NATIONAL UNIVERSITY OF ENGINEERING

PROFESSIONAL SCHOOL OF GEOLOGICAL ENGINEERING

DESIGN OF A SLOPE STABILIZATION SYSTEM FOR A TRAWLING HILL

COURSE: GEOLOGY APPLIED TO CONSTRUCTIONS

PROFESSOR: GONZALES PACHECO GRACIELA

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2016

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).

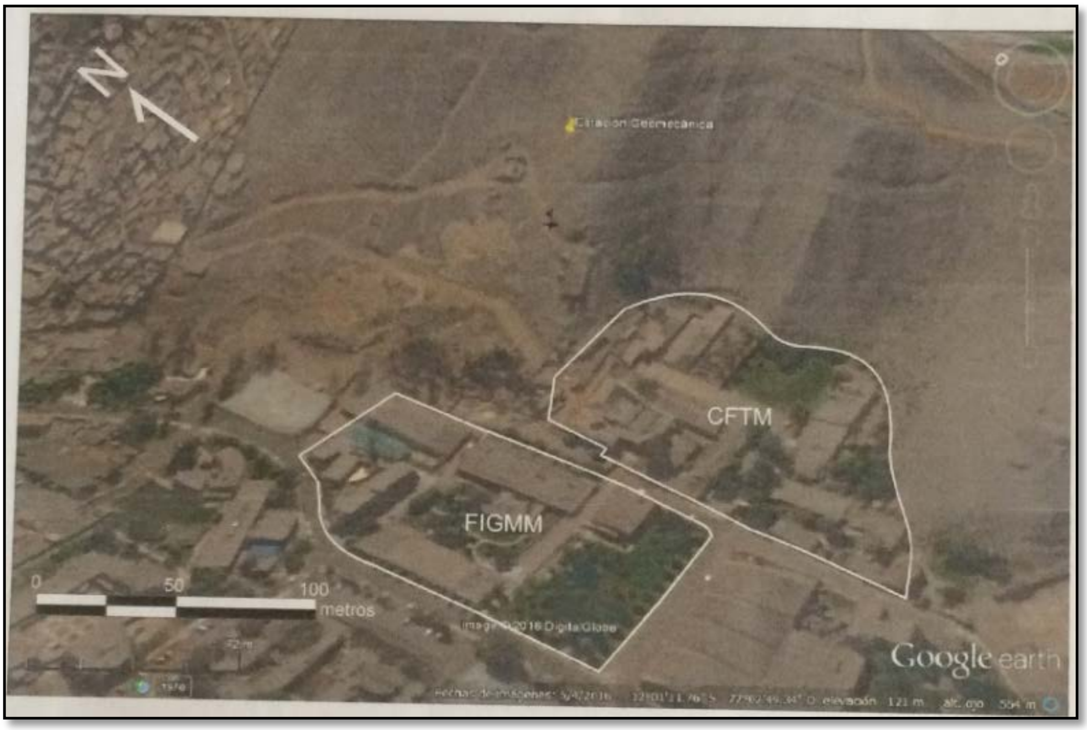

Figure 1: Location of the geomechanical station

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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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 °).

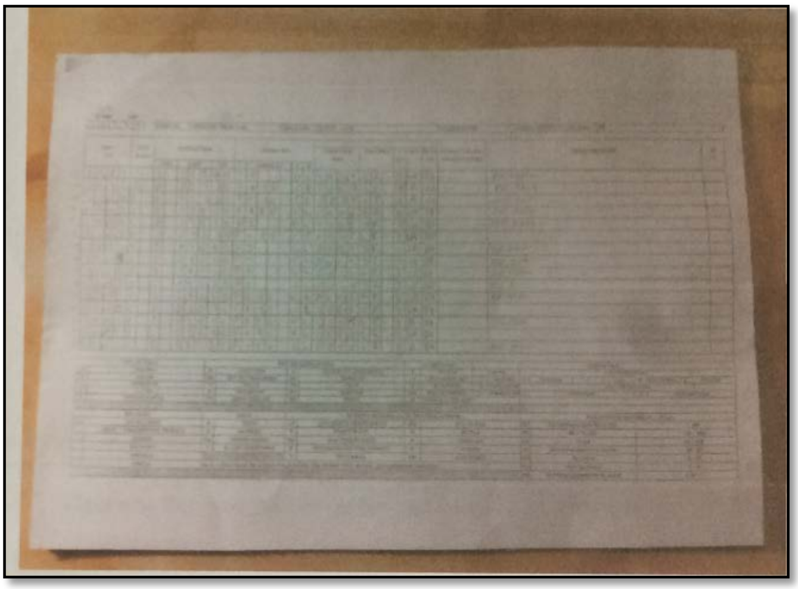

Figure 4: Format filled with field information

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

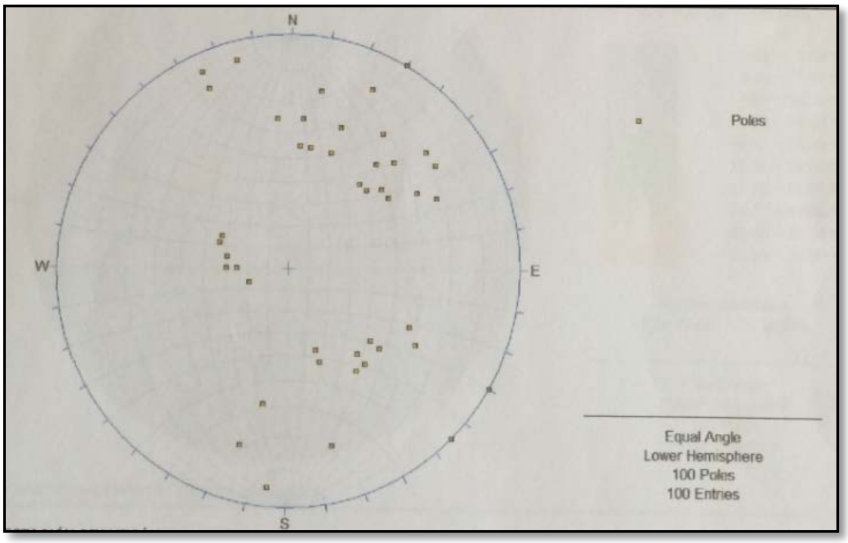

Figure 5: Representation of poles of discontinuities.

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

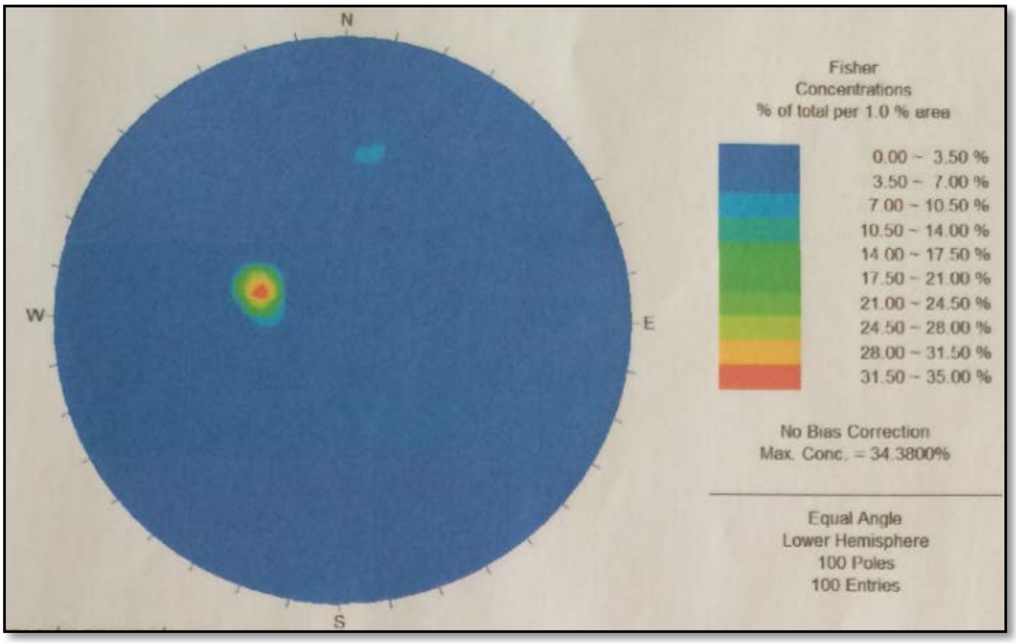

Figure 6: Representation of clouds of concentration of poles.

- 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.

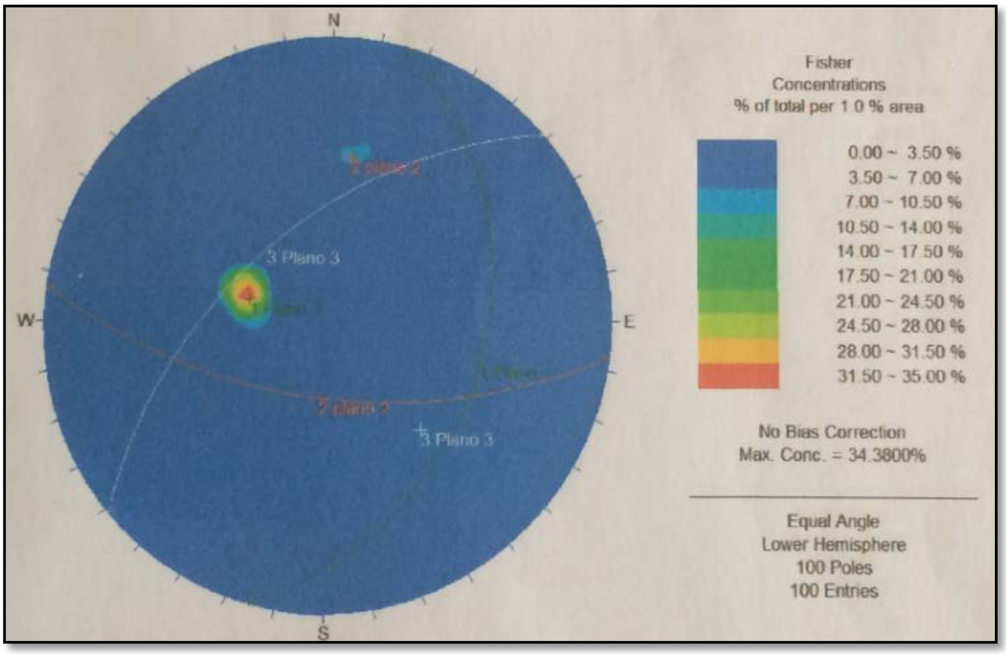

Figure 7: Representation of the planes from the clouds of poles.

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

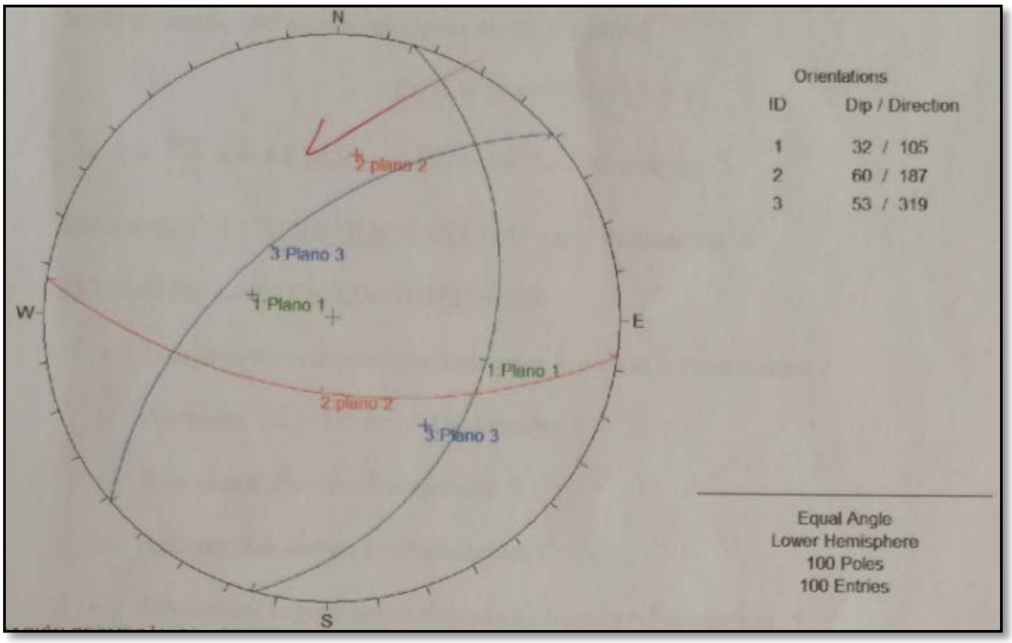

Figure 8: Representation of the planes of discontinuities and their properties.

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

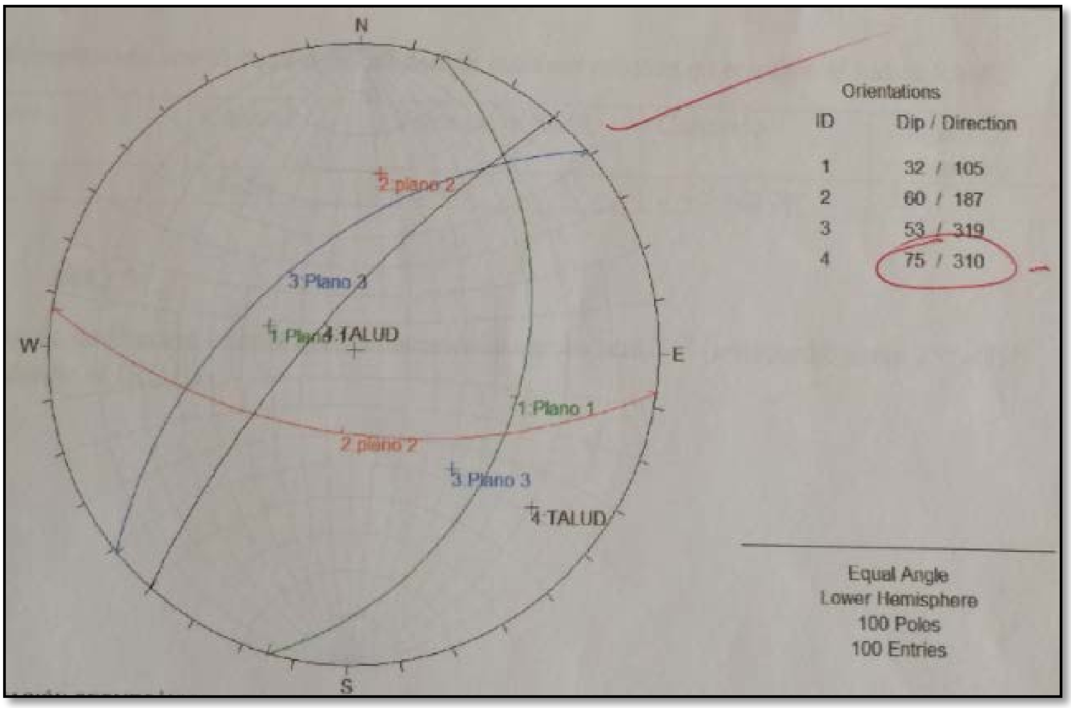

Figure 9: Representation of planes of discontinuity and slope.

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 STABILITY OF TALUD

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 °)

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

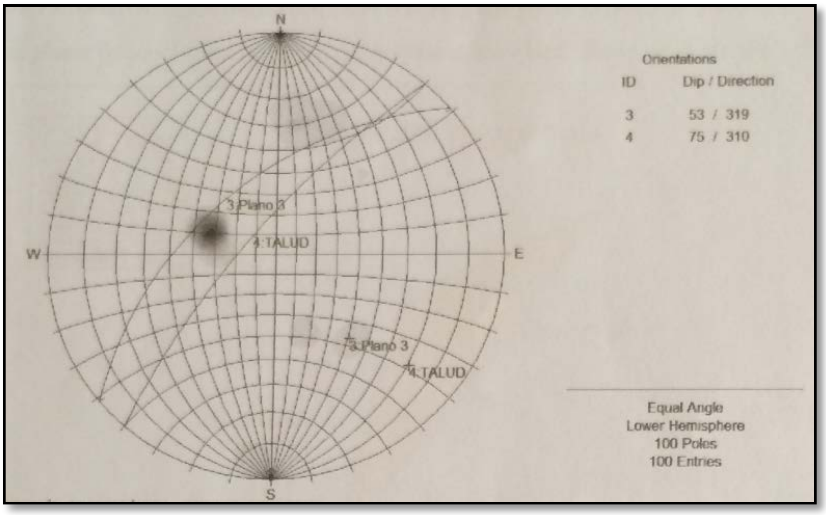

Figure 10: Graphic diagram showing the plane 3 and the plane of the slope.

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.

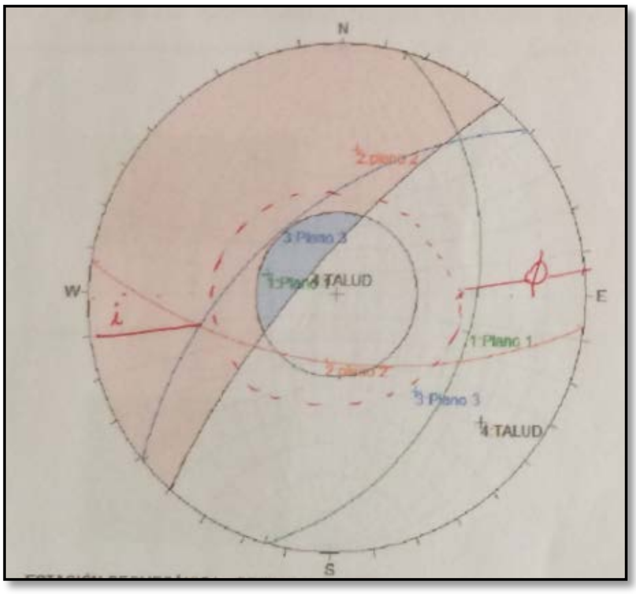

Figure 11: Representation of critical areas for wedge-type rupture.

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 (±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

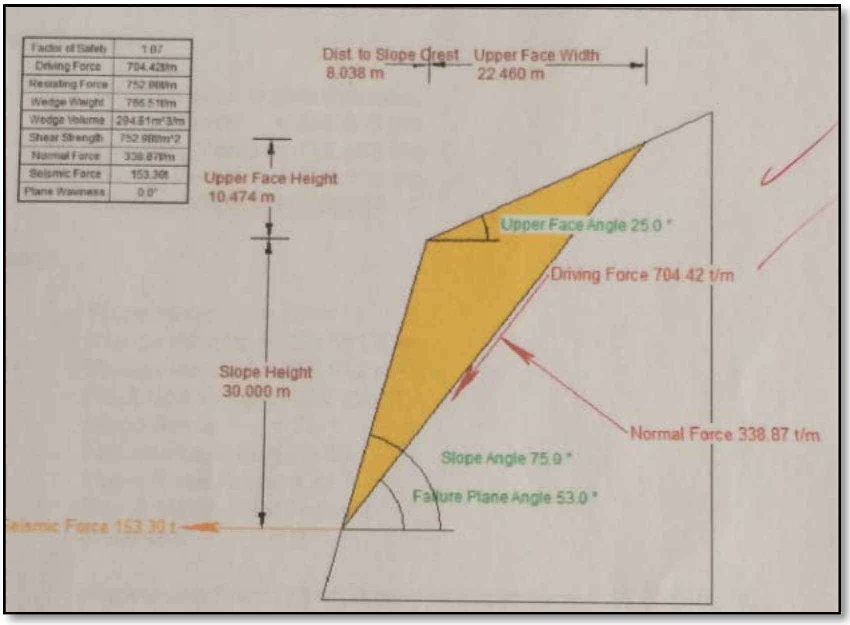

Figure 12: 2D representation of the analysis for the case of planar rupture.

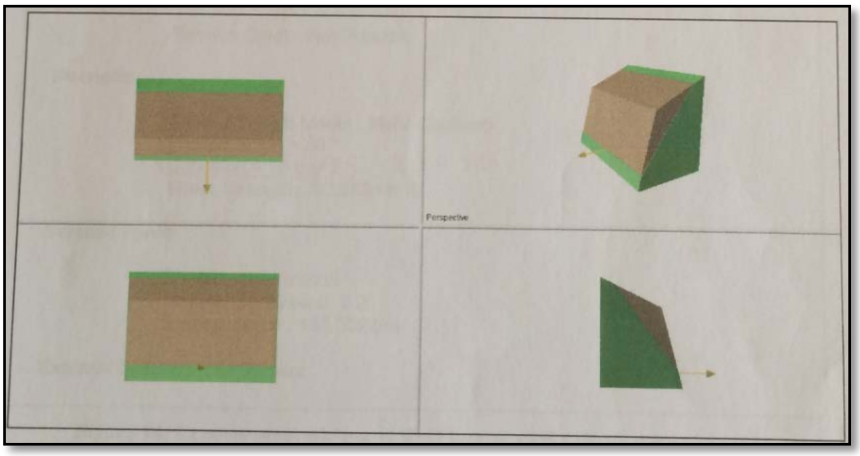

Figure 13: Views and 3D rendering of the planar break case.

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.

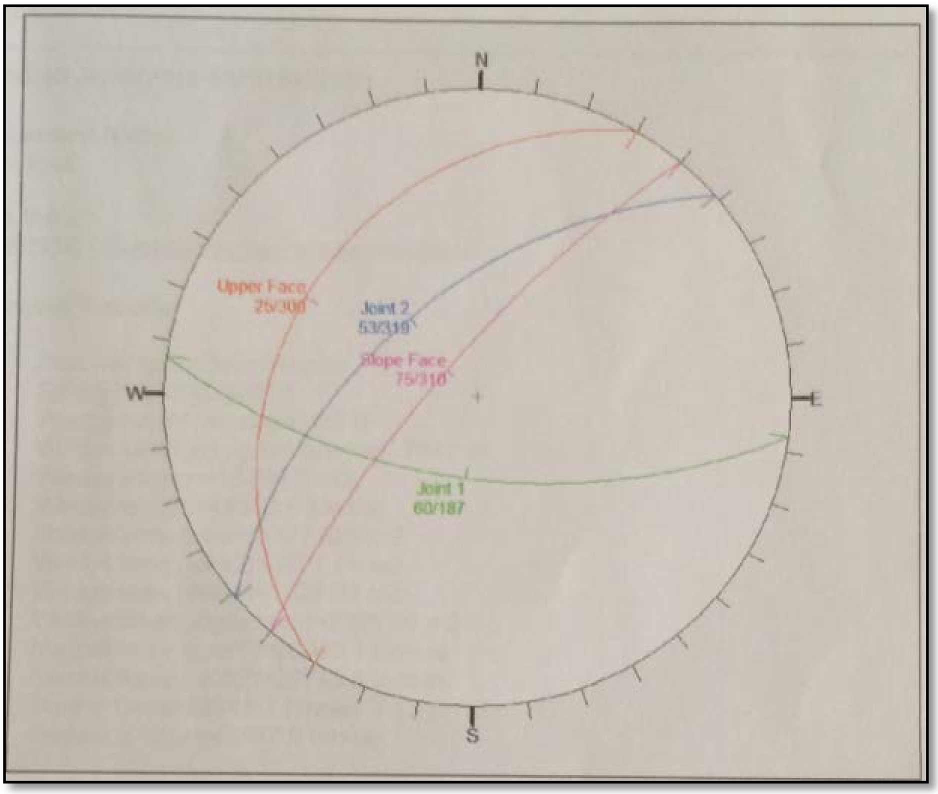

Figure 15: Projection generated with the Swedge, taking only the planes that generate the break.

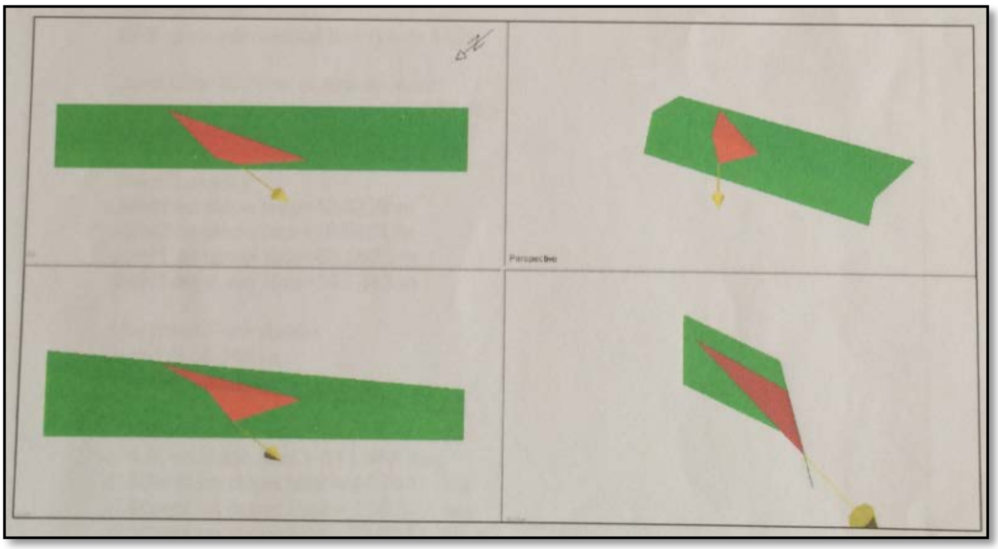

Figure 16: Views and 3D rendering of the planar break case.

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 °).

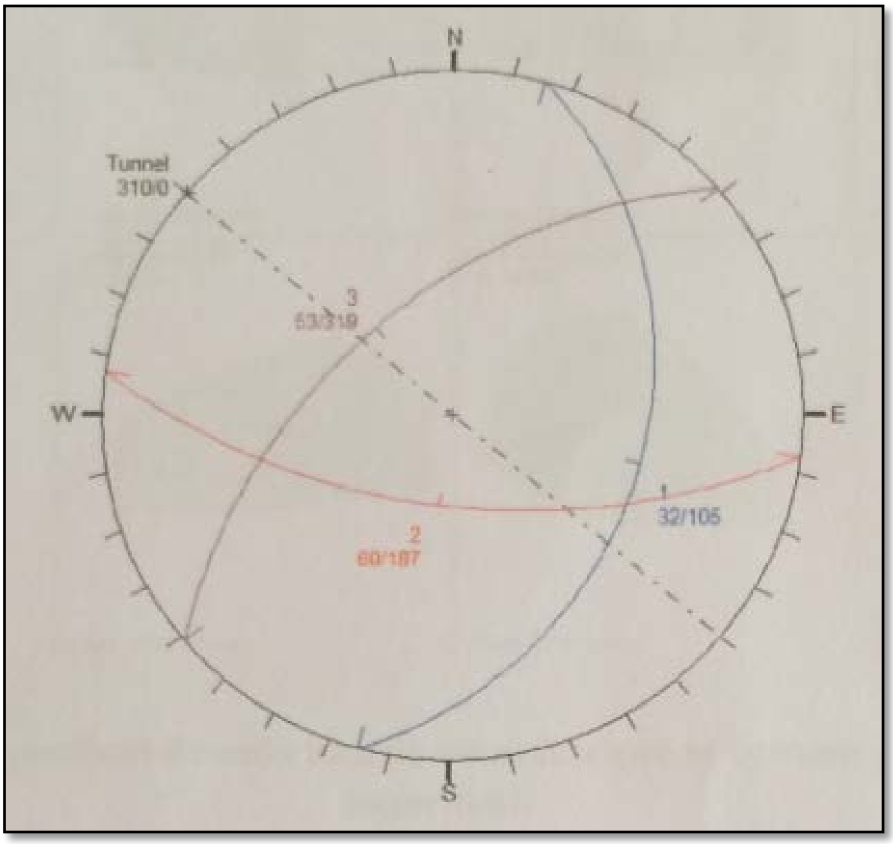

Figure 18: Stereographic projections of the families of discontinuities and the axis of advance of the tunnel (310 °).

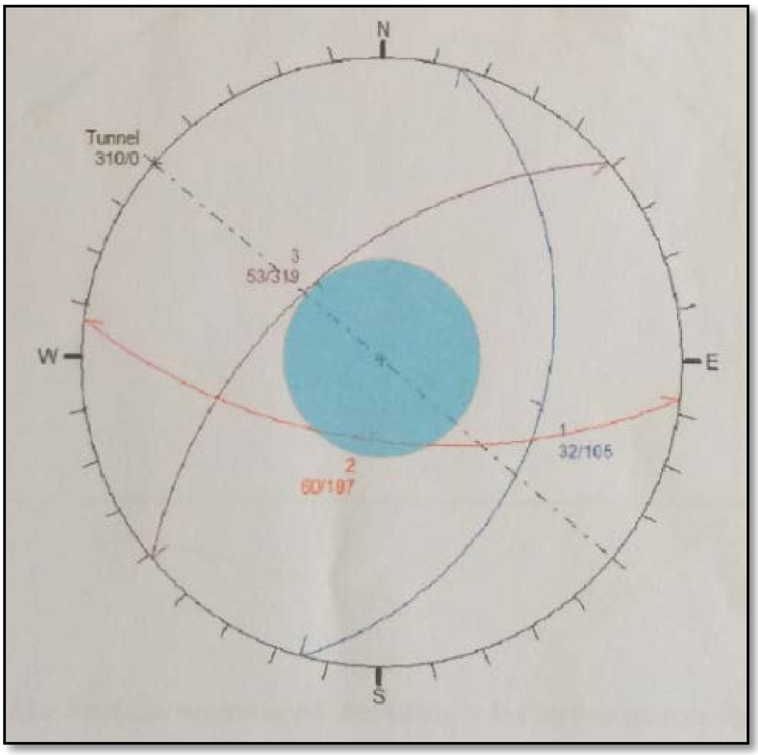

Figure 19: Projections of the families and axis of the tunnel, including the angle of friction (36 °).

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.

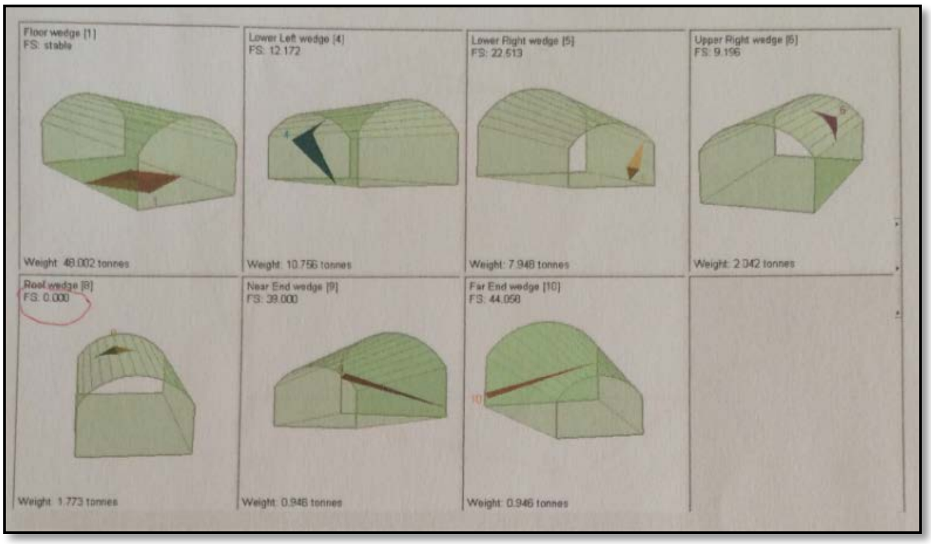

Figure 20: Perspectives of each of the wedges that are formed and their safety factors.

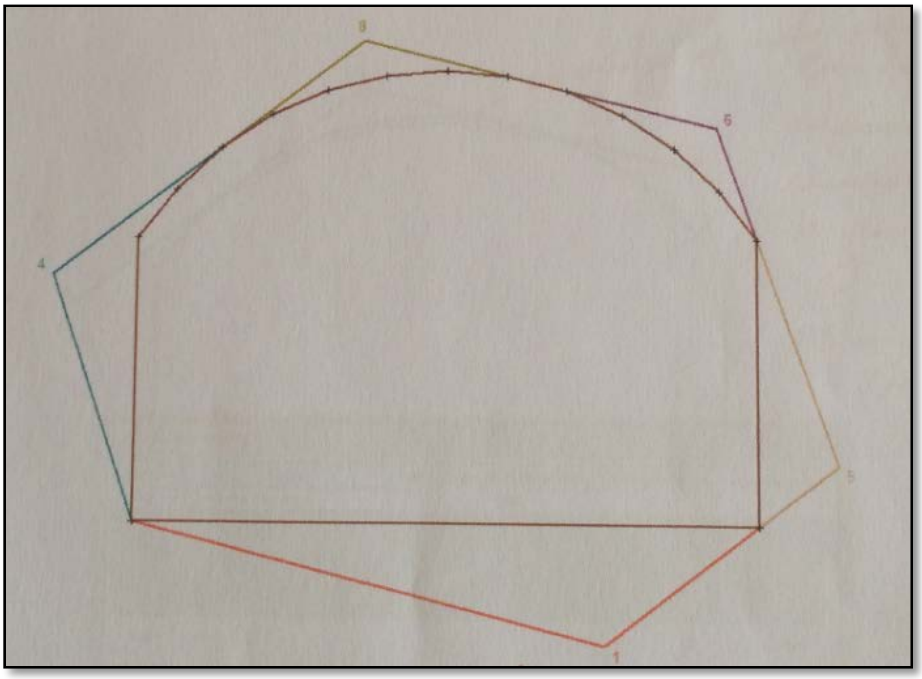

Figure 21: Cross section of the tunnel and wedges that are formed.

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).

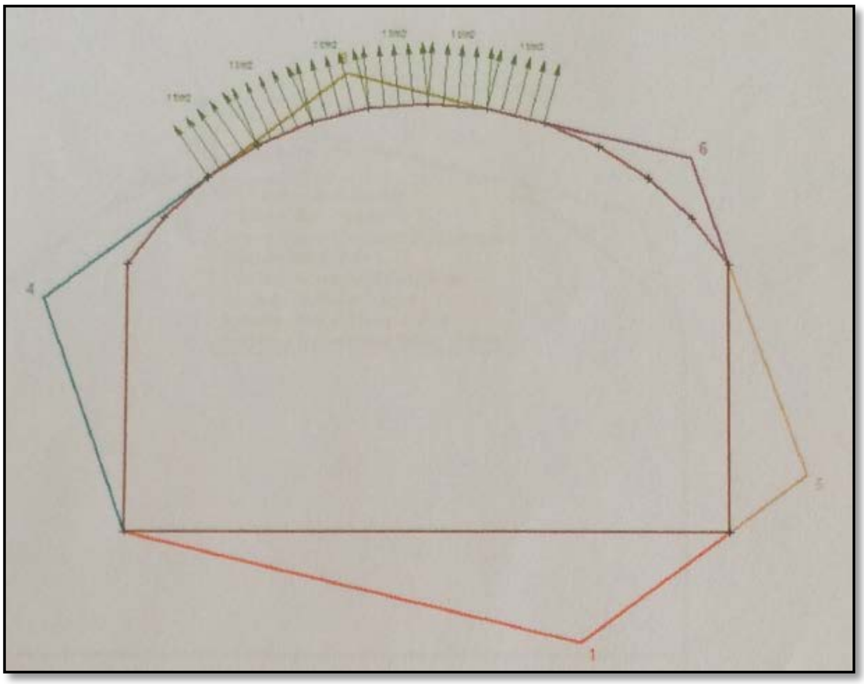

Figure 22: Diagram showing the pressure located on the wedge part 8.

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.

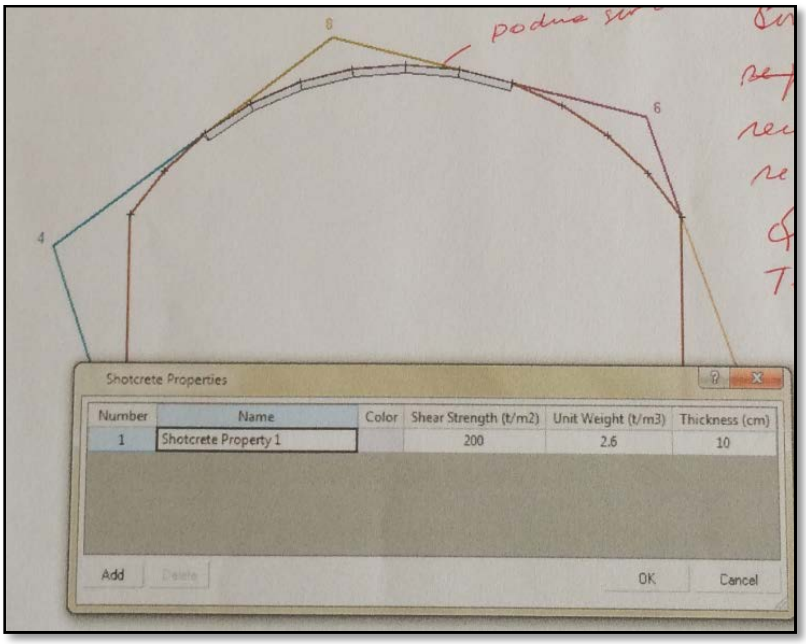

Figure 23: Shotcrete scheme and properties.

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

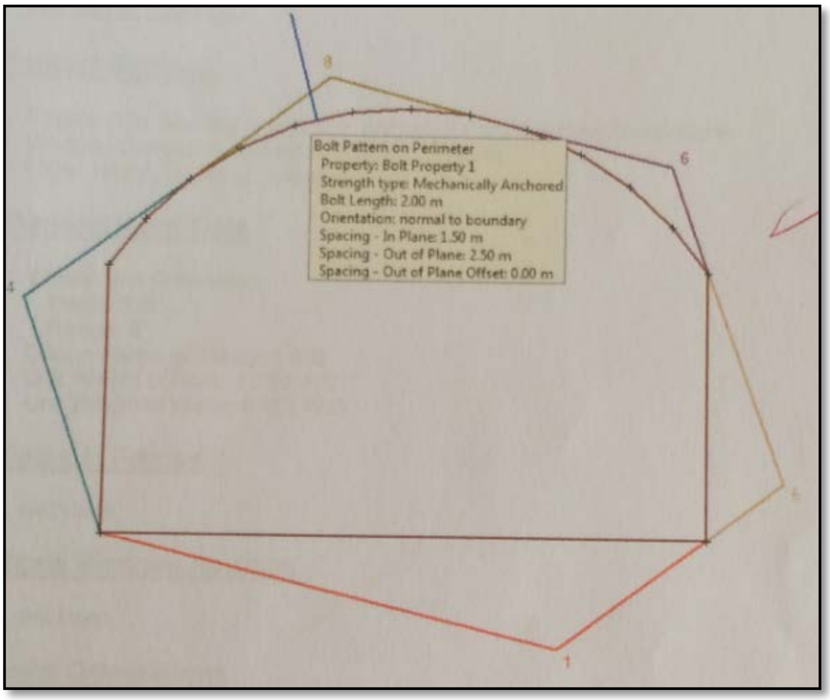

Figure 24: Diagram showing a bolt in the wedge area.

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

AZIM

D DIP	DIP
220	75

22.5

Garay

LINEA No 1 | LONGITUD: 15.4 | cota: | UBICACIÓN: CERRO UNI (E:277795,76) (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
	0 0,0 0	C	D	205	60	P	1 - 2	D	L	0 0 0 9	SR	S	LA	R4		ESP 20cm	
+	0 0,6 0	C	D	125	70	P	1 - 0,6	D	L	0 0 0 1	SR	S	LA	R4			
+	0 0,3 0	C	D	010	30	P	+10	C	E	0 0 1 0	A	S	A	R4		ESCAMIENTO 15cm	
+	0 0,3 5	C	D	210	65	P	0,5	D	L	0 0 0 2	SR	S	LA	R4		ESP. 20cm	
+	0 0,7 0	C	D	010	30	P	+10	C	E	0 0 1 0	A	S	A	R4		ESP. 15cm	
+	0 0,6 0	C	D	010	30	P	+10	C	E	0 0 0 1	A	S	A	R4		ESP. 15cm	
+	0 0,1 0	C	D	065	85	P	1 - 2	D	E	0 0 0 2	A	S	LA	R4			
+	0 0,3 0	C	D	010	30	P	+10	C	E	0 0 0 1	A	S	A	R4		ESP. 15cm	
+	0 0,0 0	C	D	220	55	P	1	D	L	0 0 0 1	SR	S	LA	R4			
+	0 0,2 5	C	D	220	55	P	1	D	L	0 0 0 1	SR	S	LA	R4			
+	0 0,4 0	C	D	010	30	P	+10	C	E	0 0 0 2	A	S	A	R4		ESP. 15cm	
+	0 1,5 0	C	D	220	55	P	1	D	L	0 0 0 1	SR	S	LA	R4			
+	0 0,8 0	C	D	210	90	P	3 - 5	C	E	0 0 0 5	A	S	A	R4			
+	0 0,6 0	C	D	170	55	P	2 - 3	D	R	0 0 0 1	SR	S	LA	R4			
+	0 0,2 5	C	D	280	60	P	3 - 5	C	L	0 0 0 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	FOLIACON	MT	MANTOS
FT	ZONA CIZALLE	DX	DIQUE

ALTERACION	
F	FRESCA
LA	LEVEMENTE ALT
A	ALTERADA
MA	MUY ALTERADA
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	
SR	SIN RELLENO
LR	LIMOS Y FRAGMENTOS DE ROCA
O	OXIDOS
S	SULFURO
A	ARCILLA
P	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	DIP
220	75

LINEA No 1 | LONGITUD 15.4 | cota: | UBICACIÓN: CERRO UNI (E: 277796,96) (N: 8670456,13) | REALIZADO POR: | FECHA: 09/06/16 | HOJA No: 02

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	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	SR	S	LA	R4			
00.20	C	D	085	65	P	5	C	L	000,5	SR	S	LA	R4			
00,00	C	D	250	40	P	2	C	L	000,5	SR	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	4	S	A	R4		ESP 20cm	
00,00	C	D	250	40	P	2	C	L	000,5	SR	S	LA	R4		ESP 5cm	
00,10	C	D	250	40	P	2	C	L	000,5	SR	S	LA	R4		ESP 10cm	
00,00	C	D	000	30	P	10	C	E	000,5	A	S	A	R4		ESP 20cm	
00,30	C	D	130	50	P	+5	C	L	000,5	SR	S	LA	R4			
00,20	C	D	250	40	P	2	C	L	000,5	SR	S	LA	R4			
00,10	C	D	000	25	P	+10	C	L	000,5	SR	S	LA	R4		ESP 20cm	
00,00	C	D	250	40	P	2	C	L	000,5	SR	S	LA	R4			
00,10	C	D	250	40	P	2	C	L	000,5	SR	S	LA	R4		Espaciado 5cm	
01,38	C	D	340	20	P	2	C	L	000,5	SR	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

LINEA No 1 | LONGITUD ~~15,4~~ 22,5 | cota: | UBICACIÓN: CERRO UNI (E: 277176,76) (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	+10	C	E	0001	SR	5	LA	R4			
00,20	C	D	140	55	P	+10	C	L	0001	SR	5	LA	R4			
00,00	C	D	285	75	P	5	D	L	000,5	SR	5	LA	R4			
00,30	C	D	020	35	P	+10	C	E	000,5	SR	5	LA	R4		Esp. 20 cm	
00,10	C	D	090	35	P	+10	C	E	000,5	SR	5	LA	R4			
00,10	C	D	020	35	P	+10	C	E	000,5	SR	5	LA	R4			
00,00	C	D	275	85	P	1	D	L	000,5	SR	5	LA	R4		Esp. 20 cm	
00,20	C	D	020	35	P	+10	C	E	000,5	SR	5	LA	R4			
00,15	C	D	020	35	P	+10	C	E	0004	LR	5	A	R4		Esp. 10 cm	
00,15	C	D	020	35	P	+10	C	E	000,5	SR	5	LA	R4		Esp. 10 cm	
00,15	C	D	020	35	P	+10	C	E	000,5	SR	5	LA	R4		Esp. 10 cm	
00,00	C	D	275	85	P	1	D	L	000,5	SR	5	LA	R4		Esp. 25 cm	
00,05	C	D	235	55	P	+10	C	L	000,5	SR	5	LA	R4		Esp. 35 cm	
00,20	C	D	275	85	P	+1	D	L	000,5	SR	5	LA	R4		Esp. 25 cm	
00,00	C	D	020	35	P	+10	C	E	0002	LR	5	A	R4		Esp. 10 cm	

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	PT	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			
SL	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 - 200
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
220	75

22,5

LINEA No	LONGITUD ~~15,4~~	cota:	UBICACIÓN: CERRO UNI (E: 277194,78) (N: 8670456,13)	REALIZADO POR:	FECHA: 03/10/16	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	000,5	S R	5	LA	R4		ESP. +25cm	
+	00.10	C	D	020	35	P	+10	C	E	0003	L R	5	A	R4		ESP. 10cm	
+	00,20	C	D	020	35	P	+10	C	E	0005	L R	5	A	R4		ESP 10cm	
+	00,00	C	D	235	55	P	+10	C	L	000,5	S R	5	LA	R4		ESP 35cm	
+	00,20	C	D	095	55	P	2	D	L	000,5	S R	5	LA	R4		ESP. 10cm	
+	00,05	C	D	020	35	P	+10	C	E	0002	L R	5	LA	R4			
+	00,15	C	D	110	65	P	5	C	L	000,5	S R	5	LA	R4		ESP. 10cm	
+	00,05	C	D	110	65	P	5	C	L	000,5	S R	5	LA	R4		ESP. 30cm	
+	00,08	C	D	110	65	P	5	C	L	000,5	S R	5	LA	R4		ESP. 10cm	
+	00,15	C	D	110	65	P	5	C	L	000,5	S R	5	LA	R4		ESP. 10cm	
+	00,00	C	D	230	55	P	+10	C	L	000,5	S R	5	LA	R4		ESP. 35cm	
+	00,28	C	D	020	35	P	+10	C	L	000,5	S R	5	LA	R4			
+	00,20	C	D	020	35	P	+10	C	L	0001	L R	5	A	R4		ESP. 15cm	
+	00,18	C	D	020	35	P	+10	C	L	000,5	S R	5	LA	R4			
+	00,40	C	D	020	35	P	+10	C	L	0001	L R	5	A	R4		ESP. 15cm	

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				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
	PIRITA							R1	MUY BLANDA	1 - 5
								R0	EXTREMADAMENTE BLANDA	0,25 - 1

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

Azim
D-DIP DIP
| 2 | 2 | 0 | 7 | 5 |

22.5

LINEA No	LONGITUD: [illegible]	cota:	UBICACIÓN: CERRO UNI	REALIZADO POR:	FECHA: 03/[illegible]	HOJA No: 05

DIST. (m)	TIPO ROCA	ESTRUCTURA D-DIP: 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	
+ 0[illegible],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	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

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: | LONGITUD: 10 ~~19A~~ | 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)	C	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	S	LA	R4			
00,00	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4		ESP. 15cm	
00,30	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4		ESP. 15 cm	
00,25	C	D	026	35	P	+10	C	L	000,5	SR	S	LA	R4		ESP. 15cm	
00,10	C	D	100	75	P	+5	D	L	000,5	SR	S	LA	R4			
00,28	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4		ESP. 15cm	
00,50	C	D	140	75	P	3	D	L	000,5	SR	S	LA	R4			
00,15	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4		ESP. 15cm	
00,15	C	D	135	50	P	1	D	L	000,5	SR	S	LA	R4			
00,20	C	D	065	80	P	1	D	L	000,5	SR	S	LA	R4			
00,00	C	D	145	75	P	4	D	L	000,5	SR	S	LA	R4		ESP. 50cm	
00,10	C	D	255	75	P	3	D	E	000,5	SR	S	LA	R4			
00,33	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4		ESP. 15 cm	
00,10	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4		ESP. 15 cm	
00,23	C	D	020	35	P	+10	C	L	000,5	SR	S	LA	R4		ESP. 15cm	

TIPO DE ROCA		TIPO DE ESTRUCTURA				ALTERACION	
A	PIZARRA	D	DIACLASA	C	CONTACTO LITOLOGICO	F	FRESCA
B	CALIZA	SO	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	
2	2	0	7	5

25.[illegible]

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

DIST. (m)	TIPO ROCA	ESTRUCTURA G21M			GEOMETRIA				ABERTURA (mm)	RELLENO	A (W)	ALT	RESIS (R)	ESTRUCTURA DEL MACIZO ROCOSO	OBSERVACIONES	No D
		TIPO	D-DIP	DIP	F	LARGO (m)	C	R								
00,25	C	D	155	70	P	1	D	L	00,5	SR	S	LA	R4			
00,30	C	D	020	35	P	+10	C	L	00,5	SR	S	LA	R4		ESP. 15cm	
00,00	C	D	100	56	P	1,5	D	L	00,5	SR	S	LA	R4		ESP. 20cm	
00,25	C	D	100	55	P	1,5	D	L	00,5	SR	S	LA	R4		ESP. 20cm	
00,30	C	D	120	90	P	1	D	L	00,5	SR	S	LA	R4			
00,30	C	D	020	35	P	+10	C	L	00,5	SR	S	A	R4		ESP. 15cm	
00,15	C	D	110	65	P	1	D	L	00,5	SR	S	LA	R4			
00,46	C	D	230	50	P	+10	D	L	00,5	SR	S	LA	R4		ESP. 15cm	
00,00	C	D	130	60	P	1	D	L	00,5	SR	S	LA	R4			
00,30	C	D	230	55	P	0,5	D	L	00,5	SR	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		(R) RUGOSIDAD					
P	PLANAR	R	RUGOSA	L	LISA	E	ESTRIADA / P PULIDA
O	ONDULADA	(C) CONTINUIDAD					
I	IRREGULAR	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