NATIONAL UNIVERSITY OF ENGINEERING

GEOLOGICAL ENGINEERING PROGRAM

DESIGN OF SLOPE STABILIZATION SYSTEM FOR A TRAWLING HILL

COURSE: GEOLOGY APPLIED TO CONSTRUCTIONS

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2020

1. INTRODUCTION

The stability analysis of slopes allows to know the conditions in which the rocky massif is found, is a very important activity and basis for more detailed studies or planned constructions. The activities indicated in class and the application of the method in the trawling hills have been carried out along 22.5 m (geomechanical station located at 12 ° 01'10 "S / 77 ° 02'46"O).

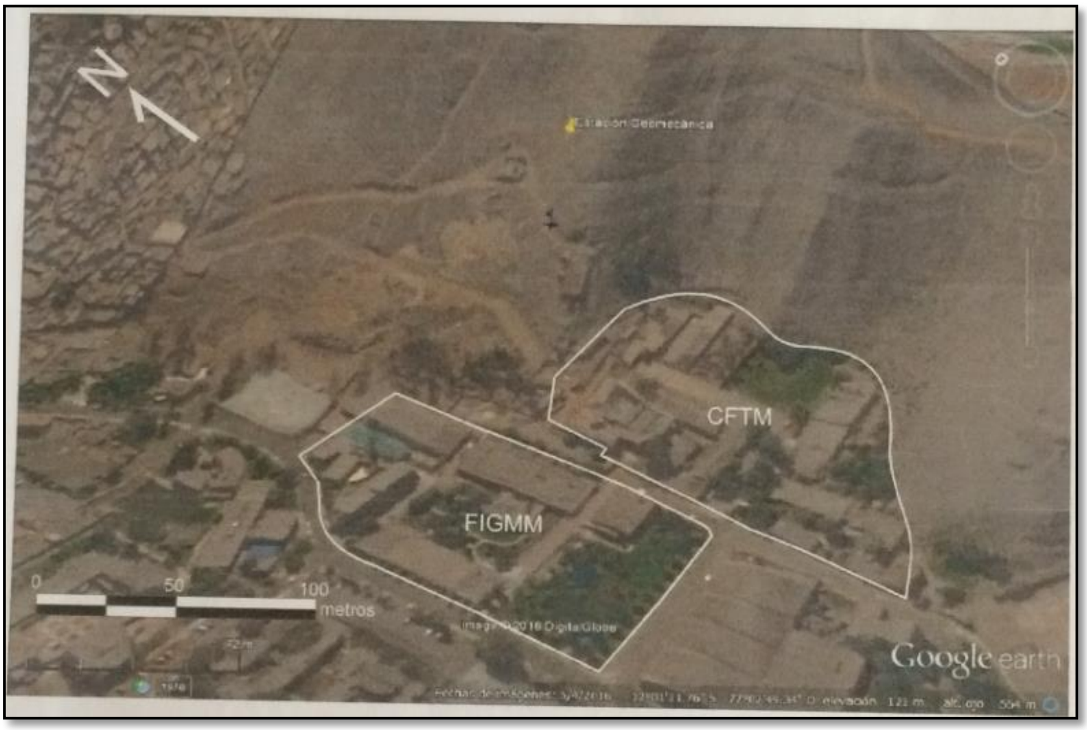

Figure 1: Location of the geomechanical station

2. JUSTIFICACIÓN

One of the most important applications of geological knowledge is in the area of constructions, constructions that require a previous study of the state of the rocky massif on which one wants to make a work. This is how we take the study or analysis of slope stability, an indispensable tool during our training.

3. OBJECTIVE

The objective of the work is to establish a geomechanical station and follow the methodology explained in class, to later analyze the information taken from the field and formulate conclusions regarding the stability of the slope.


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Estación Geomec

4. SYNTHESIS

For the fulfillment of the proposed objectives, after some theoretical sessions on geomechanical stations and stability analysis of slopes; the field work consisted mainly of data collection (100 data) required in formats for the characterization of the rocky massif.

Figure 2: Field data collection procedure.

With the information obtained from the field, the scanning was done, first in MS Excel and then the data transfer to the program Dips (signature RockScience). Already in the Dips, we start to generate graphs of the traces and poles of the discontinuity planes, highlighting the presence of families (clouds of accumulation of more information), with the information on the slope in the zone of data collection we can verify if Some type of instability (generation of planar, circular, wedge or overturn breaks). For the analysis will be necessary to use established tables or methods of calculation of information with which we do not count, such as the angle of friction, density of the mass, among others. Finally we will use some other RockScience programs to determine the safety factor.

5. TECHNIQUES USED

- For the field work, manual measurement of the required properties in the format provided in class (starting point distance, rock type, structure, geometry, aperture, fill, presence of water, alteration, resistance, observations) . Additionally we take the properties of the slope (75 °/310°).

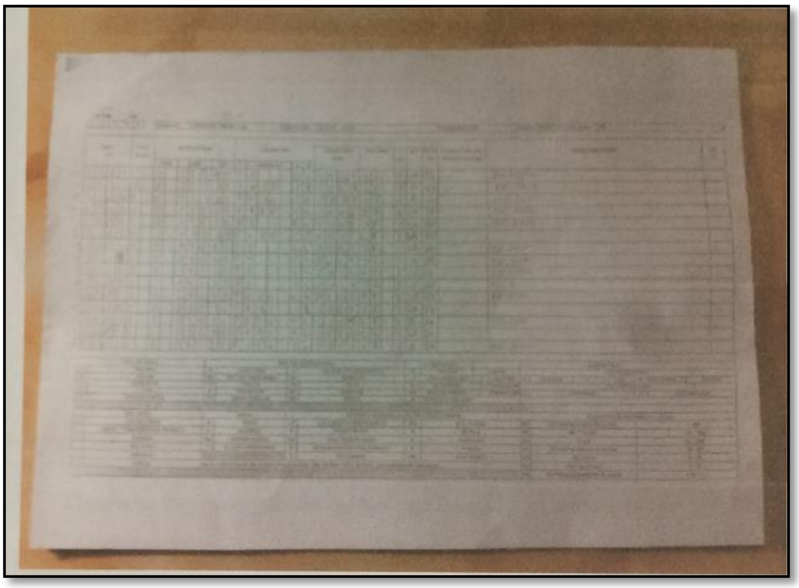

Figure 4: Format filled with field information

- After the fieldwork, the information was passed to the Excel program. We then pass the data to the Dips program.

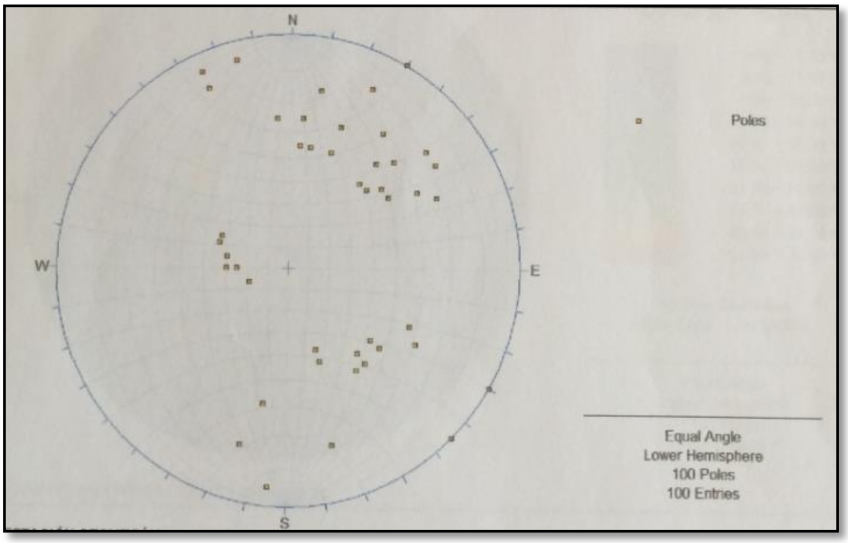

Figure 5: Representation of poles of discontinuities.

- Plotting points will show (in the window of contours or clouds) the zones with the highest concentration of poles of generated planes.

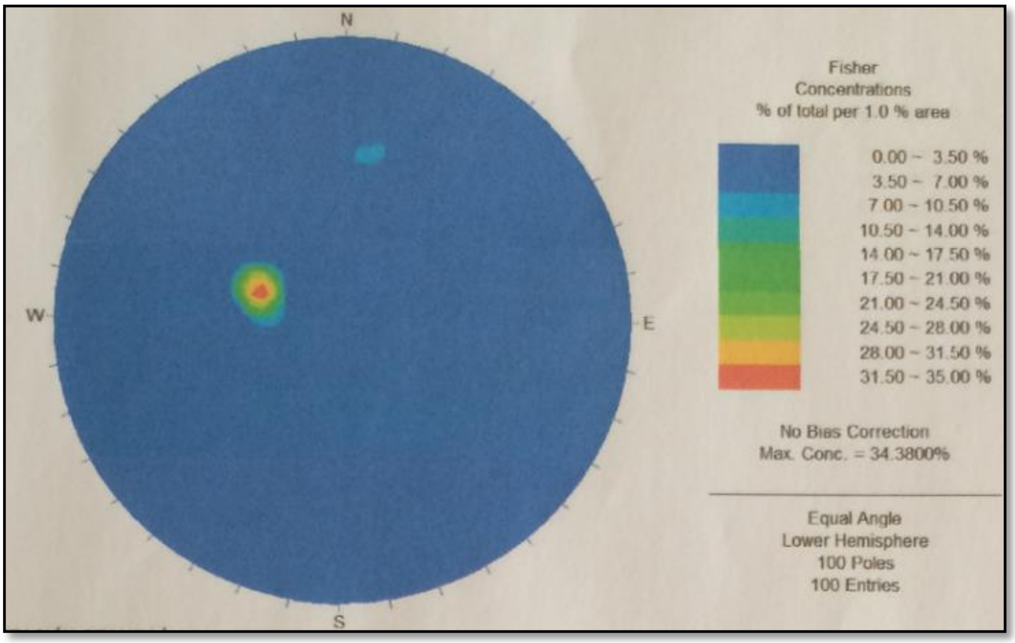

Figure 6: Representation of clouds of concentration of poles.

- In each zone of greater concentration we draw the poles of the planes with which we are going to carry out the work of stability analysis. Three planes have been detected according to the poles.

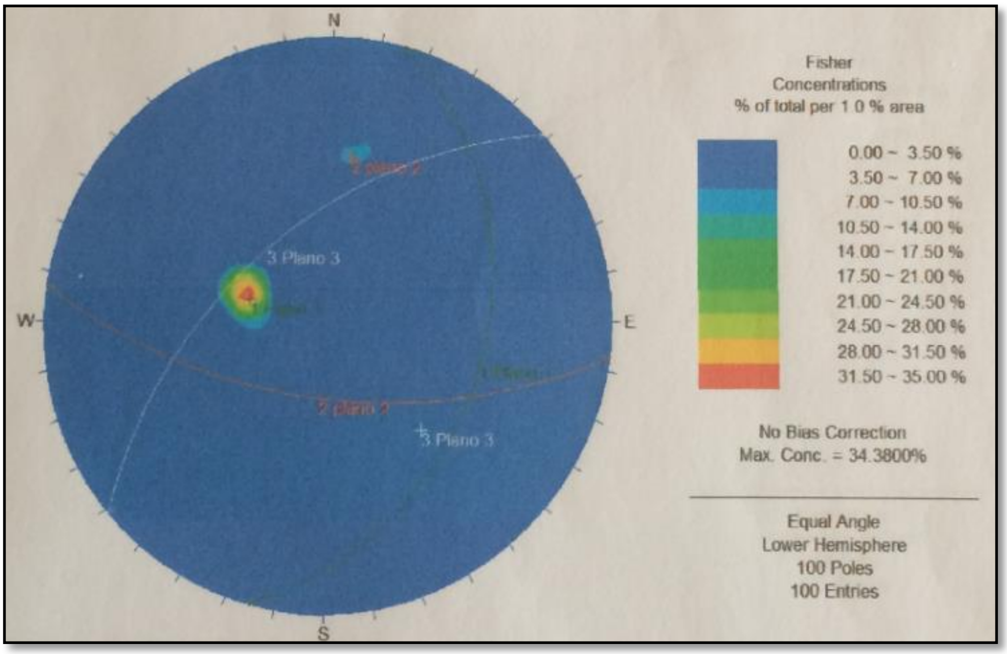

Figure 7: Representation of the planes from the clouds of poles.

- The determined planes are best visualized in a large plane plot window. Where we can visualize their properties of Dip and Dip direction.

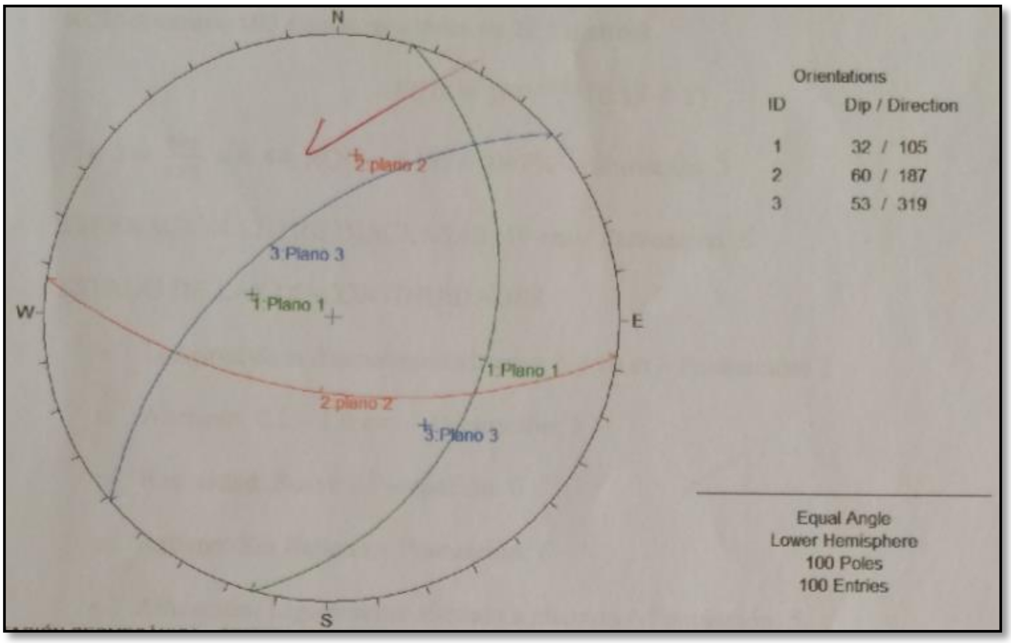

Figure 8: Representation of the planes of discontinuities and their properties.

For the stability analysis, we include the dip / dip direction of the measured slope in the field (75 ° / 310 ° - plane 4)

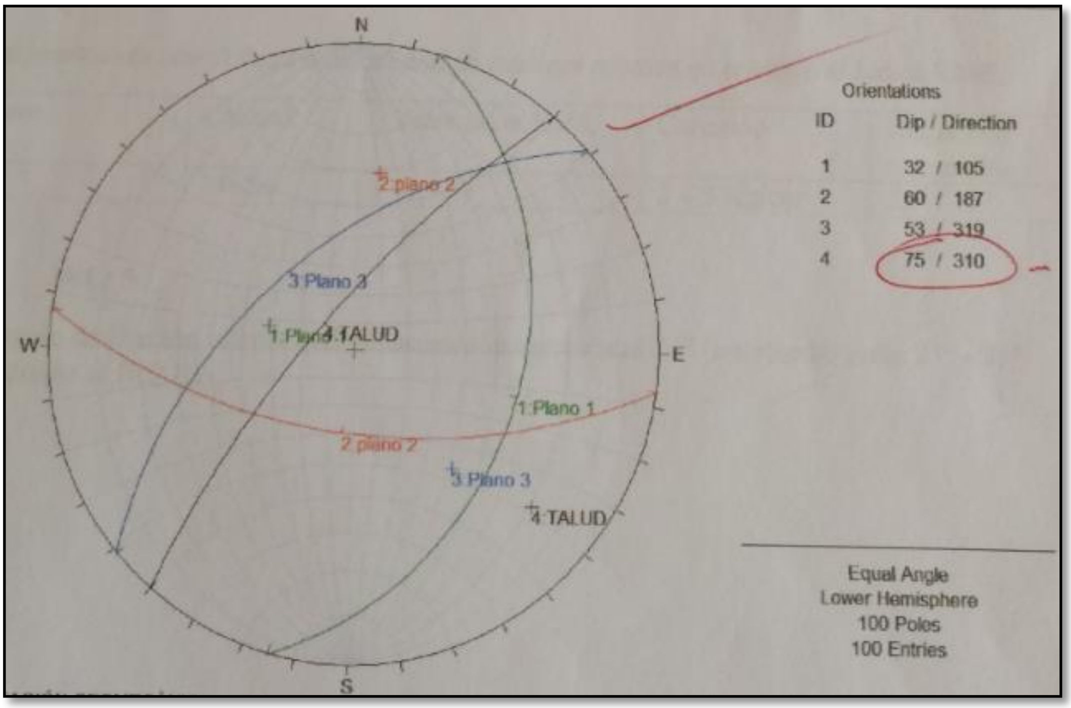

Figure 9: Representation of planes of discontinuity and slope.

RMR CALCULATION

- Resistance of the rock matrix (Mpa) 70 Mpa - Score: 7
- RQD (we have 100 discontinuities in 22.5 meters)

$$RQD = 100^{-0.1\gamma}(0.1\lambda + 1)$$

$$\lambda = \frac{100}{22.5} = 4.44, RQD = 0.187 = 18.7\% - score: 3$$

- Separation between diaclases: 10 cm - score: 8
- State of discontinuities
  - Length of discontinuity: between 3 and 10 m - Punctuation: 2
  - Opening: 0.1 - 1.0 mm - Score: 3
  - Roughness: Mild - Score: 0
  - Filling: Unfilled - Score: 6
  - Alteration: Slightly altered - Score: 5
- Groundwater
  - Dry general condition - Score: 15

RMR: 49

We compare it with the quality chart of rocky masses in relation to the RMR index.

Class	Quality	RMR Rating	Cohesion	Angle of friction
III	Average	41-60	2-3 kg/cm2	25° - 35°

JRC: 5

The angle of internal friction we will then take will be 36 ° (intermediate between 25 ° - 35 ° added to the JRC)

ANALYSIS OF SLOPE STABILITY

Planar break:

Conditions:

- The sliding plane is parallel with the slope wall ($\pm$20 °).
- The plane of rupture should appear on the face of the slope.
- Requires side take-off surfaces to allow sliding material to exit.
- The dip of the slope must be greater than the dip of the plane of rupture, and this in turn is greater than the angle of internal friction ($\beta > \alpha > \varphi$).

Wedge break:

Conditions:

- The two planes should appear on the surface of the slope and meet the condition of $\psi > \alpha > \varphi$, where ψ is the slope angle measured in the direction of the slope surface.
- The intersection line should be buried in the direction of slope dip.
- It occurs in massifs that have at least two families of discontinuities whose planes are cut.

Break by overturn:

Conditions:

- $\beta > \varphi + (90 - \alpha)$
- The break plane must have an approximately parallel course ($\pm$20 °) relative to the slope plane.

Data to be taken for calculations:

Density of quartzite:	2650 kg/m3
Resistance to compression:	900 – 4700 kg/cm2
Seismic coefficient:	0.2
Internal friction angle:	36°

With the established parameters and the determined data, we proceeded to analyze each plane, resulting in:

1. Planar breakage is generated due to plane 3 (53 ° / 319 °)

- $310° + 20° > 319° > 310° - 20°$
- $75° > 53° > 36°$

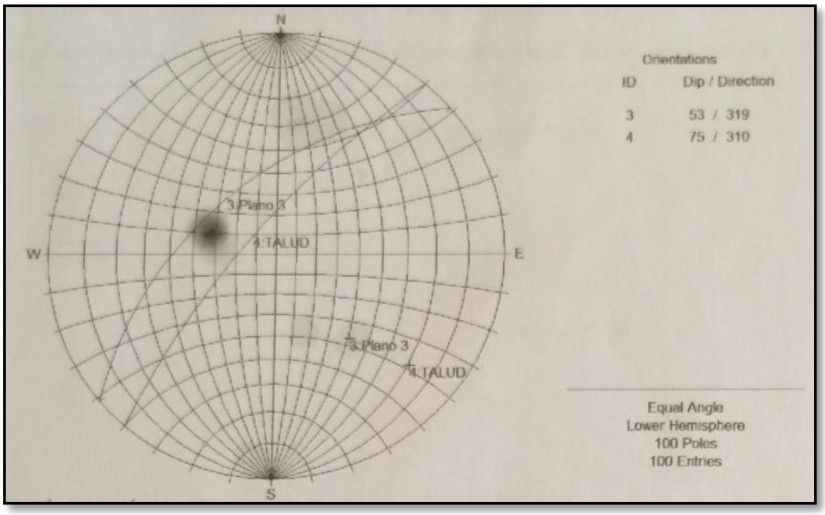

Figure 10: Graphic diagram showing the plane 3 and the plane of the slope.

2. A wedge-type break is generated by the intersection of planes 3 and 2. In the stereographic network it can be seen that the intersection falls right in the critical zone.

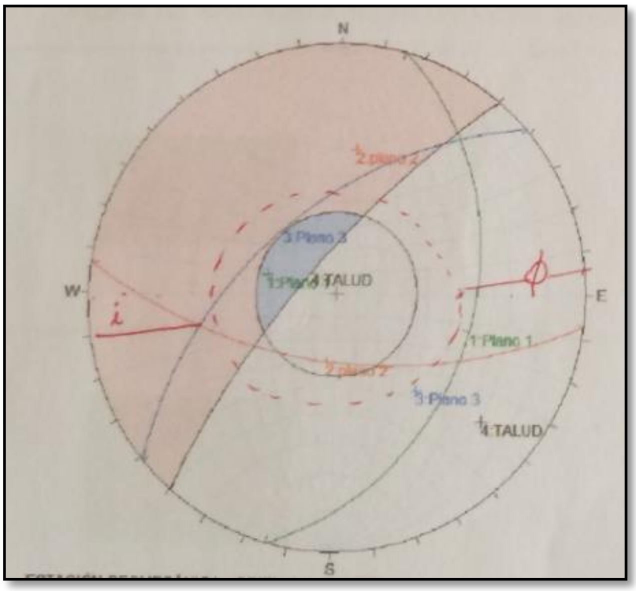

Figure 11: Representation of critical areas for wedge-type rupture.

3. No plane generates rupture by toppling or overturn, since they do not satisfy the two conditions.

- $\beta > \varphi + (90 - \alpha)$

- The break plane must have an approximately parallel course ($\pm$20 °) relative to the slope plane.

DETERMINATION OF THE SAFETY FACTOR FOR EACH CASE

1. Planar Break (Plan 3): We make use of the RocPlane program. Safety factor: 1.07

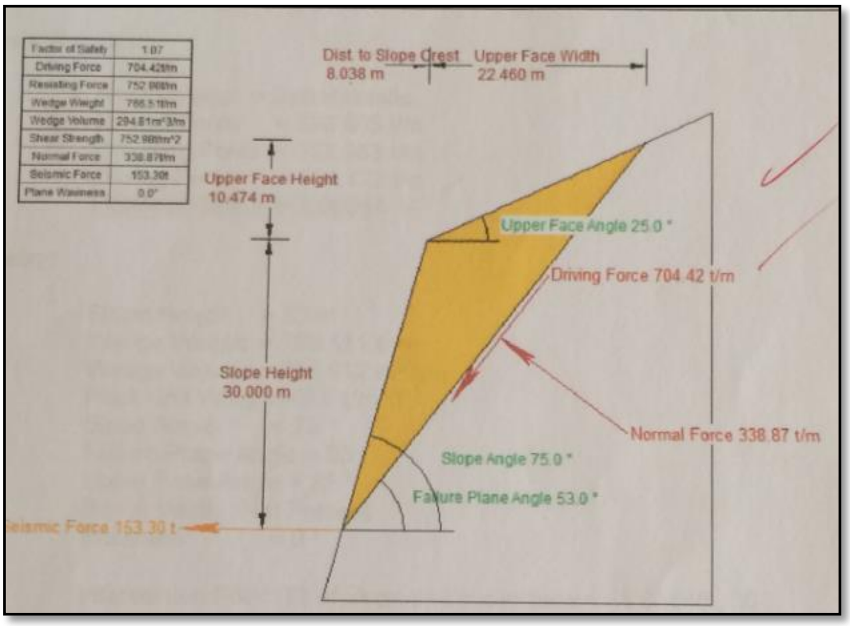

Figure 12: 2D representation of the analysis for the case of planar rupture.

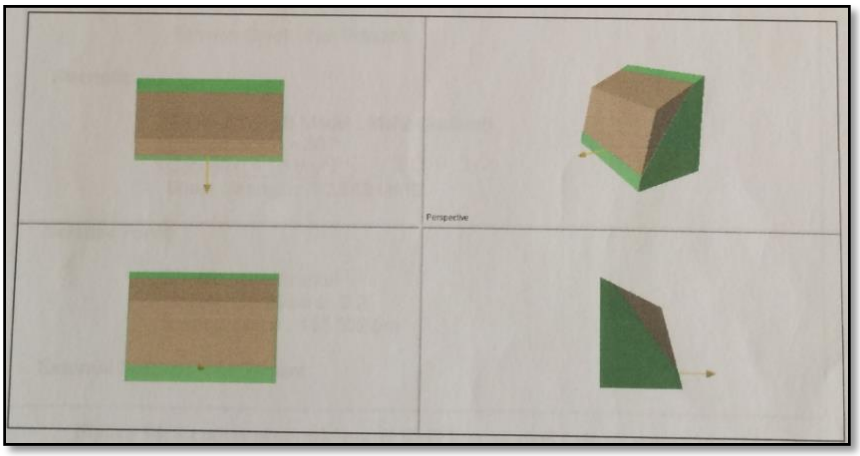

Figure 13: Views and 3D rendering of the planar break case.

Further details of the data considered for the case of planar rupture are presented below.

RocPlane Analysis Information

Document Name:
RocPlane1

Job Title:
RocPlane - Planar Wedge Stability Analysis

Analysis Results:

Analysis type = Deterministic
Normal Force = 338.865 t/m
Resisting Force = 752.983 t/m
Driving Force = 704.422 t/m
Factor of Safety = 1.06894

Geometry:

Slope Height = 30 m
Wedge Weight = 766.511 t/m
Wedge Volume = 294.812 m^3/m
Rock Unit Weight = 2.6 t/m^3
Slope Angle = 75 °
Failure Plane Angle = 53 °
Upper Face Angle = 25 °
Bench Width : Not Present
Waviness = 0 °

Intersection Point (B) of slope and upper face = (8.03848 , 30)
Intersection point (C) of failure plane and upper face = (30.499 , 40.4735)
Failure plane length (Origin --> C) = 50.6783 m
Slope length (Origin --> B) = 31.0433 m

Tension Crack : Not Present

Strength:

Shear Strength Model : Mohr-Coulomb
Friction Angle = 36 °
Cohesion = 10 t/m^2 20 - 30.
Shear Strength: 752.983 t/m^2

Seismic Force:

Direction : Horizontal
Seismic Coefficient : 0.2
Seismic Force : 153.302 t/m

External Forces : Not Present

Figure 14: Report generated by the RockPlane for the case of planar rupture.

2. Wedge break (planes 2 and 3): We use the Swedge program. Security factor: 1,591.

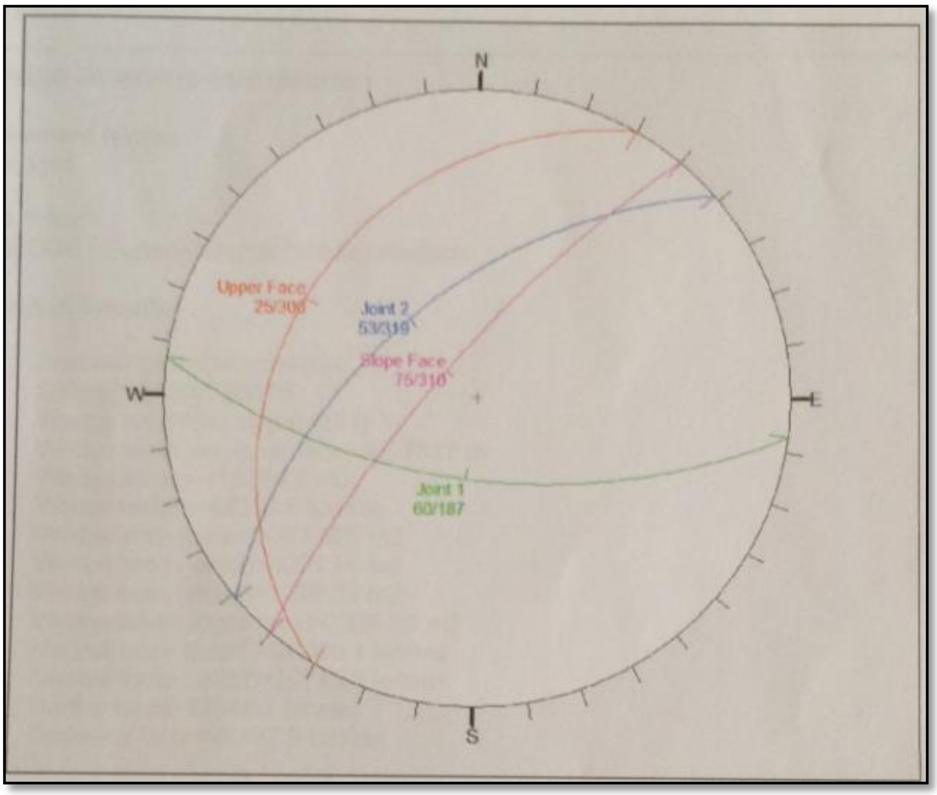

Figure 15: Projection generated with the Swedge, taking only the planes that generate the break.

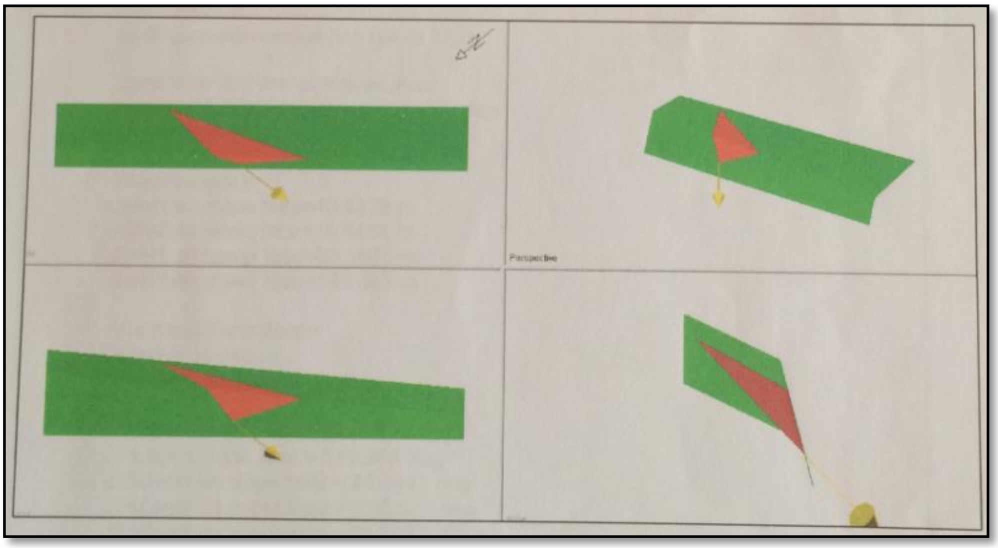

Figure 16: Views and 3D rendering of the planar break case.

Further details of the data considered for the case of wedge breakage are presented below.

Swedge Analysis Information

Document Name:
Swedge1

Job Title:
SWEDGE - Surface Wedge Stability Analysis

Analysis Results:

Analysis type=Deterministic
Safety Factor=1.59078
Wedge height(on slope)=30 m
Wedge width(on upper face)=47.7847 m
Wedge volume=16299.8 m3
Wedge weight=42379.6 tonnes
Wedge area (joint1)=787.925 m2
Wedge area (joint2)=3271.74 m2
Wedge area (slope)=1326.92 m2
Wedge area (upper face)=2228.28 m2
Normal force (joint1)=26000.1 tonnes
Normal force (joint2)=29713.8 tonnes
Driving force=30549.7 tonnes
Resisting force=48597.9 tonnes

Seismic Force:
Seismic force=8475.91 tonnes

Failure Mode:
Sliding on intersection line (joints 1&2)

Joint Sets 1&2 line of Intersection:
plunge=31.3898 deg, trend=256.373 deg
length=104.045 m

Trace Lengths:
Joint1 on slope face=40.4229 m
Joint2 on slope face=70.5461 m
Joint1 on upper face=68.2683 m
Joint2 on upper face=149.843 m

Maximum Persistence:
Joint1=104.045 m
Joint2=149.843 m

Intersection Angles:
J1&J2 on slope face = 111.468 deg
J1&Crest on slope face = 44.7441 deg
J1&Crest on upper face = 135.577 deg
J2&Crest on slope face = 23.7883 deg
J2&Crest on upper face = 18.5963 deg
J1&2 on upper face = 25.8271 deg

Joint Set 1 Data:

dip=60 deg, dip direction=187 deg
cohesion=2 tonnes/m2, friction angle=36 deg

Joint Set 2 Data:

dip=53 deg, dip direction=319 deg
cohesion=2 tonnes/m2, friction angle=36 deg

Slope Data:

dip=75 deg, dip direction=310 deg
slope height=30 meters
rock unit weight=2.6 tonnes/m3
Water pressures in the slope=NO
Overhanging slope face=NO
Externally applied force=NO
Tension crack=NO

Upper Face Data:

dip=25 deg, dip direction=300 deg

Seismic Data:

Seismic coefficient=0.2
Direction=line of interesection J1&J2
trend=256.373 deg, plunge=31.3898 deg

Wedge Vertices:

Coordinates in Easting,Northing,Up Format
1=Joint1, 2=Joint2, 3=Upper Face, 4=Slope
Point 124: 0, 0, 0
Point 134: 22.8, 14.7, 30
Point 234: -38.6, -55, 21.4
Point 123: 86.3, 20.9, 54.2

Figure 17: Report generated by the Swedge for the case of wedge-type breakage.

6. CASE OF A TRUNK SHAPE TUNNEL

We will take the premise and the case that we will build a tunnel in the shape of a trunk of dimensions 11m x 8m (model of the Santa Rosa tunnel) and we have the families so far determined. We will do the stability analysis for that tunnel using the software Unwedge (from RockScience).

We plot the families and add an axis of advance for the tunnel (axis of advance taken: 310 °).

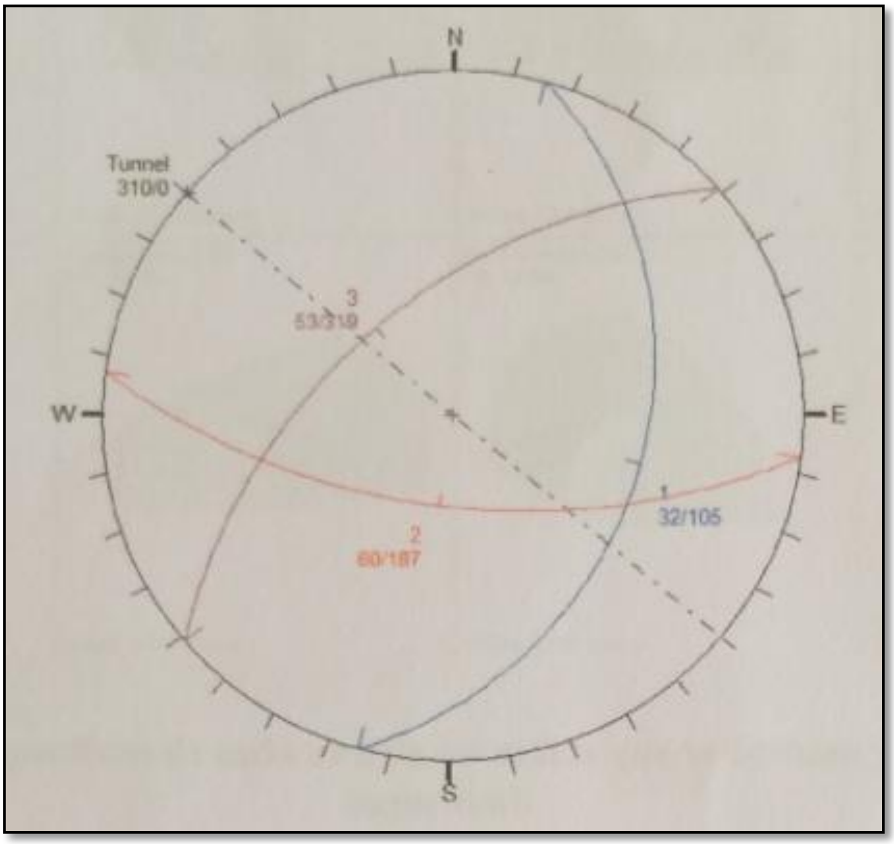

Figure 18: Stereographic projections of the families of discontinuities and the axis of advance of the tunnel (310 °).

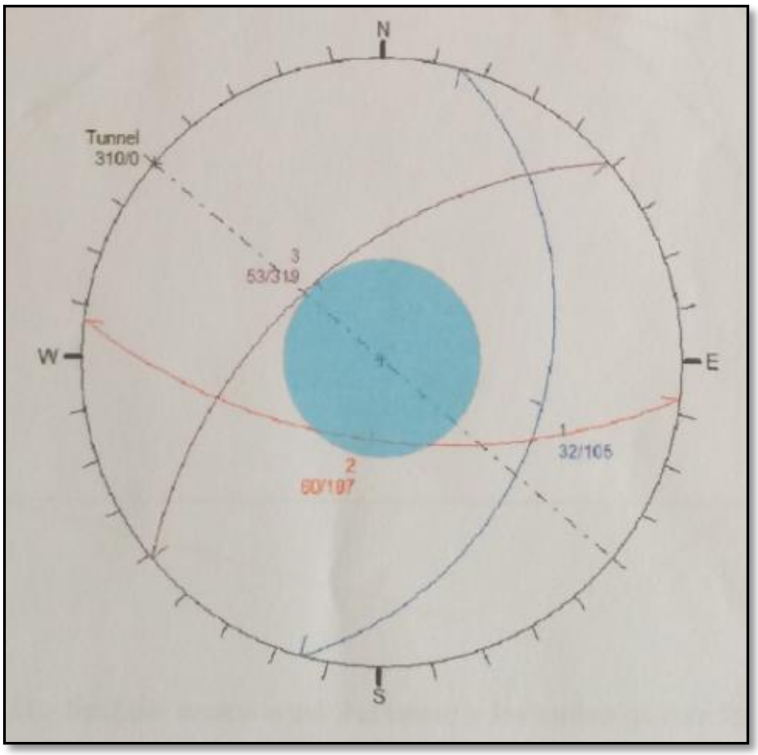

Figure 19: Projections of the families and axis of the tunnel, including the angle of friction (36 °).

Next we will see the results after having put the dimensions to the tunnel, we notice that there are 7 wedges, 6 of them have a factor of security well above the allowed (1.5), one of them has security factor 0.00.

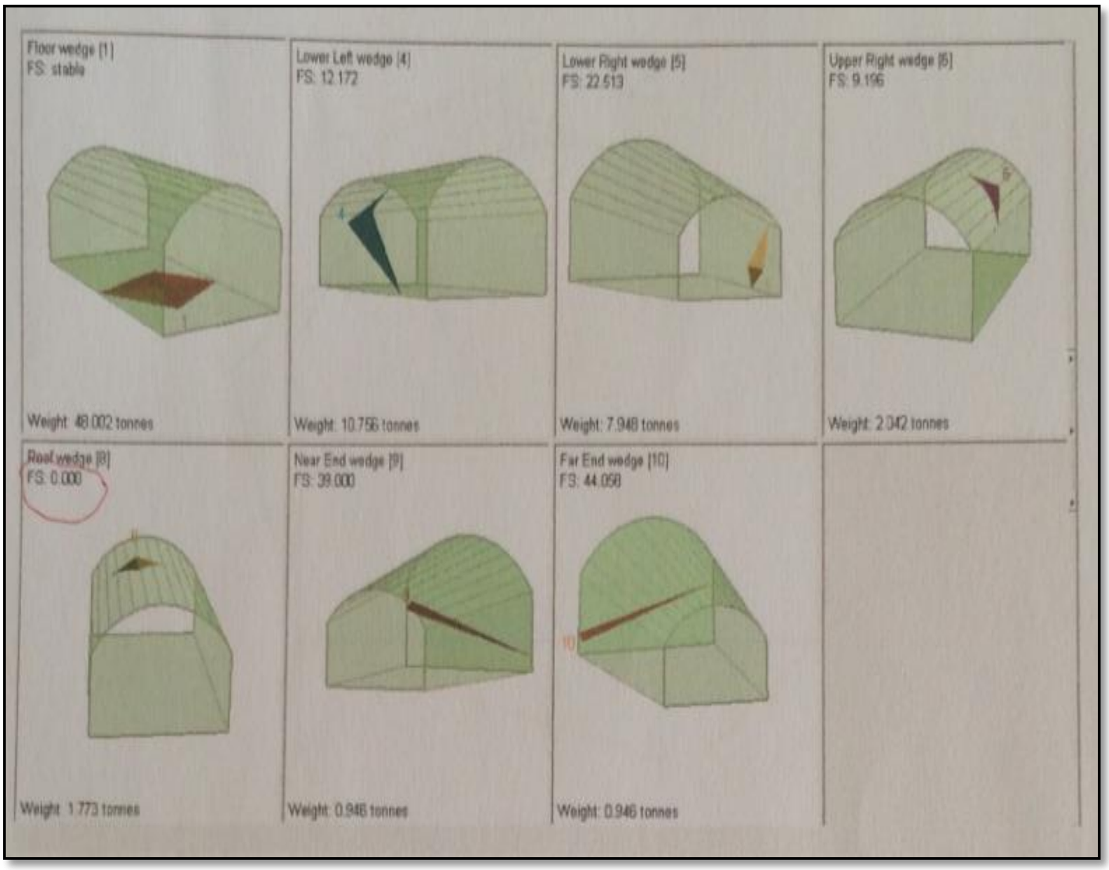

Figure 20: Perspectives of each of the wedges that are formed and their safety factors.

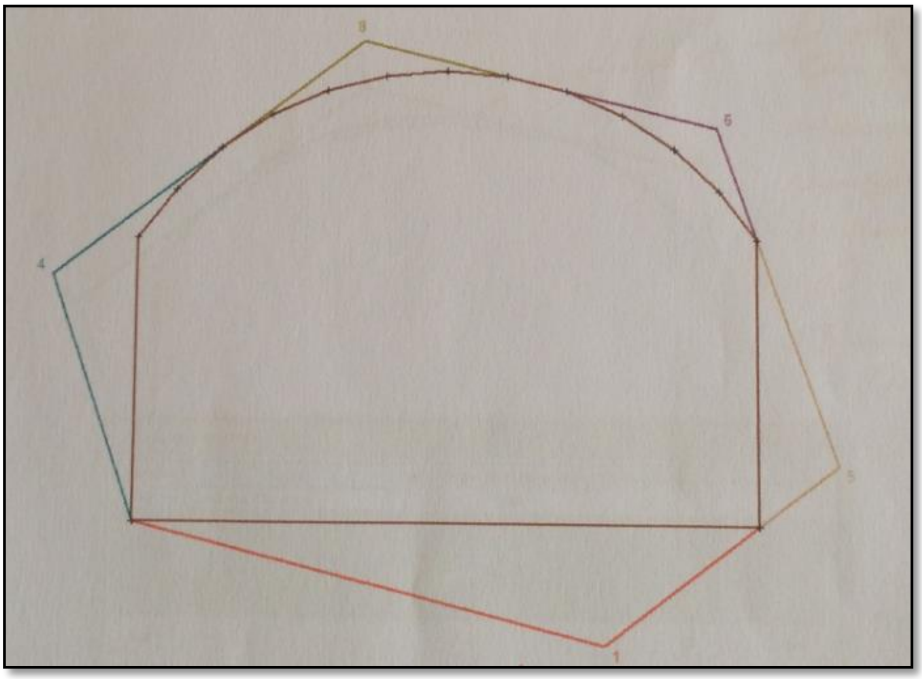

Figure 21: Cross section of the tunnel and wedges that are formed.

To have a safety factor within the permissible, we will add a tunnel support in the part of the wedge 8. We first add 1 t / m2 to the part of the wedge 8 (safety factor of 1,692).

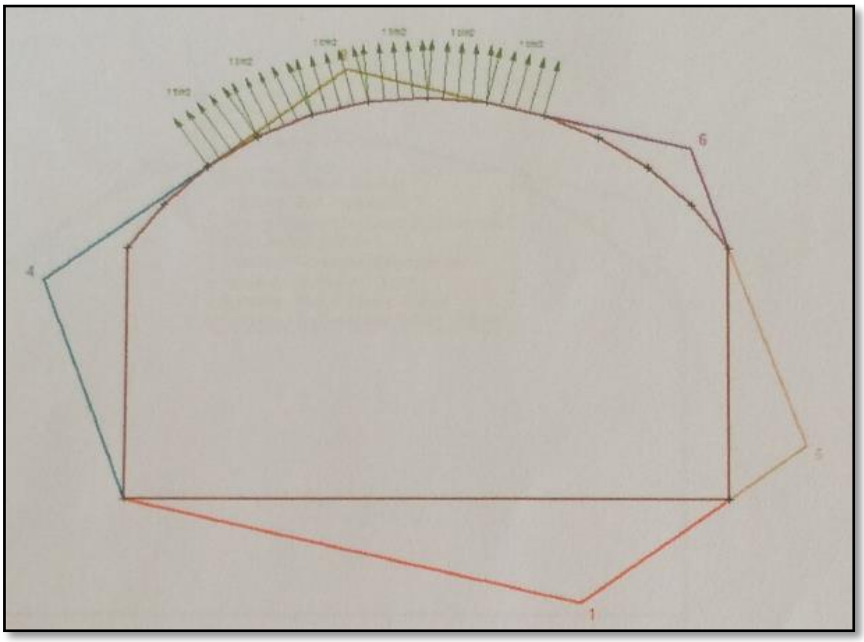

Figure 22: Diagram showing the pressure located on the wedge part 8.

If we add a layer of shotcrete of 10 cm, 2.6 t / m3 and 200 t / m2; we will have a safety factor of 92.9.

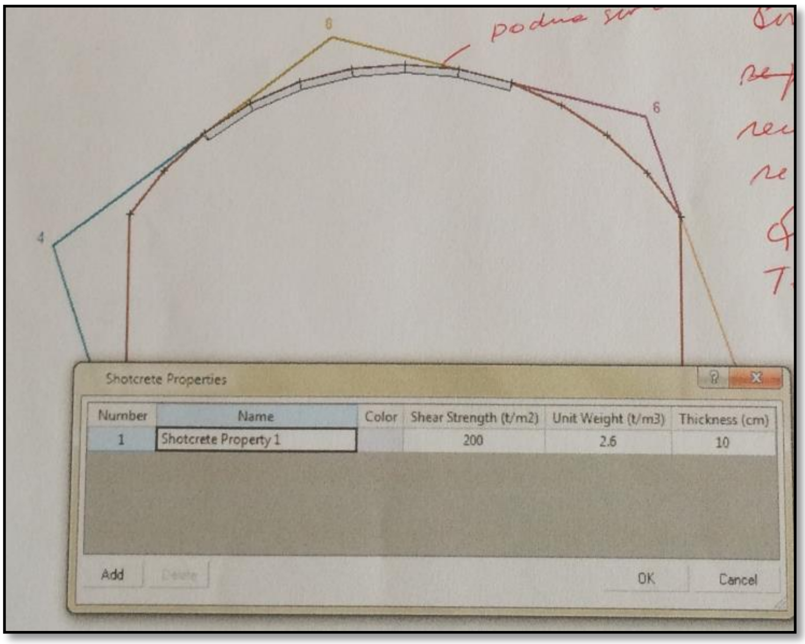

Figure 23: Shotcrete scheme and properties.

We also add a bolt for the support. In this case we obtain a safety factor of 5.297 (2 m long bolt).

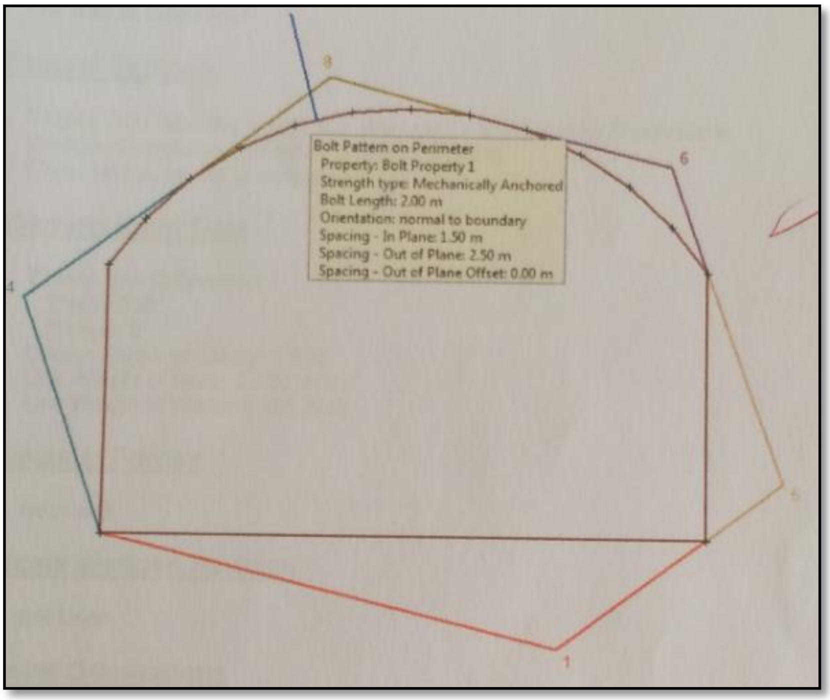

Figure 24: Diagram showing a bolt in the wedge area.

Unwedge Analysis Information

Document Name

File Name: Unwedge1

Project Settings

Project Title: Stability Analysis of Wedges for Underground Excavations
Wedges Computed: Perimeter and End Wedges
Units: Metric, stress as tonnes/m2

General Input Data

Tunnel Axis Orientation:
Trend: 310°
Plunge: 0°
Design Factor of Safety: 1.500
Unit Weight of Rock: 2.700 t/m3
Unit Weight of Water: 0.981 t/m3

Seismic Forces

Not Used

Scale Wedges Settings

Not Used

Joint Orientations

Joint 1
Dip: 32°
Dip Direction: 105°
Joint 2
Dip: 60°
Dip Direction: 187°
Joint 3
Dip: 53°
Dip Direction: 319°

Joint Properties

Joint Properties 1
Water Pressure
Constant: 0 tonnes/m2
Waviness: 0°
Shear Strength Model: Mohr-Coulomb
Phi: 35°
Cohesion: 10 tonnes/m2
Tensile Strength: 0 tonnes/m2

Bolt Properties

Bolt Property 1
Bolt Type: Mechanically Anchored
Tensile Capacity: 10 tonnes
Plate Capacity: 10 tonnes
Anchor Capacity: 10 tonnes
Shear Strength: Unused
Bolt Orientation Efficiency: Used
Method: Cosine Tension/Shear

Shotcrete Properties

Shotcrete Property 1
Shear Strength: 200.00 t/m2
Unit Weight: 2.600 t/m3
Thickness: 10.00 cm

Support Summary

Summary of Perimeter Bolt Patterns
Number of Bolt Patterns on Perimeter: 1
Perimeter Bolt Pattern: 1
Property: Bolt Property 1
Strength type: Mechanically Anchored
Bolt Length: 2.00 m
Orientation: normal to boundary
Pattern Spacing - In Plane: 1.50 m
Pattern Spacing - Out of Plane: 2.50 m
Pattern Spacing - Out of Plane Offset: 0.00 m

Wedge Information

Floor wedge [1]
Factor of Safety: stable
Wedge Weight: 48.002 tonnes

Lower Left wedge [4]
Factor of Safety: 12.172
Wedge Weight: 10.756 tonnes

Lower Right wedge [5]
Factor of Safety: 22.513
Wedge Weight: 7.948 tonnes

Upper Right wedge [6]
Factor of Safety: 9.196
Wedge Weight: 2.042 tonnes

Roof wedge [8]
Factor of Safety: 5.297
Wedge Weight: 1.773 tonnes

Near End wedge [9]
Factor of Safety: 39.000
Wedge Weight: 0.946 tonnes

Far End wedge [10]
Factor of Safety: 44.058
Wedge Weight: 0.946 tonnes

7. LIMITATIONS

The present work is strictly developed as a practice, not having an economic or project objective; Being able to have detailed in an integral way the geology and other aspects that we consider very important.

8. CONCLUSIONS

- The slope in the trailing hills was characterized by the plane 75 ° / 310 ° from the point of the geomechanical station and with view to the East.
- Three main families of discontinuities were identified: 32 ° / 105 °, 60 ° / 187 ° and 53 ° / 319 °.
- Planar rupture is generated by the presence of the family of plane 3: 53 ° / 319 ° (SF: 1.07), wedge is formed by the presence of families of planes 2 and 3 (60 ° / 187 ° and 53 ° / 319 °) with safety factor 1.59.
- In the case of a tunnel, we have a wedge with a safety factor below the permissible, it is recommended to use bolts or pressure in the wedge area 8 with the specified characteristics.

DATA SHEETS

Garay

AZIM

D DIP	DIP
220	75

22.5

LINEA No 1 | LONGITUD: 15.4 | cota: | UBICACIÓN: CERRO UNI (E: 277796,76) (N: 8670456,13) | REALIZADO POR: PINO | FECHA: 03/06/16 | HOJA No: 01

DIST. (m)	TIPO ROCA	ESTRUCTURA AZIM TIPO	D DIP	DIP	GEOMETRIA F	LARGO (m)	C	R	ABERTURA (mm)	RELLENO	A (W)	ALT	RESIS (R)	ESTRUCTURA DEL MACIZO ROCOSO	OBSERVACIONES	No D
00,00	C	D	205	60	P	1-2	D	L	0009	SR	S	LA	R4		ESP. 20cm	
00,60	C	D	125	70	P	1-0,6	D	L	0001	SR	S	LA	R4			
00,30	C	D	010	30	P	+10	C	E	0010	A	S	A	R4		ESPACIAMIENTO 15cm	
00,35	C	D	210	65	P	0,5	D	L	0002	SR	S	LA	R4		ESP. 20cm	
00,70	C	D	010	30	P	+10	C	E	0010	A	S	A	R4		ESP. 15cm	
00,60	C	D	010	30	P	+10	C	E	0001	A	S	A	R4		ESP. 15cm	
00,10	C	D	065	85	P	1-2	D	E	0002	A	S	LA	R4			
00,30	C	D	010	30	P	+10	C	E	0001	A	S	A	R4		ESP. 15 cm	
00,00	C	D	220	55	P	1	D	L	0001	SR	S	LA	R4			
00,25	C	D	220	55	P	1	D	L	0001	SR	S	LA	R4			
00,00	C	D	010	30	P	+10	C	E	0002	A	S	A	R4		ESP. 15cm	
01,50	C	D	220	55	P	1	D	L	0001	SR	S	LA	R4			
00,80	C	D	270	90	P	3-5	C	E	0005	A	S	A	R4			
00,60	C	D	170	55	P	2-3	D	R	0001	SR	S	LA	R4			
06,25	C	D	280	60	P	3-5	C	L	0005	SR	S	LA	R4			

TIPO DE ROCA		TIPO DE ESTRUCTURA				ALTERACION		GEOMETRIA FORMA	
A	PIZARRA	D	DIACLASA	C	CONTACTO LITOLOGICO	F	FRESCA		
B	CALIZA	SD	SET DE DIACLASAS	BX	BRECHA	LA	LEVEMENTE ALT	P	PLANAR
C	ARENISCA	FT	FALLA	VN	VETA	A	ALTERADA	O	ONDULADA
D	LUTITA	F	FOLIACON	MT	MANTOS	MA	MUY ALTERADA	I	IRREGULAR
E	GRANODIORITA	FT	ZONA CIZALLE	DX	DIQUE	IA	INTENS ALTERADA		

GEOMETRIA

(R) RUGOSIDAD: R – RUGOSA | L – LISA | E – ESTRIADA | P – PULIDA

(C) CONTINUIDAD: C – CONTINUA | D – DISCONTINUA

RELLENO		AGUA		CRITERIO GENERALIZADO DE HOEK - BROWN			
SR	SIN RELLENO	S	SECO	LF	LEVEMENTE FRACTURADO	MB	MUY BUENA
LR	LIMOS Y FRAGMENTOS DE ROCA	H	HUMEDO	F	FRACTURADO	B	BUENA
O	OXIDOS	Gs	GOTEO SUAVE	MF	MUY FRACTURADO	R	REGULAR
S	SULFURO	T	FLUJO CONSTANTE	IF	INTENSAMENTE FRACTURADO	P	POBRE
A	ARCILLA			T	TRITURADO	MP	MUY POBRE
P	PIRITA						

No D = CANTIDAD DE DISCONTINUIDADES DEL MISMO TIPO ENTRE LOS ESPACIOS MEDIDOS.

RESISTENCIA ESTIMADA		(Mpa)
R6	EXTREMADAMENTE DURA	> 250
R5	MUY DURA	100 - 250
R4	DURA	50 - 100
R3	MODERADAMENTE DURA	25 - 50
R2	BLANDA	5 - 25
R1	MUY BLANDA	1 - 5
R0	EXTREMADAMENTE BLANDA	0.25 - 1

D DIP	DIP
220	75

LINEA No: 1 | LONGITUD: 15,4 | cota: | UBICACIÓN: CERRO UNI (E: 277796,76) (N: 8670456,13) | REALIZADO POR: | FECHA: 03/06/16 | HOJA No: 02

DIST. (m)	TIPO ROCA	ESTRUCTURA A21M TIPO	D DIP	DIP	GEOMETRIA F	LARGO (m)	C	R	ABERTURA (mm)	RELLENO	A (w)	ALT	RESIS (R)	ESTRUCTURA DEL MACIZO ROCOSO	OBSERVACIONES	No D
00,30	C	D	000	30	P	10	C	E	0004	A	S	A	R4		ESP. 20cm	
00,30	C	D	075	85	P	0,60	D	L	0003	S R	S	LA	R4			
00,20	C	D	085	65	P	5	C	L	00,5	S R	S	LA	R4			
00,00	C	D	250	40	P	2	C	L	00,5	S R	S	LA	R4		ESP. 5cm	
00,35	C	D	000	30	P	10	C	E	0001	A	S	A	R4		ESP 20cm	
00,10	C	D	000	30	P	10	C	E	0001	A	S	A	R4		ESP 20cm	
00,00	C	D	250	40	P	2	C	L	00,5	S R	S	LA	R4		ESP 5cm	
00,10	C	D	250	40	P	2	C	L	00,5	S R	S	LA	R4		ESP 10cm	
00,00	C	D	000	30	P	10	C	E	00,5	A	S	A	R4		ESP. 20cm	
00,30	C	D	130	50	P	+5	C	L	00,5	S R	S	LA	R4			
00,20	C	D	250	40	P	2	C	L	00,5	S R	S	LA	R4			
00,10	C	D	000	25	P	+10	C	L	00,5	S R	S	LA	R4		ESP 20cm	
00,00	C	D	250	40	P	2	C	L	00,5	S R	S	LA	R4			
00,10	C	D	250	40	P	2	C	L	00,5	S R	S	LA	R4		Espaciado 5 cm	
01,38	C	D	340	20	P	2	C	L	00,5	S R	S	LA	R4			

TIPO DE ROCA		TIPO DE ESTRUCTURA				ALTERACION	
A	PIZARRA	D	DIACLASA	C	CONTACTO LITOLOGICO	F	FRESCA
B	CALIZA	SD	SET DE DIACLASAS	BX	BRECHA	LA	LEVEMENTE ALT
C	ARENISCA	FT	FALLA	VN	VETA	A	ALTERADA
D	LUTITA	F	FOLIACON	MT	MANTOS	MA	MUY ALTERADA
E	GRANODIORITA	FT	ZONA CIZALLE	DX	DIQUE	IA	INTENS ALTERADA

GEOMETRIA

FORMA		(R) RUGOSIDAD							
P	PLANAR	R	RUGOSA	L	LISA	E	ESTRIADA	P	PULIDA
O	ONDULADA	(C) CONTINUIDAD							
I	IRREGULAR	C	CONTINUA	D	DISCONTINUA				

RELLENO		AGUA		CRITERIO GENERALIZADO DE HOEK - BROWN			
SR	SIN RELLENO	S	SECO	LF	LEVEMENTE FRACTURADO	MB	MUY BUENA
	LIMOS Y FRAGMENTOS DE ROCA	H	HUMEDO	F	FRACTURADO	B	BUENA
	OXIDOS	Gs	GOTEO SUAVE	MF	MUY FRACTURADO	R	REGULAR
	SULFURO	T	FLUJO CONSTANTE	IF	INTENSAMENTE FRACTURADO	P	POBRE
	ARCILLA			T	TRITURADO	MP	MUY POBRE
	PIRITA						

No D = CANTIDAD DE DISCONTINUIDADES DEL MISMO TIPO ENTRE LOS ESPACIOS MEDIDOS.

RESISTENCIA ESTIMADA (Mpa)		
R6	EXTREMADAMENTE DURA	> 250
R5	MUY DURA	100 - 250
R4	DURA	50 - 100
R3	MODERADAMENTE DURA	25 - 50
R2	BLANDA	5 - 25
R1	MUY BLANDA	1 - 5
R0	EXTREMADAMENTE BLANDA	0.25 - 1

D DIP	DIP
220	75

22.5

LINEA No 1 | LONGITUD: ~~15~~ A | cota: | UBICACIÓN: CERRO UNI (E: 277196,76) (N: 8670466,13) | REALIZADO POR: | FECHA: 03/06/16 | HOJA No: 03

DIST. (m)	TIPO ROCA	ESTRUCTURA AZIM TIPO	D DIP	DIP	GEOMETRIA F	LARGO (m)	C	R	ABERTURA (mm)	RELLENO	A (w)	ALT	RESIS (R)	ESTRUCTURA DEL MACIZO ROCOSO	OBSERVACIONES	No D
+ 00,30	C	D	095	55	P	Y10	C	E	0001	SR	S	LA	R4			
+ 00,20	C	D	140	55	P	+10	C	L	0001	SR	S	LA	R4			
+ 00,00	C	D	285	75	P	5	D	L	000,5	SR	S	LA	R4			
+ 00,30	C	D	020	35	P	+10	C	E	000,5	SR	S	LA	R4		Esp. 20 Cm	
+ 00,10	C	D	020	35	P	+10	C	E	000,5	SR	S	LA	R4			
+ 00,10	C	D	020	35	P	+10	C	E	000,5	SR	S	LA	R4			
+ 00,00	C	D	275	85	P	1	D	L	000,5	SR	S	LA	R4		ESP. 20 cm	
+ 00,20	C	D	020	35	P	+10	C	E	000,5	SR	S	LA	R4			
+ 00,15	C	D	020	35	P	+10	C	E	0004	LR	S	A	R4		ESP. 10 cm	
+ 00,15	C	D	020	35	P	+10	C	E	000,5	SR	S	LA	R4		ESP 10cm	
+ 00,15	C	D	020	35	P	+10	C	E	000,5	SR	S	LA	R4		ESP. 10cm	
+ 00,00	C	D	275	85	P	1	D	L	000,5	SR	S	LA	R4		ESP. 25cm	
+ 00,05	C	D	235	55	P	+10	C	L	000,5	SR	S	LA	R4		ESP. 35 cm	
+ 00,20	C	D	275	85	P	1	D	L	000,5	SR	S	LA	R4		ESP. 25cm	
+ 00,00	C	D	020	35	P	+10	C	E	0002	LR	S	A	R4		ESP. 10cm	

TIPO DE ROCA		TIPO DE ESTRUCTURA				ALTERACION	
A	PIZARRA	D	DIACLASA	C	CONTACTO LITOLOGICO	F	FRESCA
B	CALIZA	SD	SET DE DIACLASAS	BX	BRECHA	LA	LEVEMENTE ALT
C	ARENISCA	FT	FALLA	VN	VETA	A	ALTERADA
D	LUTITA	F	FOLIACON	MT	MANTOS	MA	MUY ALTERADA
E	GRANODIORITA	FT	ZONA CIZALLE	DX	DIQUE	IA	INTENS ALTERADA

GEOMETRIA									
FORMA		(R) RUGOSIDAD							
P	PLANAR	R	RUGOSA	L	LISA	E	ESTRIADA	P	PULIDA
O	ONDULADA	(C) CONTINUIDAD							
I	IRREGULAR	C	CONTINUA			D	DISCONTINUA		

RELLENO		AGUA		CRITERIO GENERALIZADO DE HOEK - BROWN			
SR	SIN RELLENO	S	SECO	LF	LEVEMENTE FRACTURADO	MB	MUY BUENA
LR	LIMOS Y FRAGMENTOS DE ROCA	H	HUMEDO	F	FRACTURADO	B	BUENA
	OXIDOS	Gs	GOTEO SUAVE	MF	MUY FRACTURADO	R	REGULAR
	SULFURO	T	FLUJO CONSTANTE	IF	INTENSAMENTE FRACTURADO	P	POBRE
	ARCILLA			T	TRITURADO	MP	MUY POBRE
	PIRITA	No D = CANTIDAD DE DISCONTINUIDADES DEL MISMO TIPO ENTRE LOS ESPACIOS MEDIDOS.					

RESISTENCIA ESTIMADA (Mpa)		
R6	EXTREMADAMENTE DURA	> 250
R5	MUY DURA	100 - 250
R4	DURA	50 - 100
R3	MODERADAMENTE DURA	25 - 50
R2	BLANDA	5 - 25
R1	MUY BLANDA	1 - 5
R0	EXTREMADAMENTE BLANDA	0.25 - 1

~~AZIM~~ ~~D DIP~~ DIP

2	2	0	7	5

22.5

LINEA No | LONGITUD ~~15.4~~ | cota: | UBICACIÓN: CERRO UNI (E: 277190,78) (N: 8670456,13) | REALIZADO POR: | FECHA: 03/[illegible]/16 | HOJA No: 04

DIST. (m)	TIPO ROCA	ESTRUCTURA TIPO	ESTRUCTURA D DIP	ESTRUCTURA DIP	GEOMETRIA F	GEOMETRIA LARGO (m)	GEOMETRIA C	GEOMETRIA R	ABERTURA (mm)	RELLENO	A (w)	ALT	RESIS (R)	ESTRUCTURA DEL MACIZO ROCOSO	OBSERVACIONES	No D
00,35	C	D	275	85	P	1	D	L	00,5	S R	5	LA	R4		Esp. +25cm	
00,10	C	D	020	35	P	+10	C	E	003	L R	5	A	R4		ESP. 10cm	
00,20	C	D	020	35	P	+10	C	E	005	L R	5	A	R4		ESP. 10cm	
00,00	C	D	235	55	P	+10	C	L	00,5	S R	5	LA	R4		ESP. 10cm	
00,20	C	D	095	55	P	2	D	L	00,5	S R	5	LA	R4		ESP 35cm	
00,05	C	D	020	35	P	+10	C	E	002	L R	5	LA	R4		ESP. 10cm	
00,15	C	D	110	65	P	5	C	L	00,5	S R	5	LA	R4			
00,05	C	D	110	65	P	5	C	L	00,5	S R	5	LA	R4		Esp. 10cm	
00,08	C	D	110	65	P	5	C	L	00,5	S R	5	LA	R4		ESP. 10cm	
00,15	C	D	110	65	P	5	C	L	00,5	S R	5	LA	R4		ESP. 10cm	
00,00	C	D	230	55	P	+10	C	L	00,5	S R	5	LA	R4		ESP. 10cm	
00,20	C	D	020	35	P	+10	C	L	00,5	S R	5	LA	R4		ESP. 35cm	
00,20	C	D	020	35	P	+10	C	L	001	L R	5	A	R4		ESP. 15cm	
00,18	C	D	020	35	P	+10	C	L	00,5	S R	5	LA	R4			
00,40	C	D	020	35	P	+10	C	L	001	L R	5	A	R4		ESP. 15cm	

TIPO DE ROCA		TIPO DE ESTRUCTURA				ALTERACION		GEOMETRIA FORMA	
A	PIZARRA	D	DIACLASA	C	CONTACTO LITOLOGICO	F	FRESCA		
B	CALIZA	SO	SET DE DIACLASAS	BX	BRECHA	LA	LEVEMENTE ALT	P	PLANAR
C	ARENISCA	FT	FALLA	VN	VETA	A	ALTERADA	O	ONDULADA
D	LUTITA	F	FOLIACON	MT	MANTOS	MA	MUY ALTERADA	I	IRREGULAR
E	GRANODIORITA	FT	ZONA CIZALLE	DX	DIQUE	IA	INTENS ALTERADA		

GEOMETRIA — (R) RUGOSIDAD: R RUGOSA | L LISA | E ESTRIADA | P PULIDA — (C) CONTINUIDAD: C CONTINUA | D DISCONTINUA

RELLENO		AGUA		CRITERIO GENERALIZADO DE HOEK - BROWN			
SR	SIN RELLENO	S	SECO	LF	LEVEMENTE FRACTURADO	MB	MUY BUENA
	LIMOS Y FRAGMENTOS DE ROCA	H	HUMEDO	F	FRACTURADO	B	BUENA
	OXIDOS	Gs	GOTEO SUAVE	MF	MUY FRACTURADO	R	REGULAR
	SULFURO	T	FLUJO CONSTANTE	IF	INTENSAMENTE FRACTURADO	P	POBRE
	ARCILLA			T	TRITURADO	MP	MUY POBRE
	PIRITA						

No D = CANTIDAD DE DISCONTINUIDADES DEL MISMO TIPO ENTRE LOS ESPACIOS MEDIDOS.

RESISTENCIA ESTIMADA (Mpa)		
R6	EXTREMADAMENTE DURA	> 250
R5	MUY DURA	100 - 250
R4	DURA	50 - 100
R3	MODERADAMENTE DURA	25 - 50
R2	BLANDA	5 - 25
R1	MUY BLANDA	1 - 5
R0	EXTREMADAMENTE BLANDA	0.25 - 1

Azim

D-DIP			DIP	
2	2	0	7	5

22.5

LINEA No | LONGITUD: 154 | cota: | UBICACIÓN: CERRO UNI | REALIZADO POR: | FECHA: 03/06/16 | HOJA No: 05

DIST. (m)	TIPO ROCA	ESTRUCTURA Azim TIPO	D-DIP	DIP	GEOMETRIA F	LARGO (m)	C	R	ABERTURA (mm)	RELLENO	A (w)	ALT	RESIS (R)	ESTRUCTURA DEL MACIZO ROCOSO	OBSERVACIONES	No D
00,40	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4			
00,10	C	D	115	80	P	+5	C	E	000,5	SR	S	LA	R4			
00,30	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4			
00,00	C	D	150	65	P	+10	C	L	000,5	SR	S	LA	R4			
00,10	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4		Esp. 15cm	
00,40	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4		Esp. 15cm	
00,00	C	D	225	90	P	2	D	L	000,5	SR	S	LA	R4			
00,30	C	D	135	65	P	2	D	L	000,5	SR	S	LA	R4			
00,40	C	D	145	55	P	+10	C	L	000,5	SR	S	LA	R4		Esp.	
00,20	C	D	095	65	P	+5	C	L	000,5	SR	S	LA	R4			
00,00	C	D	095	65	P	+5	C	L	000,5	SR	S	LA	R4		Esp. 10cm	
00,05	C	D	095	65	P	+5	C	L	000,5	SR	S	LA	R4		Esp. 10cm	
00,07	C	D	095	65	P	+5	C	L	000,5	SR	S	LA	R4		Esp. 10cm	
00,20	C	D	095	65	P	+5	C	L	000,5	SR	S	LA	R4		Esp. 10cm.	
00,18	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4			

TIPO DE ROCA	
A	PIZARRA
B	CALIZA
C	ARENISCA
D	LUTITA
E	GRANODIORITA

TIPO DE ESTRUCTURA			
D	DIACLASA	C	CONTACTO LITOLOGICO
SD	SET DE DIACLASAS	BX	BRECHA
FT	FALLA	VN	VETA
F	FOLIACION	MT	MANTOS
FT	ZONA CIZALLE	DX	DIQUE

ALTERACION	
F	FRESCA
LA	LEVEMENTE ALT
A	ALTERADA
MA	MUY ALTERADA
IA	INTENS ALTERADA

GEOMETRIA FORMA	
P	PLANAR
O	ONDULADA
I	IRREGULAR

(R) RUGOSIDAD							
R	RUGOSA	L	LISA	E	ESTRIADA	P	PULIDA

(C) CONTINUIDAD			
C	CONTINUA	D	DISCONTINUA

RELLENO	
SR	SIN RELLENO
	LIMOS Y FRAGMENTOS DE ROCA
	OXIDOS
	SULFURO
	ARCILLA
	PIRITA

AGUA	
S	SECO
H	HUMEDO
Gs	GOTEO SUAVE
T	FLUJO CONSTANTE

CRITERIO GENERALIZADO DE HOEK - BROWN			
LF	LEVEMENTE FRACTURADO	MB	MUY BUENA
F	FRACTURADO	B	BUENA
MF	MUY FRACTURADO	R	REGULAR
IF	INTENSAMENTE FRACTURADO	P	POBRE
T	TRITURADO	MP	MUY POBRE

No D = CANTIDAD DE DISCONTINUIDADES DEL MISMO TIPO ENTRE LOS ESPACIOS MEDIDOS.

RESISTENCIA ESTIMADA		(Mpa)
R6	EXTREMADAMENTE DURA	> 250
R5	MUY DURA	100 - 250
R4	DURA	50 - 100
R3	MODERADAMENTE DURA	25 - 50
R2	BLANDA	5 - 25
R1	MUY BLANDA	1 - 5
R0	EXTREMADAMENTE BLANDA	0.25 - 1

D-DIP 220 DIP 75

LINEA No | LONGITUD: 19,A | cota: | UBICACIÓN: CERRO UNI (E: 277196,76) (N: 8670456,13) | REALIZADO POR: | FECHA: 03/06/16 | HOJA No: 06

DIST. (m)	TIPO ROCA	ESTRUCTURA TIPO	ESTRUCTURA D-DIP	ESTRUCTURA DIP	GEOMETRIA F	GEOMETRIA LARGO (m)	GEOMETRIA C	GEOMETRIA R	ABERTURA (mm)	RELLENO	A (w)	ALT	RESIS (R)	ESTRUCTURA DEL MACIZO ROCOSO	OBSERVACIONES	No D
00,15	C	D	140	75	P	0,50	D	L	000,5	SR	5	LA	R4			
00,00	C	D	020	35	P	+10	C	L	000,5	SR	5	LA	R4		ESP. 15cm	
00,30	C	D	020	35	P	+10	C	L	000,5	SR	5	LA	R4		ESP. 15 cm	
00,25	C	D	020	35	P	+10	C	L	000,5	SR	5	LA	R4		ESP. 15cm	
00,10	C	D	100	75	P	+5	D	L	000,5	SR	5	LA	R4			
00,28	C	D	020	35	P	+10	C	L	000,5	SR	5	LA	R4		ESP. 15cm	
00,50	C	D	140	75	P	3	D	L	000,5	SR	5	LA	R4			
00,15	C	D	020	35	P	+10	C	L	000,5	SR	5	LA	R4		ESP. 15 cm	
00,15	C	D	135	50	P	1	D	L	000,5	SR	5	LA	R4			
00,20	C	D	065	80	P	1	D	L	000,5	SR	5	LA	R4			
00,00	C	D	145	75	P	4	D	L	000,5	SR	5	LA	R4		ESP. 50cm	
00,10	C	D	255	75	P	3	D	E	000,5	SR	5	LA	R4			
00,33	C	D	020	35	P	+10	C	L	000,5	SR	5	LA	R4		ESP. 15cm	
00,10	C	D	020	35	P	+10	C	L	000,5	SR	5	LA	R4		ESP. 15cm	
00,23	C	D	020	35	P	+10	C	L	000,5	SR	5	LA	R4		ESP. 15cm	

TIPO DE ROCA		TIPO DE ESTRUCTURA				ALTERACION		GEOMETRIA FORMA	
A	PIZARRA	D	DIACLASA	C	CONTACTO LITOLOGICO	F	FRESCA		
B	CALIZA	SD	SET DE DIACLASAS	BX	BRECHA	LA	LEVEMENTE ALT	P	PLANAR
C	ARENISCA	FT	FALLA	VN	VETA	A	ALTERADA	O	ONDULADA
D	LUTITA	F	FOLIACON	MT	MANTOS	MA	MUY ALTERADA	I	IRREGULAR
E	GRANODIORITA	FT	ZONA CIZALLE	DX	DIQUE	IA	INTENS ALTERADA		

GEOMETRIA: (R) RUGOSIDAD: R RUGOSA, L LISA, E ESTRIADA, P PULIDA. (C) CONTINUIDAD: C CONTINUA, D DISCONTINUA.

RELLENO		AGUA		CRITERIO GENERALIZADO DE HOEK - BROWN				RESISTENCIA ESTIMADA (Mpa)		
SR	SIN RELLENO	S	SECO	LF	LEVEMENTE FRACTURADO	MB	MUY BUENA	R6	EXTREMADAMENTE DURA	> 250
	LIMOS Y FRAGMENTOS DE ROCA	H	HUMEDO	F	FRACTURADO	B	BUENA	R5	MUY DURA	100 - 250
	OXIDOS	Gs	GOTEO SUAVE	MF	MUY FRACTURADO	R	REGULAR	R4	DURA	50 - 100
	SULFURO	T	FLUJO CONSTANTE	IF	INTENSAMENTE FRACTURADO	P	POBRE	R3	MODERADAMENTE DURA	25 - 50
	ARCILLA			T	TRITURADO	MP	MUY POBRE	R2	BLANDA	5 - 25
								R1	MUY BLANDA	1 - 5
	PIRITA							R0	EXTREMADAMENTE BLANDA	0.25 - 1

No D = CANTIDAD DE DISCONTINUIDADES DEL MISMO TIPO ENTRE LOS ESPACIOS MEDIDOS.

D-DIP			DIP	
2	2	0	7	5

25.09

LINEA No	LONGITUD:	cota:	UBICACIÓN: CERRO UNI	REALIZADO POR:	FECHA:	HOJA No 07

	DIST. (m)	TIPO ROCA	ESTRUCTURA TIPO	ESTRUCTURA AZIM	ESTRUCTURA DIP	GEOMETRIA F	GEOMETRIA LARGO (m)	GEOMETRIA C	GEOMETRIA R	ABERTURA (mm)	RELLENO	A (W)	ALT	RESIS (R)	ESTRUCTURA DEL MACIZO ROCOSO	OBSERVACIONES	No D
+	0 0,2 5	C	D	1 5 5	7 0	P	1	D	L	0 0 0,5	S R	S	LA	R4			
+	0 0,3 0	C	D	0 2 0	3 5	P	+ 1 0	C	L	0 0 0,5	S R	S	LA	R4		ESP. 15cm	
+	0 0,0 0	C	D	1 0 0	5 5	P	1,5	D	L	0 0 0,5	S R	S	LA	R4		ESP. 20cm	
+	0 0,2 5	C	D	1 0 0	5 5	P	1,5	D	L	0 0 0,5	S R	S	LA	R4		ESP. 20cm	
+	0 0,3 0	C	D	1 2 0	9 0	P	1	D	L	0 0 0,5	S R	S	LA	R4			
+	0 0,3 0	C	D	0 2 0	3 5	P	+ 1 0	C	L	0 0 0,5	S R	S	A	R4		ESP. 15cm	
+	0 0,1 5	C	D	1 1 0	6 5	P	1	D	L	0 0 0,5	S R	S	LA	R4			
+	0 0,4 0	C	D	2 3 0	5 0	P	+ 1 0	D	L	0 0 0,5	S R	S	LA	R4		ESP. 15cm	
+	0 0,0 0	C	D	1 3 0	6 0	P	1	D	L	0 0 0,5	S R	S	LA	R4			
+	0 0,3 0	C	D	2 3 0	5 5	P	0,5	D	L	0 0 0,5	S R	S	LA	R4		ESP. 15cm	

TIPO DE ROCA	
A	PIZARRA
B	CALIZA
C	ARENISCA
D	LUTITA
E	GRANODIORITA

TIPO DE ESTRUCTURA			
D	DIACLASA	C	CONTACTO LITOLOGICO
SD	SET DE DIACLASAS	BX	BRECHA
FT	FALLA	VN	VETA
F	FOLIACON	MT	MANTOS
FT	ZONA CIZALLE	DX	DIQUE

ALTERACION	
F	FRESCA
LA	LEVEMENTE ALT
A	ALTERADA
MA	MUY ALTERADA
IA	INTENS ALTERADA

GEOMETRIA

FORMA	
P	PLANAR
O	ONDULADA
I	IRREGULAR

(R) RUGOSIDAD: R RUGOSA | L LISA | E ESTRIADA | P PULIDA

(C) CONTINUIDAD: C CONTINUA | D DISCONTINUA

RELLENO	
SR	SIN RELLENO
	LIMOS Y FRAGMENTOS DE ROCA
	OXIDOS
	SULFURO
	ARCILLA
	PIRITA

AGUA	
S	SECO
H	HUMEDO
Gs	GOTEO SUAVE
T	FLUJO CONSTANTE

CRITERIO GENERALIZADO DE HOEK - BROWN

LF	LEVEMENTE FRACTURADO	MB	MUY BUENA
F	FRACTURADO	B	BUENA
MF	MUY FRACTURADO	R	REGULAR
IF	INTENSAMENTE FRACTURADO	P	POBRE
T	TRITURADO	MP	MUY POBRE

RESISTENCIA ESTIMADA		(Mpa)
R6	EXTREMADAMENTE DURA	> 250
R5	MUY DURA	100 - 250
R4	DURA	50 - 100
R3	MODERADAMENTE DURA	25 - 50
R2	BLANDA	5 - 25
R1	MUY BLANDA	1 - 5
R0	EXTREMADAMENTE BLANDA	0.25 - 1

No D = CANTIDAD DE DISCONTINUIDADES DEL MISMO TIPO ENTRE LOS ESPACIOS MEDIDOS.

APPENDIX A

Engineering Standards Applied in the Project

ASTM D2487 - 17e1

Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)

This standard classifies soils from any geographic location into categories representing the results of prescribed laboratory tests to determine the particle-size characteristics, the liquid limit, and the plasticity index.

The various groupings of this classification system have been devised to correlate in a general way with the engineering behavior of soils. This standard provides a useful first step in any field or laboratory investigation for geotechnical engineering purposes.

Slope Stability Evaluation and Acceptance Standards

Document No.: P/BC 2017-049

Department of Building and Safety

This standard is to provide uniform requirements for evaluation of and standards for acceptance of stability of slopes. These requirements include consideration of pertinent engineering geologic and soils engineering factors of the critical field conditions that may reasonably be expected at the project location. These requirements include documentation and recommendations needed to determine if the site as proposed to be developed has an acceptable level of stability.

Types of Analysis: (a) Deep-Seated Stability; (2) Steep Rock Slope Stability; (3) Surficial Stability; (4) Seismic Stability

Material Properties: (a) Soil properties, including unit weight and shear strength parameters; (b) Shear strength parameters used in stability evaluations may be based upon peak test values; (c) Prior to shear tests, samples are to be soaked to approximate a saturated moisture content.

Geotechnical Design Standard – Minimum Requirements

Manual

Department of Transport and Main Roads

General requirements. Performance requirements. Unreinforced embankments. Reinforced embankments. Cut slopes. Unreinforced cuts. Reinforced cut slopes. Deep foundations. Retaining structures. Embedded retaining walls. Reinforced concrete cantilever retaining walls. Soil nailed walls. Reinforced soil structure RSS walls. Gabion retaining walls. Boulder retaining walls.

ISO 18674-2:2016

Geotechnical monitoring by field instrumentation - Measurement of displacements along a line: Extensometers

This standard specifies the measurement of displacements along a line by means of extensometers carried out for geotechnical monitoring. The standard presents general rules of performance monitoring of the ground, of structures interacting with the ground, of geotechnical fills and of geotechnical works.

The standard is applicable to: monitoring the behavior of soils, fills and rocks; - checking geotechnical designs; deriving geotechnical key parameters; evaluating stability ahead of, during or after construction (e.g. stability of natural slopes, slope cuts, embankments, excavation walls, foundations, dams, refuse dumps, tunnels).

ISO 19434:2017

Mining — Classification of mine accidents

This standard establishes a classification of mine accidents by their origin or causes, by the type of accident, and by their results or consequences. The latter includes only the accidents resulting into consequences on people, not equipment or machinery.

Different categories of causes, types and consequences of mine accidents are briefly defined, and a 3-digit code is assigned to each category. These can be combined to ultimately allocate a unique 15-digit code to each type of mine accident. This code can then be used in statistical analysis. Similarly, an allocated code clearly shows to which categories of causes, type of accident and resulting consequences the mine accident belongs to. The standard is applicable to all surface and underground mines.

APPENDIX B

Multiple Constraints, Restrictions and Limitations Considered in the Project

Geological and Geotechnical Constraints

The following geological constraints were considered in the project: active erosion, uncompacted fill materials, potential flood hazards, weak rock layers, high swelling-shrinkage soils, shallow and unconfirmed groundwater, susceptibility to corrosion and pollution.

Availability of Geological and Geotechnical Data

Part of the required soil and rock information was obtained by laboratory testing of soil and rock samples, as well as from in-situ analysis. Remaining information was obtained from other sources such as reports from technical reports Peruvian Geological Institute, Geological Engineering Chapter of Peruvian Engineers Association, Geological, Mining and Metallurgical Peruvian Institute IGMMP. All required information and data was finally found and made available, and applied to the project.

Uncertainties and Risks

Geotechnical and geological works involve some degree of uncertainty. Geological and geotechnical concepts with respect to structure could be uncertain. On the other hand, economic evaluations have uncertainties related to cost estimation, changing conditions in economically viable sites, changes in geotechnical technology, fluctuations in costs and market conditions, political situation, community relations, etc. All these issues must be carefully analyzed in order to ensure the profitability of the project for the most conservative economic conditions and diversity of scenarios. In this project, all these issues have been considered from a conservative scenario and criteria.

Safety Considerations

Geological and geotechnical activities present diverse safety issues that must be taken into account in the development of the project. It is important to comply with safety standards pointing to satisfy proper safety levels considering their impact in the project budget. Care of human life, well-being and safety is an important issue to take into account throughout the different stages of the project and its life-cycle.

Environment and Sustainability

Geological and geothecnical activities face diverse and broad environmental issues at both local and global levels which could affect the project sustainability. The project considers environmental issues such as potential effluents spills, soil, air and water pollution, habitat protection and biodiversity. The project also considers community relations with local people as an important stakeholder of the project.

Schedule

The project must be completed in one academic semester. It is estimated the project requires an average of 150 hours of teamwork with 4-5 students per team. Considering that, besides the senior design project course, students are enrolled in 3-4 additional courses in the academic semester, students have to plan ahead in order for identify all required activities, distribute the tasks among all team members and, finally, integrate all partial tasks to configure the final project.

Other Constraints

The following constraints have also been considered in the project:

- Geographical and accessibility restrictions that make difficult the transport of materials and equipment.
- Technology availability and applicability in the well(s) area.