 mm	Narrow	Closed			
0.25-2.5 mm	Partly opened				
0.5-2.5 mm	Opened	Semi-open			
2.5-10 mm	Moderately large				
>10 mm	Large				
1-10 cm	Very large				
10-100 cm	Extremely large	Open			
> 1 m	Cavernous				

ISRM classification according to aperture



6.FILLING

(is the discontinuity empty or filled and with what?)

- The infilling between discontinuity
- surfaces
- • The infilling may be:
 - Soil introduced into the opening
 - Minerals such as calcite
 - Faults clay gouge (deep hole)
 - Breccia
- Must be identified and described
- The strength of the infill must be assessed
- visually and manually.

7.SEEPAGE (water)

- Water flow
- Free moisture
- Describe and rate of flow
 estimated (liter/hr)



ROCK MASS RATING (RMR)

- <u>SIX parameters</u> are required:
 - 1. Uniaxial Compressive Strength (J_{A1})
 - 2. Rock Quality Design, $RQD(J_{A2})$
 - 3. Discontinuity spacing(J_{A3})
 - 4. Conditions of the discontinuities(J_{A4})
 - 5. Groundwater (flow and general condition) (J_{A5})
 - 6. Rating adjustment for discontinuity orientations(J_B)
- Based on ratings (total of 6 ratings)
- Total ratings (0-100) will give rock mass classes (I to V).
- Higher rating better rock
 - RMR = JA1 + JA2 + JA3 + JA4 + JA5 + JB

ROCK SLOPE STABILITY ANALYSIS

FLOW CHART OF ROCK SLOPE STABILITY ANALYSIS



A.KINEMATIC STEREONET ANALYSIS

STEREONET BASED KINEMATIC ANALYSIS



😣 Rockpack III - Beta

File Edit View Tools Window Help

sta Cat	Discontinuitu	Traugree Trend	Distance	Chucharo	Din Direction	Die	Pook Tupo	Hardnoon	Mator	Longth	Continuitu	Poughness	Copping	Eilling Tupp	Filling Hardpoor	Zono Width	Zono 9
	Discontinuity	Traverse Trenu	Distance	Surcture	Dip Direction	Dip	поск туре	Haruness	w aler	Lengun	Continuity	noughness	spacing	ruing type	Filling naturess	ZONE WILLIN	ZUNE 3
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1	204	345	068	04	156	47	া	11	6	1000	1	2	00	001	00	00	
1	205	345	091	04	156	47	া	11	6	1000	1	2	00	001	00	00	
1	206	345	185	04	156	47	া	11	6	1000	1	2	00	001	00	00	
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CASE STUDY BUKIT ANGGERIK

- 1. Site Sketch
- 2. Geomorphological Map
- 3. Stereonet Analysis

Site Sketch

ROCK AND SOIL BOUNDARY







LAYOUT FOR STEREONET ANALYSIS



EXPOSED ROCK OUTCROP AT THE FAILURE AREA



Potential Rock Failure Seen on Site





100.00




Picture Of Outcrop 3





STEREONET PLOT FOR OUTROP 4 (LENGTH: 50M)

INTERVAL: 20 – 50M



B.SAFETY FACTOR ANALYSIS

OVERVIEW of SAFETY FACTOR CALCULATION PROGRAMS (PLANE, RAPWEDGE, CMPWEDGE and TOPPLE)

Starting the safety factor programs





Plane - Plane	Failure Analysis
RapWedge ⋅ Rapid	Wedge Failure Analysis
mpWedge - Compreher	isive Wedge Failure Analys
Topple - Toppli	ng Failure Analysis

Plane Failure Analysis Input Screen

	🗌 Standard Input Data	
	(H) Height	0 ft
	(SF) Inclination of Slope Face	0 *
	(SS) Inclination of Upper Slope	0 *
55	(SP) Inclination of Failure Plane	0 *
SF -	(CO) Cohesive Strength of Failure Surface	0 lb(f)
SP-	(PH) Friction Angle of Failure Surface	0 *
H AB	GR) Density of Rock	0 lb(f)/ft ³
	(GW) Density of Water	0 lb(f)/ft 3
	⊥ Bolt Data	
	(AB) Starting Rock Bolt Angle 0 * (T	(1) Starting Bolt Tension 0 lb(f)
	(AR) Ending Rock Bolt Angle 0 * (T	(2) Ending Bolt Tension 0 lb(f)
	(AA) Bolt Angle Increment 0 * (T	(3) Bolt Tension Increment 0 lb(f)
itus: READY		
CALCULATE FACTOR OF SAFE	TY Tension Crack Data	
Intional Input Data	No Tension Crack	
	C Tension Crack Location Known	
	C Tension Crack Location Unknown	
[12] Amount of Discontinuity 0 decil Saturated	(B) Horizontal Distance of Tension Crack from Crest	n ft
(VSUR) Vertical Surcharge 0 lb(f)	(DZ) Bolsting Height of Mater in Tansien Crock	
(HSUR) Horizontal Surcharge n Ib(f)		U uconnaixe

Rapid Wedge Failure Analysis Input Screen

C3. Rapid Wedge Failure Analysis					×
File View Units Reset Help					
	Crientation Data for Planes (1-4)			
~	Plane 1: (D1) Dip Value	0 *	(E1) Dip Direction		0 *
3	Plane 2: (D2) Dip Value	0 *	(E2) Dip Direction		0 *
\sim	Plane 3: (D3) Dip Value	0 *	(E3) Dip Direction		0 *
2	Plane 4: (D4) Dip Value	0 *	(E4) Dip Direction		0 *
$\downarrow $ $\downarrow $ \downarrow \downarrow	Cohesion and Friction Data				
H H	Plane 1: (C1) Cohesion	0 lb(f)/ft ²	(P1) Friction Angle		0 *
	Plane 2: (C2) Cohesion	0 lb(f)/ft ²	(P2) Friction Angle		0 *
\langle	C Cracks Completely Filled (Free	Draining)			
	(GW) Density of Wat	er		n lb(f)/ft3	
CALCULATE FACTOR OF SAFETY	(HW) Overall Vertical	Height of Wedge		0 ft	
Preliminary Data	(INTTRND) Trend of	line of intersection		0	
(GR) Density of Rock	(INTPLNG) Plunae o	f line of intersection		0	
(H) Height of Crest Above 0 ft	C Other		I	0	25
Slope Undercutting		100/10			
Does the slope face overhand the top of the slope?	(U1) Pressure on Pla	ne 1		0 lb(f)/ft ²	
C Yes No	(U2) Pressure on Pla	ne 2		0 lb(f)/ft ²	

Comprehensive Wedge Failure Analysis Input Screen

3 Comprehensive Wedge Failure Analysis		
File View Units Reset Help		
0429.	Wedge Data	Cohesion and Friction Data
	🔲 Include Tension Crack	Plane 1: (C1) Cohesion 0 lb(f)/ft ²
	(TL) Distance of Tension 0 ft Crack from Crest along Plane 1 Trace	(P1) Friction 0 * Angle Plane 2: (C2) Cohesion 0 lb(f)/ft ²
	Include Cable or Bolt Tension	(P2) Friction 0 * Angle
4 1	(T) Cable or Bolt 0 lb(f)	Water Pressure
	(DT) Plunge of Tensile 0 *	Dry Slope
н	Force (ET) Trend of Tensile	C Cracks Completely Filled (Free Draining)
	Include External Load	(GW) Density of Water 0 lb(f)/ft 3
	(E) External Load 0 lb(f)	(U1) Pressure on Plane 1 0 lb(f)/ft 2
	(DE) Plunge of External 0 *	(U2) Pressure on Plane 2 lb(f)/ft ²
CALCULATE FACTOR OF SAFETY	(EE) Trend of External 0 *	(U5) Pressure on Plane 5 0 lb(f)/ft ²
Preliminary Data	Orientation Data	
(GR) Density of Rock	Plane 1: (D1) Dip Value 0 *	(E1) Dip Direction 0 *
(H1) Slope Height Referred to 0 ft	Plane 2: (D2) Dip Value 0 *	(E2) Dip Direction 0 *
110161	Plane 3: (D3) Dip Value 0 *	(E3) Dip Direction 0 *
Slope Undercut Data	Plane 4: (D4) Dip Value 0 *	(E4) Dip Direction 0 *
Does the slope face overhang the toe of the slope? C Yes	Plane 5: (D5) Dip Value 0 *	(E5) Dip Direction

Toppling Failure Analysis Input Screen

 Calculate Sum of Moments Calculate the tension required to bolt in Calculate the thickness required to pre- 	n place event toppling
Height of the Block	ft
Width of the Block	0 ft
Angle of the Block	•
Density of Water	0 lb(f)/ft 3
Density of Rock	0 lb(f)/ft 3
Tension of the Rock Bolt	0 lb(f)
Height of Water in Tension Crack	0 ft
Height of Rock Bolt in Block	0 ft
Results	

EXAMPLE OF WEDGE FAILURE ANALYSIS





Example of Plane Failure Analysis

4.0 ROCK SLOPE STABILIZATION AND PROTECTION

ROCK SLOPE STABILIZATION & PROTECTION MEASURES



-



VARIOUS METHODS OF STABILISING ROCK SLOPES

- Sprayed Concrete/Shotcrete
- Dowels
- Rock Bolts
- Rock Anchors / Ground Anchors
- Inclined Drainholes / Horizontal Drains
- Dentition



- 1. Reinforced concrete dowel to prevent loosening of slab at crest.
- 2. Tensioned rock anchors to secure sliding failure along crest.
- 3. Tieback wall to prevent sliding failure on fault zone.
- 4. Shotcrete to prevent ravelling of zone of fractured rock.
- 5. Drain hole to reduce water pressure within slope.
- 6. Concrete butress to support rock above cavity.

REINFORCEMENT METHODS OF STABILISING ROCK SLOPES

(After Keith et al., 1996)



REMOVAL METHODS OF ROCK SLOPES

- Reprofiling/resloping of unstable weathered material in upper part of slope
- 2. Removal of rock overhang by trim blasting.
- 3. Removal of trees with roots growing in cracks
- 4. Hand scaling of loose blocks in shattered rock
- 5. Clean ditch or Rock Trap Ditch

(After Keith et al., 1996)

ROCK SLOPE PROTECTION METHODS



Possible measures to restrain and to reduce damage due to rockfalls (after Spang, 1987)

Wire Mesh Drappe



ROCK SLOPE STABILISATION (REINFORCEMENT) - Some common practices in Malaysia -

Wire Mesh Drapery

• <u>Concept:</u>

- The design intent of a mesh is to cover a slope and control the rockfall trajectory by restricting the rock's movement;
- Mesh weight and strength provides an important stabilizing factor. High tensile strength wire mesh
- Hanging loose on the slope face
- The rockfall drape shall be capable of being pulled on/out at the bottom to clear rocks retained upslope from the draped slope and for rock removal.
- The top of the wire mesh drapery shall be secured to a top support cable.





Vegetation



 Proposed rock buttresses to arrest a large scale wedge

ROCK BUTRESS





Rock Buttress – founded on micropiles socketed in sound bedrock, and tied back to the slope with rock anchors.



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IMPLEMENTATION



ROCKBOLTS

- Rockbolts generally consist of plain steel rods with a mechanical anchor at one end and a face plate and nut at the other.
- They are always tensioned after installation.
- the space between the bolt and the rock can be filled with cement or resin grout.







DOWELS

- Dowels or anchor bars generally consist of deformed steel bars which are grouted into the rock.
- No tensioning!
- In order to be effective, dowels have to be installed before significant movement in the rock mass has taken place.



Grouted dowel using a deformed bar inserted into a grout-filled hole.

ROCK SLOPE STABILISATION (ROCK REMOVAL) - Some common practices in Malaysia -

Mechanized Rock Removal/Scaling

Rock Scaling



Rock Trimming



Rock Scaling



ROCK FALL PROTECTION MEASURES

A) BERMS/BENCHING



Lebuhraya Ipoh-Changkat Jering, PLUS.

CATCH BERM



CATCH BERM



A 20m wide catch berm on Bukit Lanjan Rock Slope



..and it was installed with Geobrugg Rock Fall Fence (after Euroculture Sdn. Bhd., 2005)

Photo 2 : Completed Geobrugg Rock Fall Fence at 20m Wide Berm

B) ROCKSHED



C) ROCK TRAP DITCH & FILL – RAWANG PERDANA



D) ROCK FALL FENCE/BARRIER



Geobrugg ring net shown restraining a boulder. These nets can be designed with energy absorbing capacities of up to 2500 kNm which is equivalent to a 6 tone boulder moving at 20 m per second.

D) ROCK FALL FENCE/BARRIER



Geobrugg energy absorbing ring. When subjected to impact loading the ring deforms plastically and absorbs the energy of the boulder.

D) ROCK FALL FENCE

Application of Geobrugg Ro Barrier – the Malaysian Expe



An example rockfall fence / barrier installed at:

- Bukit Lanjan Rock Slope, NKVE Highway.
- Ipoh-Chkt Jering Highway
D) ROCK FALL BARRIER



Tom Price Iron Ore Mine, West Australia (after Geobrugg, 2006)



EXAMPLE: ROCK FALL FENCE @ GUNUNG PASS



E) WIRE MESH DRAPPE



Top edge with hinged supports and suspension of the TECCO® drape





TECCO® drape in June 2005 after installation; Ramsau Germany (after Geobrugg AG)