

SUPPLEMENTARY MATERIALS

Article

Surface and underground geomechanical characterization of an area affected by instability phenomena in Zaruma mining zone (Ecuador)

Supplementary Materials:

Supplementary Material 1. Parameters used for the susceptibility assessment [65–69].

Parameter	Rock characteristics and conditions	Category	Weight
Lithology	Strong and competent rock	I	0.0
	Rock somewhat weathered and with some weathering degree	II	1.0
	Deteriorated rock (saprolite type) that preserves matrix characteristics	III	2.0
	Very deteriorated saprolites	IV	3.0
	Very erodible residual soils	V	4.0
Structures	Favorable slope position concerning weakening planes	I	0.5
	Slope position somewhat favorable concerning weakening planes	II	1.5 – 2.0
	Weakness planes favor land-slide	III	2.5 – 3.0
	Weakness planes create conditions very favourable to landslide	IV	4.0
Morphometry	Very little slope	I	0.0
	Gentle or medium slope	II	1.0
	Middle slope	III	2.0
	High slope	IV	3.0
	Very high slope	V	4.0
Discontinuities	Spacing between discontinuities spacing more significant than 2.0 m, openings less than 0.1 mm (practically closed). Non-weathered discontinuity.	I	0.0
	60 cm to 2.0 m spacing, 0.1 to 0.5 m discontinuity opening. Discontinuity somewhat affected.	II	1.0
	20 cm to 60 cm spacing, 0.5 to 1.0 m discontinuity opening. Discontinuity somewhat affected.	III	2.0
	6.0 cm to 20 cm spacing, 1.0 to 5.0 m discontinuity opening. Discontinuity affected.	IV	3.0
	Spacing between discontinuities less than 6 cm, aperture greater than 50mm. Discontinuity affected.	V	4.0
Water	There is no presence of water (neither surface nor underground).	I	0.0
	Very little surface waters action. There is some groundwater influence.	II	0.5
	There is an appreciable surface water action. There is groundwater presence.	III	1.0
	There are significant surface water and groundwater presence.	IV	2.0
	There is a lot of influence from surface water and groundwater.	V	3.0
Vegetable cover	The slope is totally covered by an adequate vegetation cover.	I	0.0
	The slope is largely covered by adequate vegetation cover.	II	0.5
	The slope is only partially covered by adequate vegetation cover	III	1.5
	There is little vegetation cover	IV	2.5
	There is no vegetation cover, the slope is completely denuded.	V	3.0
Seismic	There is practically no seismicity.	I	0.0
	It is considered very low seismic action $a_s=(0.2 \text{ a } 0.5)g$	II	1.0
	Low seismicity $a_s=(0.5 \text{ a } 0.10)g$	III	2.0
	It is considered a medium seismicity $a_s=(0.10 \text{ a } 0.14)g$	IV	2.5
	High seismicity $a_s=(0.14 \text{ a } 0.18)g$	V	3.5

	Very high seismicity $a_s > 0.18g$	VI	4.0
Weathering Rank	Soils that are practically without being eroded	I	0.0
	Soils with little erosion	II	0.5
	Soils with medium erosion	III	1.0
	Soils with a significant erosion process	IV	2.0
	Eroded soil	V	3.0
	Very eroded soil	VI	4.0

Supplementary Material 2. Descriptions and ratings for the Jr, Jn, Ja y Jw parameters [34].

Joint roughness number (Jr)		Value
(a) Rock wall contact and (b) Rock wall contact before 10 cm shear.	A. Discontinuos joints	4
	B. Rough or irregular, undulating	3
	C. Smooth, undulating	2
	D. Slickensided, undulating	1.5
	E. Rough or irregular, planar	1.5
	F. Smooth, planar	1.0
	G. Slickensided, planar	0.5
(c) No rock wall contacts when sheared	H. Zone containing clay minerals thick enough to prevent rock wall contact	1.0
	J. Sandy, enough to prevent rock wall contact	1.0
Joint set number (Jn)		
	A. Massive rock	0.5 – 1.0
	B. One family of joints	2
	C. One family of joints with other occasional joints	3
	D. Two families of joints	4
	E. Two families of joints with other occasional joints	5
	F. Three families of joints	9
	G. Three families of joints with other occasional joints	12
	H. Four or more families, highly fractured rock	15
	J. Crushed rock	20
Joint alteration number (Ja)		
	Sound-walled joints	0.75 – 1.0
	Slight alteration	2
	Clay alterations	4
	With gritty detritus	4
	With pre consolidated clay detritus	6
	With unconsolidated clayey detritus	8
	With Expansive clay detritus	8 – 12
	Rock and clay mylonites	5 – 12
	Smooth clay mylonites	5
	Coarse clayey mylonites	10 – 20
Joint water reduction factor (Jw)		
	A. Dry excavations or minor inflow, i.e. <5l/min. locally	1.0
	B. Medium inflow or pressure occasional outwash of joint fillings	0.66
	C. Large inflow or high pressure in competent rock with unfilled joints	0.5
	D. Large inflow or high pressure, considerable outwash of joint fillings	0.33
	E. Exceptionally high inflow or water pressure at blasting, decaying with time	0.2 – 0.1
	F. Exceptionally high inflow or water pressure continuing without noticeable decay	0.1 – 0.05

Supplementary Material 3. Descriptions and ratings for the C.D., Cw, Co, Cs y Cb parameters [35].

Joint orientation (Co)					
No. of joints defining the block	No. of faces inclined away from the vertical				
	70%	75%	80%	85%	90%
3	3		2		
4	4	3		2	
5	5	4	3	2	1
6	6	5	4	3	2 – 1

Blasting Effects (Cb)	
Technique	Adjustment (%)
Boring	100
Smooth-wall blasting	97
Good conventional blasting	94
Poor blasting	80

Weathering (Cw)					
Degree of weathering	Exposure period and adjustments, %				
	½ year	1 year	2 years	3 years	4 + years
Fresh	100	100	100	100	100
Slight	88	90	92	94	96
Moderate	82	84	86	88	90
Hihg	70	72	74	76	78
Complete	56	56	58	60	62
Residual soil	30	32	34	36	38

Tensiones inducidas por actividad minera (Cs)	
Causa	Adjustment (%)
The joints are in compression	120
Risk of a cutting movement	90
Open and thin-filled fissures	76
Major cutting movements	60