Explorações a Céu Aberto: Novos desenvolvimentos

CARACTERIZAÇÃO GEOTÉCNICA DE MACIÇOS ROCHOSOS

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EXPLORAÇÕES A CÉU ABERTO

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MACIÇO ROCHOSO

DESCREVER - MACIÇO E DESCONTINUIDADES (ISRM, GSI)

CLASSIFICAR (RMR, Q, SMR)

PARAMETRIZAR

ZONIFICAR

MODELIZAR e CALCULAR

EXECUTAR e AJUSTAR em OBRA

Maciço Rochoso

Maciço Rochoso

ENTIDADE NATURAL

COM CAPACIDADE PARA ARMAZENAR TENSÕES

FORMADA POR ROCHA – DESCONTINUIDADES - FLUIDOS

Maciço Rochoso

Maciço Rochoso

Descrição de Maciços Rochosos

ESPACIAMIENTOS ENTRE DISCONTINUIDADES. ISRM 1978

INTERVALOS (cm)	SIMBOLOGIA	TERMINOS DESCRIPTIVOS
> 200	F1	MUY ESPACIADA
60 - 200	F2	ESPACIADA
20 - 60	F3	MODERADA
.6 - 20	F4	PRÓXIMAS
< 6	F5	MUY PRÓXIMAS

GRADO DE ALTERACIÓN. ISRM 1978

SÍMBOLO	DESIGNACIÓN	TERMINOS DESCRIPTIVOS
W1	INALTERADO	Sin alteración visible
W2	POCO ALTERADO	Alguna decoloración
W3	ALTERACIÓN MEDIA	Macizo alterado (< 50%)
W4	MUY ALTERADO	Macizo alterado (> 50%)
W5	TOTALMENTE ALTERADO	Macizo desintegrado en suelo

Descrição de Descontinuidades

ORIENTAÇÃO ESPACIAL

ESPAÇAMENTO

PERSISTÊNCIA

RUGOSIDADE

RESISTÊNCIA DAS PAREDES

ABERTURA

ENCHIMENTO

PRESENÇA DE ÁGUA

FAMÍLIAS – TAMANO DOS BLOCOS

ISRM - 1977

Classificação

Observar em modo semi-cuantitativo

Ordenar a observação

Correlacionar – comparar elementos empíricos

Fases preliminares de um projecto

Melhorar o potencial de diagnose e prognose

Em fases avançadas de projecto: consoante a maior quantidade de dados disponíveis, outros métodos mais precisos devem ser utilizados

Clasificación

Clasificação de Maciços Rochosos

(BIENIAWSKI)

$$RMR = \sigma_{ci} + RQD + ESP.DISC. + AGUA$$

(BARTON, ET AL)

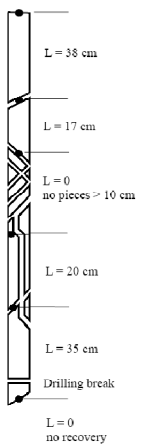
$$Q = RQD/Jn \cdot Jr/Ja \cdot Jw/SRF$$

(ROMANA, M)

$$SMR = RMR + (F1 \cdot F2 \cdot F3) + F4$$

Classificação – RQD%

RQD % - Donald Deere



Total length of core run = 200 cms

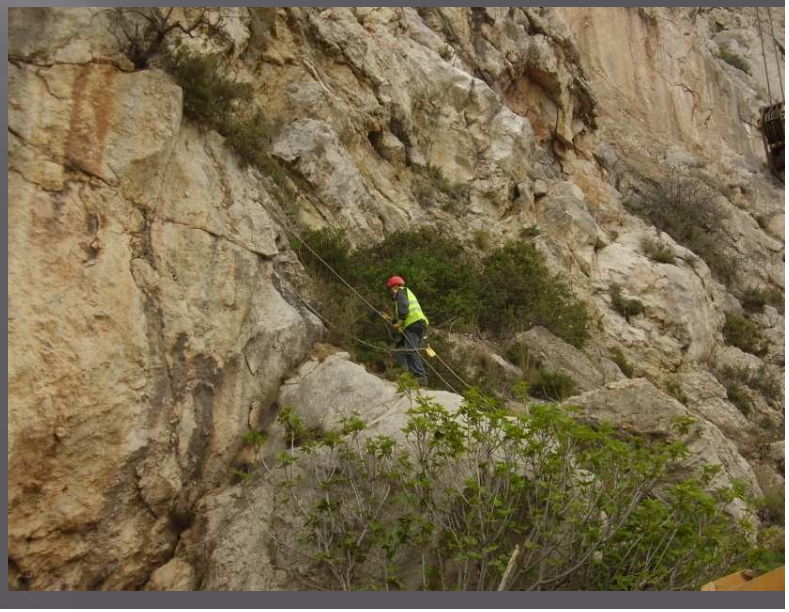
$$RQD = \frac{\Sigma \text{ Length of core pieces} > 10 \text{ cm length}}{\text{Total length of core run}} \times 100$$

$$RQD = \frac{38 + 17 + 20 + 35}{200} \times 100 = 55\ \%$$

RQD a partir de afloramentos:

RQD = 115 – 3.3 Jv

Jv: soma das descontinuidades por unidade de comprimento. Não considerar fracturas produzidas por explosivos.



Classificação - Bieniawski, 1989

Clasificación geomecánica RMR (Bieniawski, 1989)

Parámetros de clasificación

1	Resistencia de la matriz rocosa (MPa)	Ensayo de carga puntual	> 10	10-4	4-2	2-1	Compresión simple (MPa)		
		Compresión simple	> 250	250-100	100-50	50-25	25-5	5-1	< 1
	Puntuación		15	12	7	4	2	1	0
2	RQD		90 %-100 %	75 %-90 %	50 %-75 %	25 %-50 %	< 25 %		
	Puntuación		20	17	13	6	3		
3	Separación entre diaclasas		> 2 m	0,6-2 m	0,2-0,6 m	0,06-0,2 m	< 0,06 m		
	Puntuación		20	15	10	8	5		
4	Estado de las discontinuidades	Longitud de la discontinuidad	<1 m	1-3 m	3-10 m	10-20 m	>20 m		
		Puntuación	6	4	2	1	0		
		Abertura	Nada	<0,1 mm	0,1-1,0 mm	1-5 mm	>5 mm		
		Puntuación	6	5	3	1	0		
		Rugosidad	Muy rugosa	Rugosa	Ligeramente rugosa	Ondulada	Suave		
		Puntuación	6	5	3	1	0		
		Relleno	Ninguno	Relleno duro <5 mm	Relleno duro >5 mm	Relleno blando <5 mm	Relleno blando >5 mm		
		Puntuación	6	4	2	2	0		
		Alteración	Inalterada	Ligeramente alterada	Moderadamente alterada	Muy alterada	Descompuesta		
		Puntuación	6	5	3	1	0		
5	Agua freática	Caudal por 10 m de túnel	Nulo	<10 litros/min	10-25 litros/min	25-125 litros/min	> 125 litros/min		
		Relación: Presión de agua/Tensión principal mayor	0	0-0,1	0,1-0,2	0,2-0,5	> 0,5		
		Estado general	Seco	Ligeramente húmedo	Húmedo	Goteando	Agua fluyendo		
	Puntuación		15	10	7	4	0		

Classificação

Corrección por la orientación de las discontinuidades

Dirección y buzamiento		Muy favorables	Favorables	Medias	Desfavorables	Muy desfavorables
Puntuación	Túneles	0	−2	−5	−10	−12
	Cimentaciones	0	−2	−7	−15	−25
	Taludes	0	−5	−25	−50	−60

Clasificación

Clase	I	II	III	IV	V
Calidad	Muy buena	Buena	Media	Mala	Muy mala
Puntuación	100-81	80-61	60-41	40-21	< 20

Classificação

Calidad de macizos rocosos en relación al índice RMR

Clase	Calidad	Valoración RMR	Cohesión	Ángulo de rozamiento
I	Muy Buena	100-81	> 4 kg/cm²	> 45°
II	Buena	80-61	3-4 kg/cm²	35°-45°
III	Media	60-41	2-3 kg/cm²	25°-35°
IV	Mala	40-21	1-2 kg/cm²	15°-25°
V	Muy mala	< 20	< 1 kg/cm²	< 15°

Classificação

Barton, et al, 1974...

DESCRIPTION	VALUE	NOTES
1. ROCK QUALITY DESIGNATION	*RQD*	
A. Very poor	0 - 25	1. Where *RQD* is reported or measured as ≤ 10 (including 0), a nominal value of 10 is used to evaluate Q.
B. Poor	25 - 50	
C. Fair	50 - 75	
D. Good	75 - 90	2. *RQD* intervals of 5, i.e. 100, 95, 90 etc. are sufficiently accurate.
E. Excellent	90 - 100	
2. JOINT SET NUMBER	J_n	
A. Massive, no or few joints	0.5 - 1.0	
B. One joint set	2	
C. One joint set plus random	3	
D. Two joint sets	4	
E. Two joint sets plus random	6	
F. Three joint sets	9	1. For intersections use $(3.0 \times J_n)$
G. Three joint sets plus random	12	
H. Four or more joint sets, random, heavily jointed, 'sugar cube', etc.	15	2. For portals use $(2.0 \times J_n)$
J. Crushed rock, earthlike	20	

Classificação

3. JOINT ROUGHNESS NUMBER	J_r	
a. Rock wall contact		
b. Rock wall contact before 10 cm shear		
A. Discontinuous joints	4	
B. Rough and irregular, undulating	3	
C. Smooth undulating	2	
D. Slickensided undulating	1.5	1. Add 1.0 if the mean spacing of the relevant joint set is
E. Rough or irregular, planar	1.5	greater than 3 m.
F. Smooth, planar	1.0	
G. Slickensided, planar	0.5	2. J_r = 0.5 can be used for planar, slickensided joints having
c. No rock wall contact when sheared		lineations, provided that the lineations are oriented for
H. Zones containing clay minerals thick	1.0	minimum strength.
enough to prevent rock wall contact	(nominal)	
J. Sandy, gravely or crushed zone thick	1.0	
enough to prevent rock wall contact	(nominal)	

4. JOINT ALTERATION NUMBER	J_a	ϕr degrees (approx.)	
a. Rock wall contact			
A. Tightly healed, hard, non-softening,	0.75		1. Values of ϕr, the residual friction angle,
impermeable filling			are intended as an approximate guide
B. Unaltered joint walls, surface staining only	1.0	25 - 35	to the mineralogical properties of the
C. Slightly altered joint walls, non-softening	2.0	25 - 30	alteration products, if present.
mineral coatings, sandy particles, clay-free			
disintegrated rock, etc			
D. Silty-, or sandy-clay coatings, small clay-	3.0	20 - 25	
fraction (non-softening)			
E. Softening or low-friction clay mineral coatings,	4.0	8 - 16	
i.e. kaolinite, mica. Also chlorite, talc, gypsum			
and graphite etc., and small quantities of swelling			
clays. (Discontinuous coatings, 1 - 2 mm or less)			

Classificação

4. JOINT ALTERATION NUMBER	J_a	ϕr degrees (approx.)
b. Rock wall contact before 10 cm shear		
F. Sandy particles, clay-free, disintegrating rock etc.	4.0	25 - 30
G. Strongly over-consolidated, non-softening clay mineral fillings (continuous < 5 mm thick)	6.0	16 - 24
H. Medium or low over-consolidation, softening clay mineral fillings (continuous < 5 mm thick)	8.0	12 - 16
J. Swelling clay fillings, i.e. montmorillonite, (continuous < 5 mm thick). Values of J_a depend on percent of swelling clay-size particles, and access to water.	8.0 - 12.0	6 - 12
c. No rock wall contact when sheared		
K. Zones or bands of disintegrated or crushed	6.0	
L. rock and clay (see G, H and J for clay	8.0	
M. conditions)	8.0 - 12.0	6 - 24
N. Zones or bands of silty- or sandy-clay, small clay fraction, non softening	5.0	
O. Thick continuous zones or bands of clay	10.0 - 13.0	
P. & R. (see G,H and J for clay conditions)	6.0 - 24.0	

Classificação

5. JOINT WATER REDUCTION	J_w	approx. water pressure (kgf/cm^2)	
A. Dry excavation or minor inflow i.e. < 5 l/m locally	1.0	< 1.0	
B. Medium inflow or pressure, occasional outwash of joint fillings	0.66	1.0 - 2.5	
C. Large inflow or high pressure in competent rock with unfilled joints	0.5	2.5 - 10.0	1. Factors C to F are crude estimates; increase J_w if drainage installed.
D. Large inflow or high pressure	0.33	2.5 - 10.0	
E. Exceptionally high inflow or pressure at blasting, decaying with time	0.2 - 0.1	> 10	2. Special problems caused by ice formation are not considered.
F. Exceptionally high inflow or pressure	0.1 - 0.05	> 10	

6. STRESS REDUCTION FACTOR	*SRF*	
a. Weakness zones intersecting excavation, which may cause loosening of rock mass when tunnel is excavated		
A. Multiple occurrences of weakness zones containing clay or chemically disintegrated rock, very loose surrounding rock any depth)	10.0	1. Reduce these values of *SRF* by 25 - 50% but only if the relevant shear zones influence do not intersect the excavation
B. Single weakness zones containing clay, or chemically disintegrated rock (excavation depth < 50 m)	5.0	
C. Single weakness zones containing clay, or chemically disintegrated rock (excavation depth > 50 m)	2.5	
D. Multiple shear zones in competent rock (clay free), loose surrounding rock (any depth)	7.5	
E. Single shear zone in competent rock (clay free). (depth of excavation < 50 m)	5.0	
F. Single shear zone in competent rock (clay free). (depth of excavation > 50 m)	2.5	
G. Loose open joints, heavily jointed or 'sugar cube', (any depth)	5.0	

Classificação

6. STRESS REDUCTION FACTOR			*SRF*
b. Competent rock, rock stress problems			
	σ_c/σ_1	$\sigma_t\sigma_1$	
H. Low stress, near surface	> 200	> 13	2.5
J. Medium stress	200 - 10	13 - 0.66	1.0
K. High stress, very tight structure (usually favourable to stability, may be unfavourable to wall stability)	10 - 5	0.66 - 0.33	0.5 - 2
L. Mild rockburst (massive rock)	5 - 2.5	0.33 - 0.16	5 - 10
M. Heavy rockburst (massive rock)	< 2.5	< 0.16	10 - 20
c. Squeezing rock, plastic flow of incompetent rock under influence of high rock pressure			
N. Mild squeezing rock pressure			5 - 10
O. Heavy squeezing rock pressure			10 - 20
d. Swelling rock, chemical swelling activity depending on presence of water			
P. Mild swelling rock pressure			5 - 10
R. Heavy swelling rock pressure			10 - 15

2. For strongly anisotropic virgin stress field (if measured): when $5 \leq \sigma_1/\sigma_3 \leq 10$, reduce σ_c to $0.8\sigma_c$ and σ_t to $0.8\sigma_t$. When $\sigma_1/\sigma_3 > 10$, reduce σ_c and σ_t to $0.6\sigma_c$ and $0.6\sigma_t$, where σ_c = unconfined compressive strength, and σ_t = tensile strength (point load) and σ_1 and σ_3 are the major and minor principal stresses.
3. Few case records available where depth of crown below surface is less than span width. Suggest *SRF* increase from 2.5 to 5 for such cases (see H).

Classificação de Romana

SMR = RMR + (F1 . F2 . F3) + F4

SMR	Plane/failures	Wedge	
> 75	None	None	
60-75	None	Some	
40-55	Big	Many	
15-40	Major	No	
SMR	**Toppling failures**	**SMR**	**Soil-like failures**
> 65	None	30	None
50-65	Minor	10-30	Possible
30-35	Major		

Classificação de Romana

Table 18. Recommended Support Measures for Each Stability Class

Class	SMR	Support
Ia	91-100	None
Ib	81-90	None. Scaling
II a	71-80	(None. Toe ditch or fence)
		Spot bolting
II b	61-70	Toe ditch or fence. Nets
		Spot or systematic bolting
III a	51-60	Toe ditch and/or nets
		Spot or systematic bolting
		Spot shotcrete
III b	41-50	(Toe ditch and/or nets)
		Systematic bolting. Anchors
		Systematic shotcrete
		Toe wall and/or dental concrete
IV a	31-40	Anchors
		Systematic shotcrete
		Toe wall and/or concrete
		(Reexcavation) Drainage
IV b	21-30	Systematic reinforced shotcrete
		Toe wall and/or concrete
		Reexcavation. Deep drainage
V a	11-20	Gravity or anchored wall
		Reexcavation

(i) Very often several different support methods are used in the same slope.

(ii) Less usual support measures are in brackets

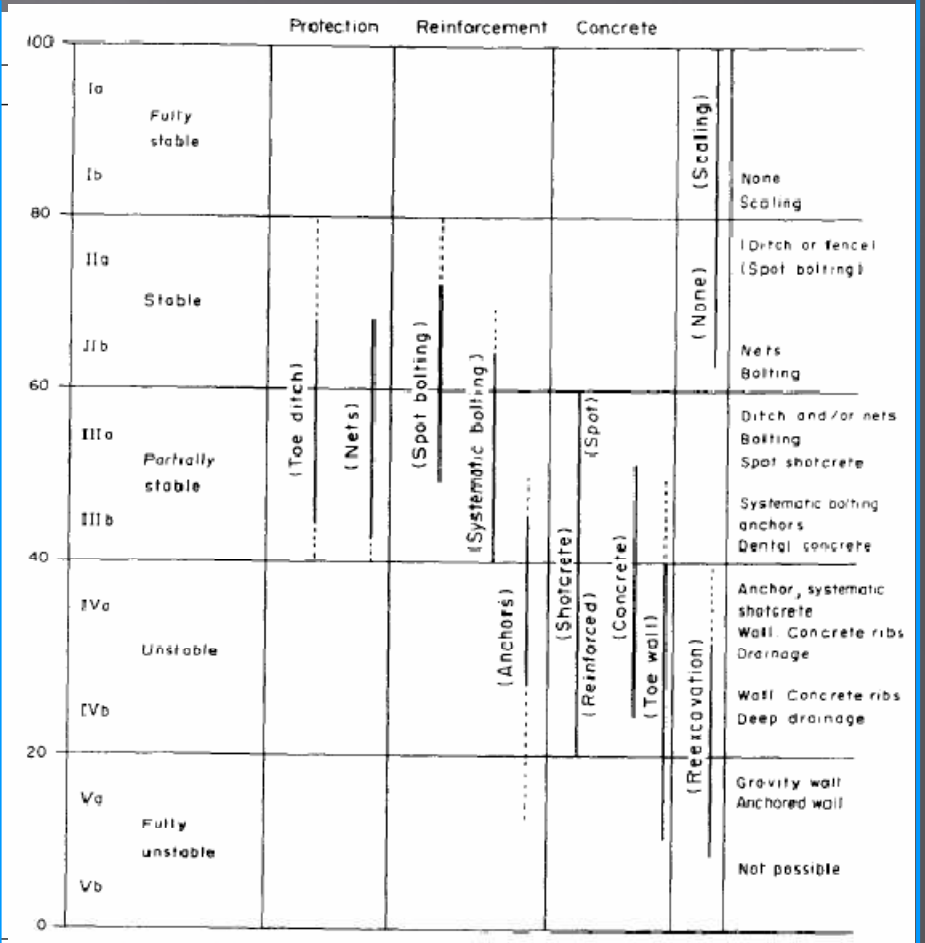


Figure 5. Correction methods according to SMR range

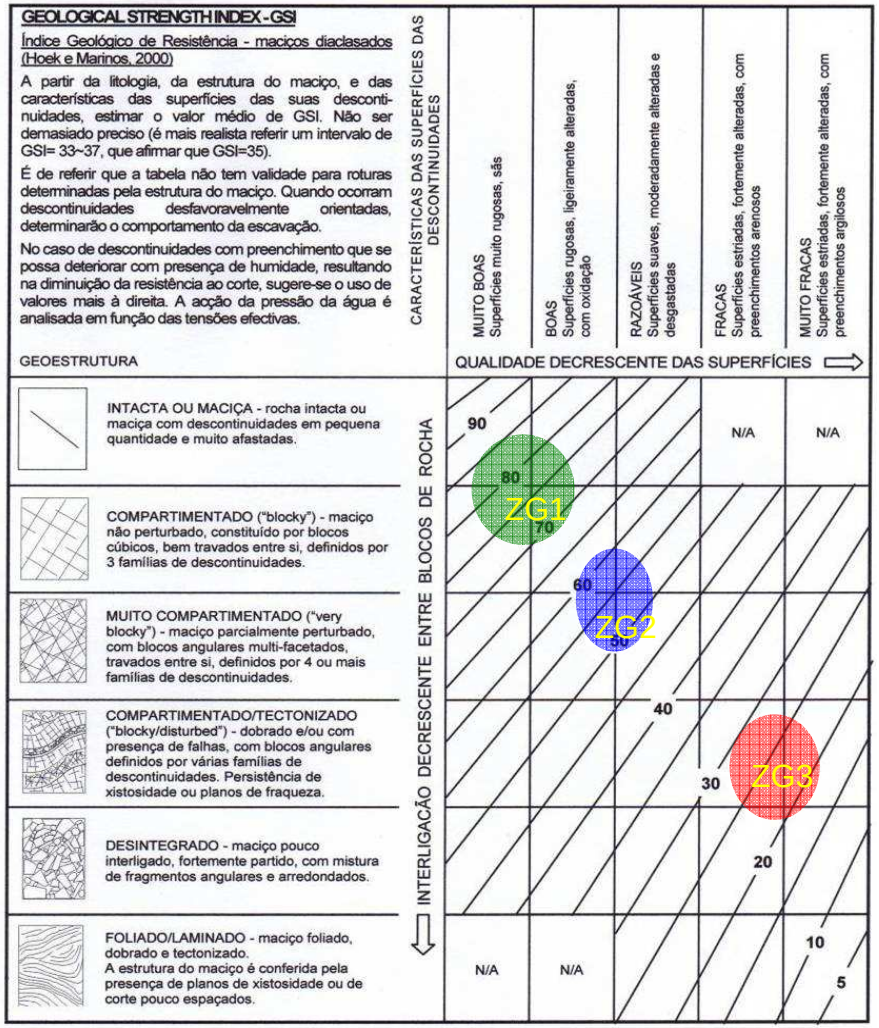
GSI

(Hoek, 2000)

ZG1

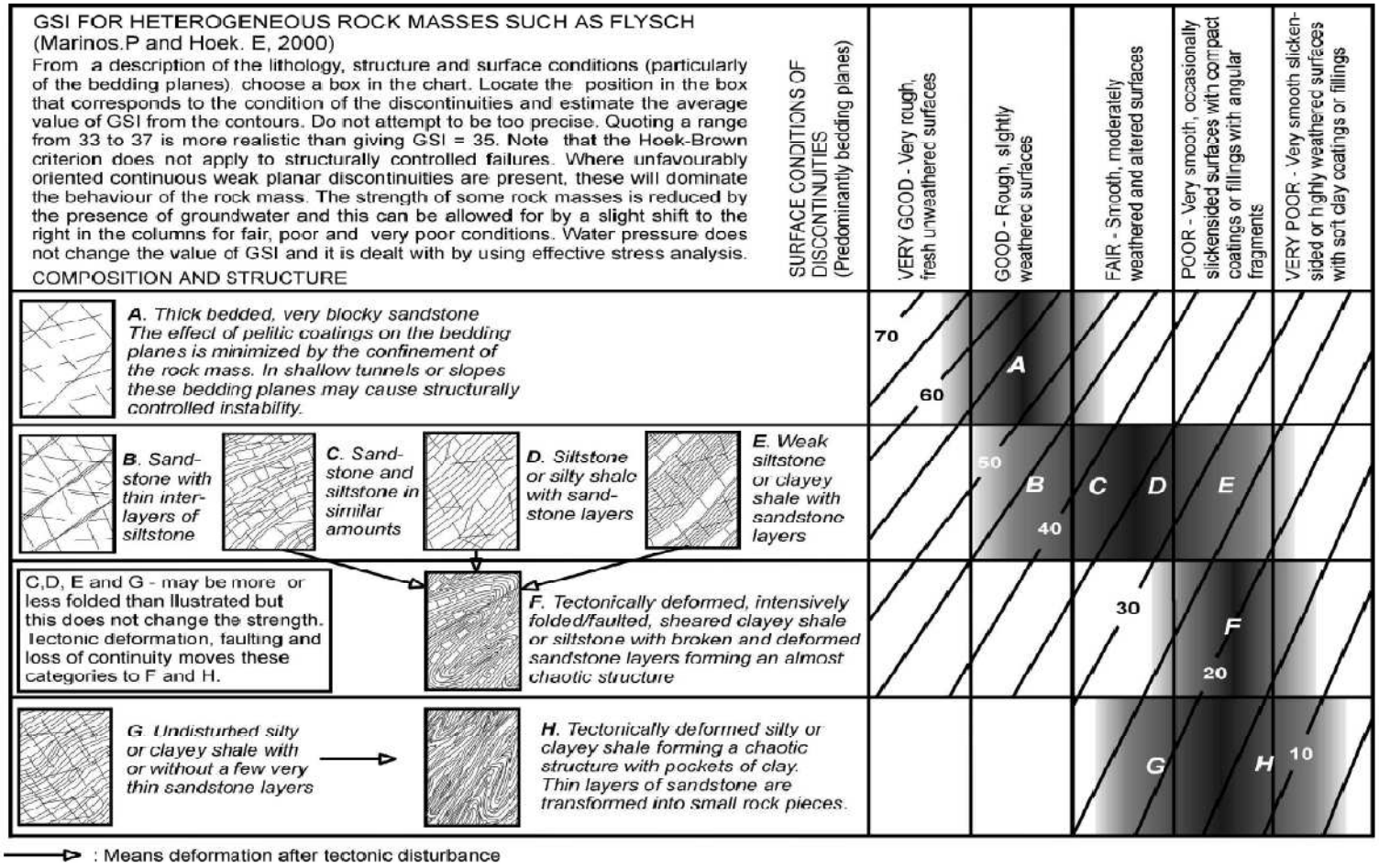
ZG2

ZG3



GSI

GSI de maciços heterogéneos, como Flysch (Marinos - Hoek, 2001)



GSI

GSI de maciços heterogéneos, como Flysch (Marinos - Hoek, 2001)

Modelo Geológico-Geotécnico

MODELO GEOLÓGICO

Características naturales del macizo en la escala, extensión y profundidad propias de cada obra

1. Litología del macizo:
   a. Petrología
   b. Grado de Alteración

2. Estructura del macizo:
   a. Sistema de discontinuidades
      i. Distribución espacial
      ii. Abertura
      iii. Rugosidad
      iv. Relleno

   b. Discontinuidades singulares
      i. Fallas
      ii. Zonas de cizalla

   c. Foliación, clivaje, esquistosidad

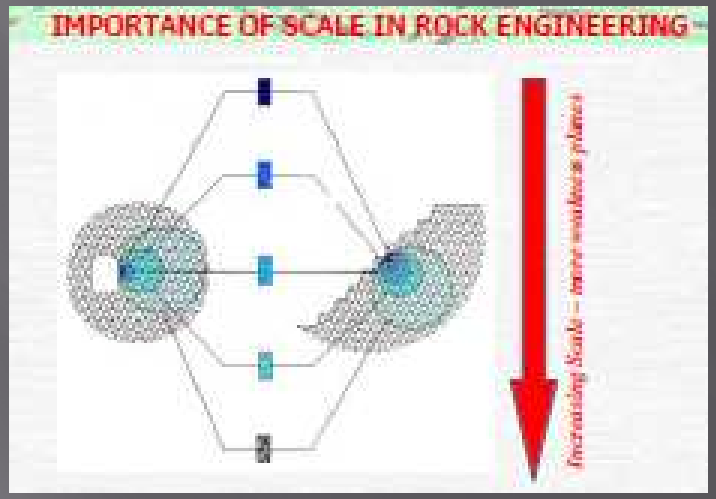
3. Permeabilidad

Modelo Geomecânico

Deformabilidade
Resistência

Modelo Geomecânico

Deformabilidade
Resistência



Deformabilidade de Maciços Rochosos

Deformabilidade de Maciços Rochosos - Anisotropia

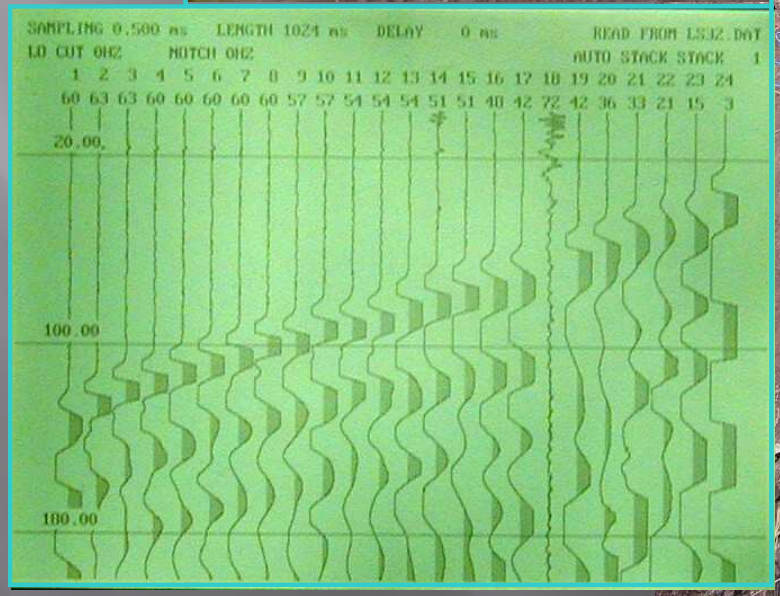
Sistemas de simetría	nº de Coeficientes de la matriz de Deformabilidade
Isótropo-Esférico	2 (E, v)
Cúbico	3 (E, v, G)
Transversal isótropo o axial	5 (2 E, 2 v, G)
Tetragonal	6 (2 E, 2 v, 2 G)
Ortotrópico	9 (3E, 3 v, 3 G)
Monoclínico-Triclínico	13 – 21 (isotropía)

Deformabilidade de Maciços Rochosos

* COMPRESÃO UNIAXIAL	1
* COMPRESÃO TRIAXIAL	3 - 5
* DILATÓMETRO NX (BHD)	10
* GRANDES MACACOS PLANOS (LFJ)	50
* CARGA COM PLACAS (PBT)	80
• PRESURIZAÇÃO DE GALERIAS (OBERTI)	800

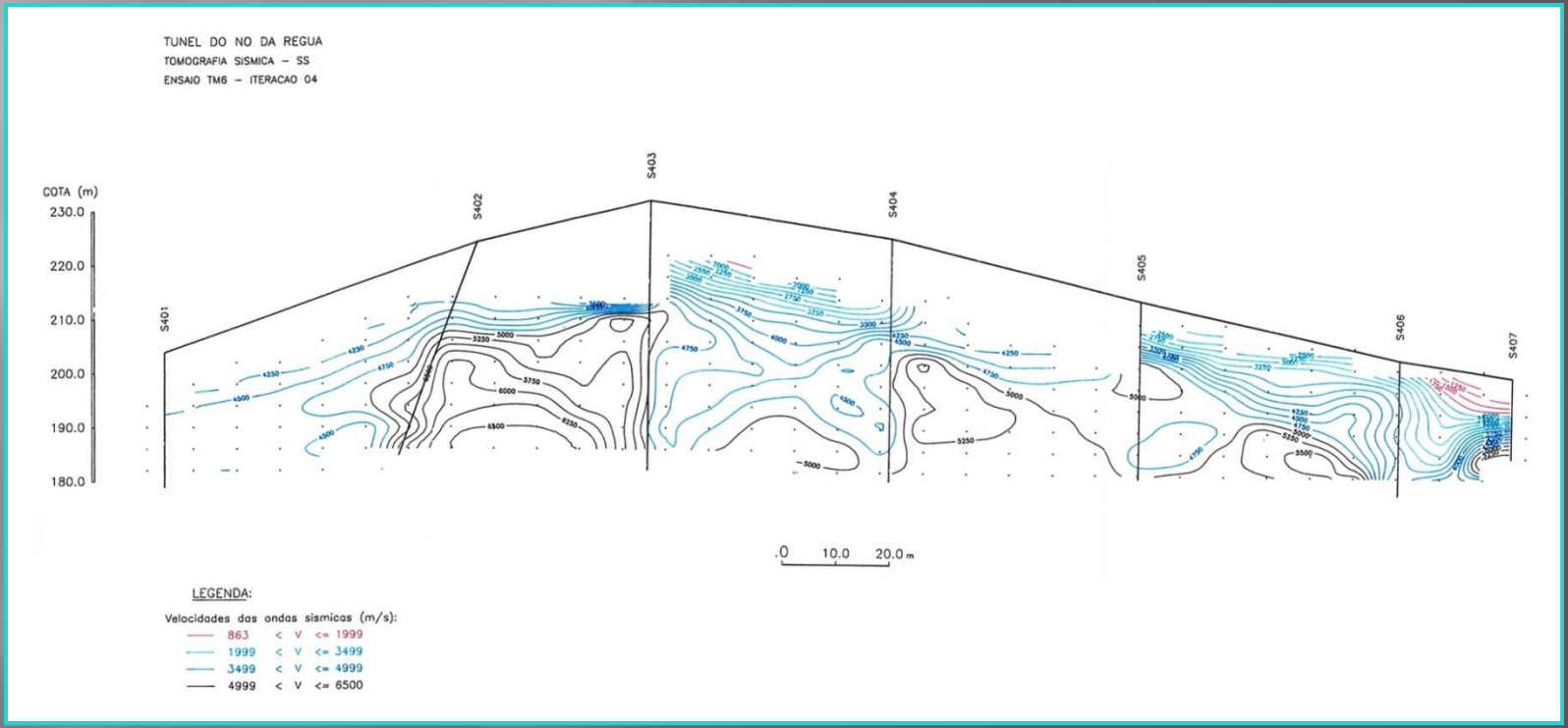
Deformabilidade de Maciços Rochosos

Métodos geofísicos



Deformabilidade de Maciços Rochosos

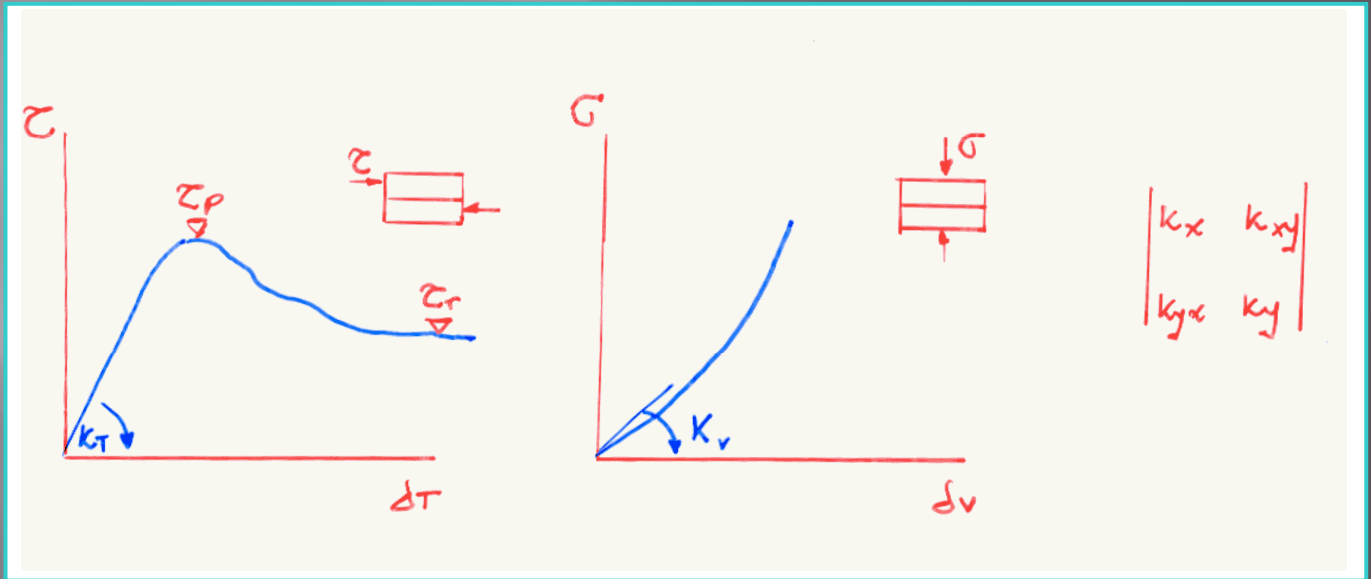
Métodos geofísicos – Tomografía sísmica



Deformabilidade de Maciços Rochosos

Deformabilidade de Descontinuidades

Rigidez Tangencial e Normal



Deformabilidade de Maciços Rochosos

FORMULAS EMPIRICAS

Bieniawski (1978)

Em (GPa) = 2 x RMR - 100

Serafim & Pereira (1983)

Em (GPa) = 10 (RMR - 10)/40

Barton (1983)

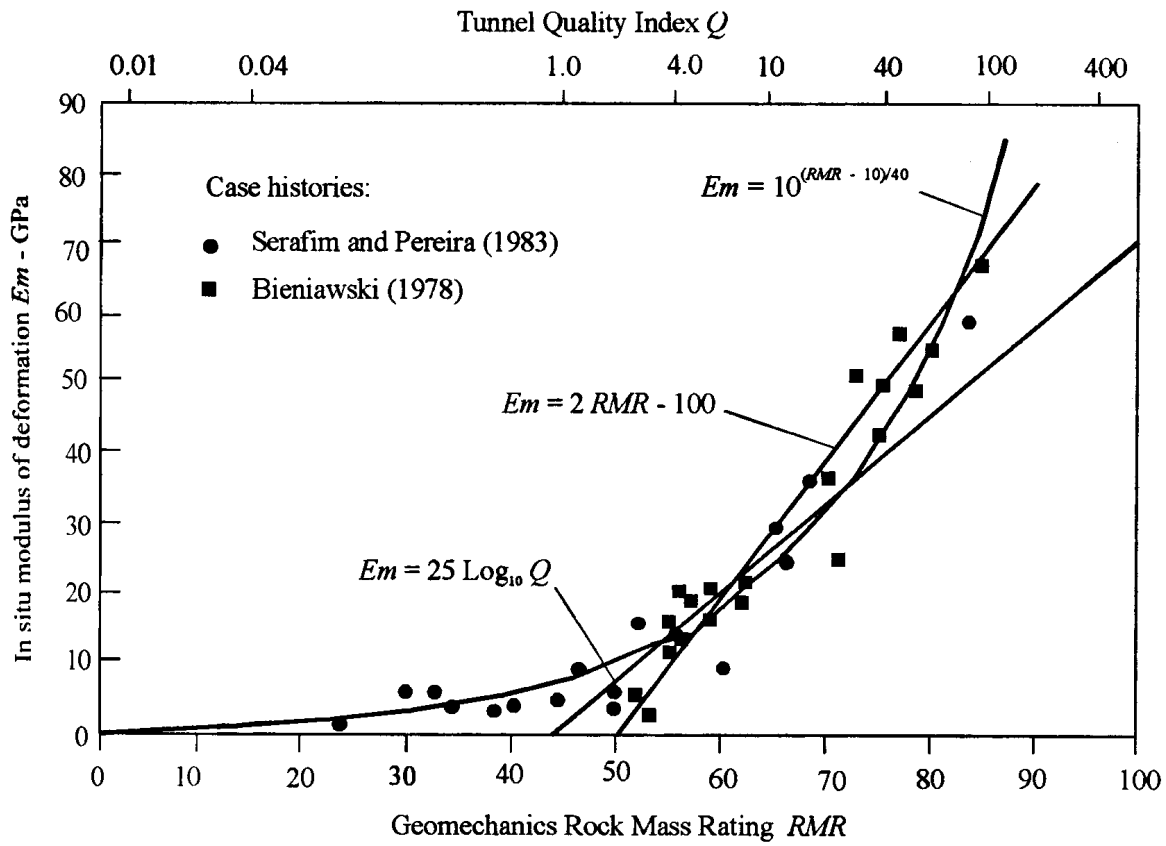
Emáx = 40 Log Q
Emín = 10 Log Q
Emedio = 25 Log Q

Hoek (2000) , para valores de σ_c < 100 MPa:

Em (GPa) = SQRT(σ_{ci} / 100) 10 (GSI - 10)/40

Deformabilidade de Maciços Rochosos

FORMULAS EMPIRICAS.



Deformabilidade de Maciços Rochosos

FORMULAS EMPIRICAS

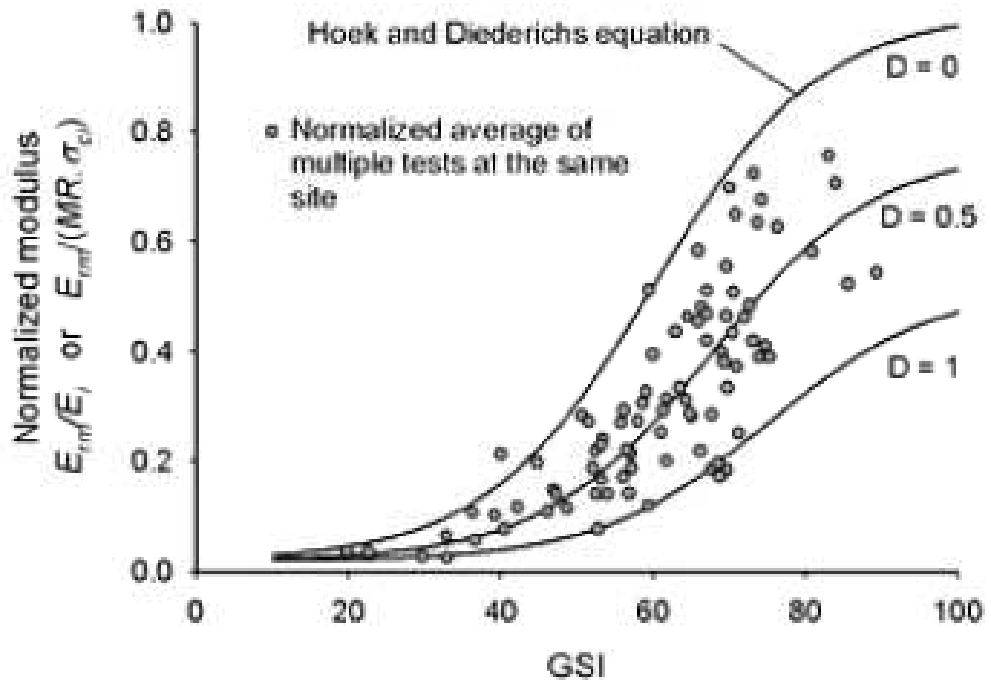


Figure 9: Plot of normalized in situ rock mass deformation modulus from China and Taiwan against Hoek and Diederichs Equation (27). Each data point represents the average of multiple tests at the same site in the same rock mass.

Resistência

A RESISTÊNCIA DE UM MACIÇO ROCHOSO ATÉ PROFUNDIDADES MODERADAS (400 – 500 m) DEPENDE ESSENCIALMENTE DAS DESCONTINUIDADES

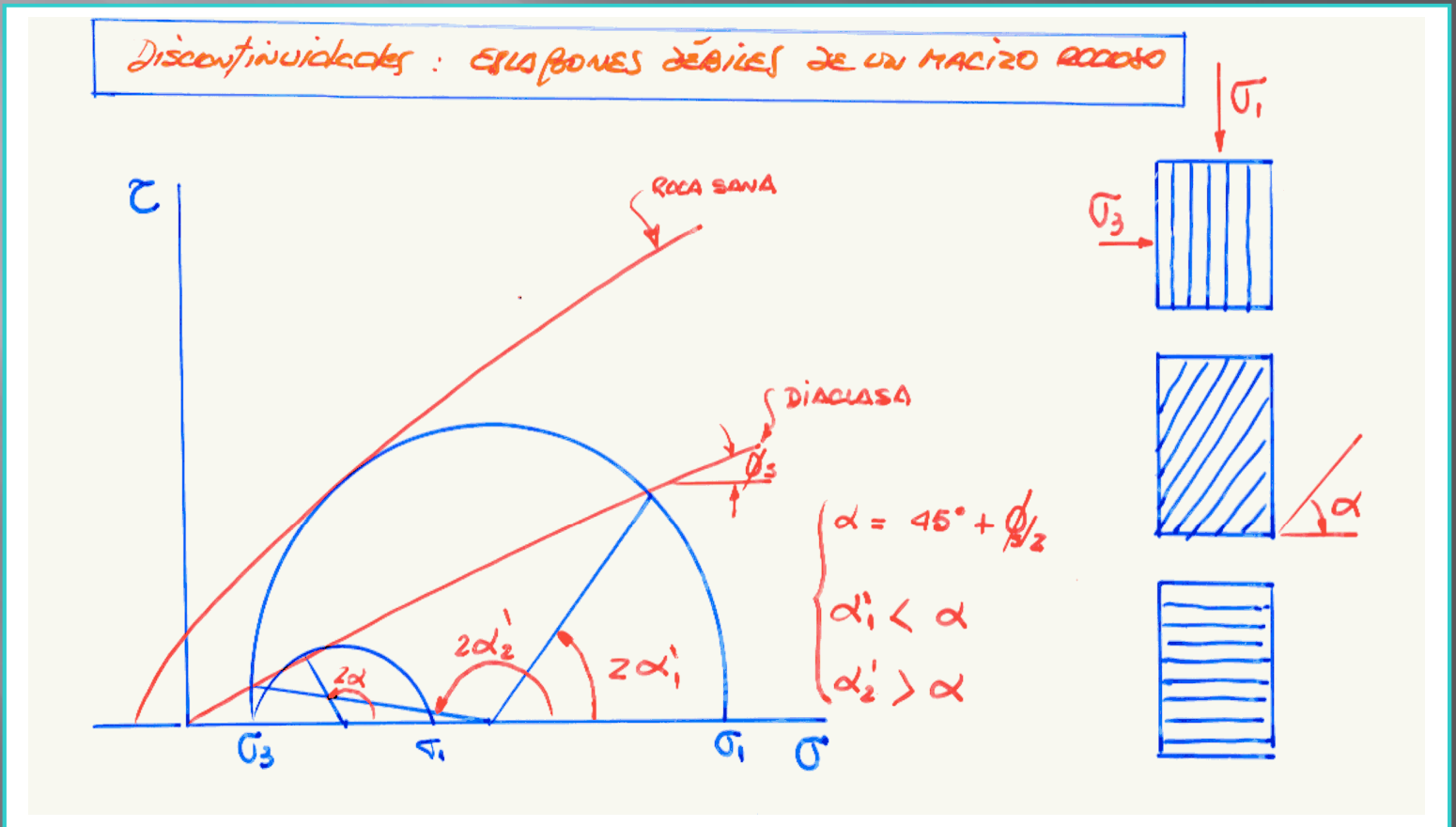
ATENÇÃO ÀS ESTRUTURAS DE GEOMETRIAS COMPLEXAS (CONCENTRAÇÃO DE TENSÕES) EM AMBIENTES FORTEMENTE TECTONIZADOS

Resistência

DESCONTINUIDADES

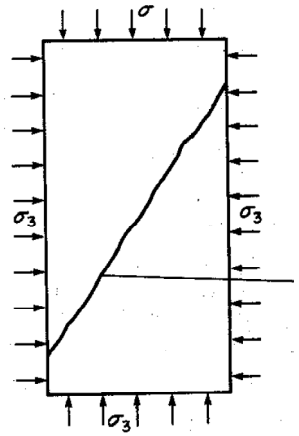
Resistência

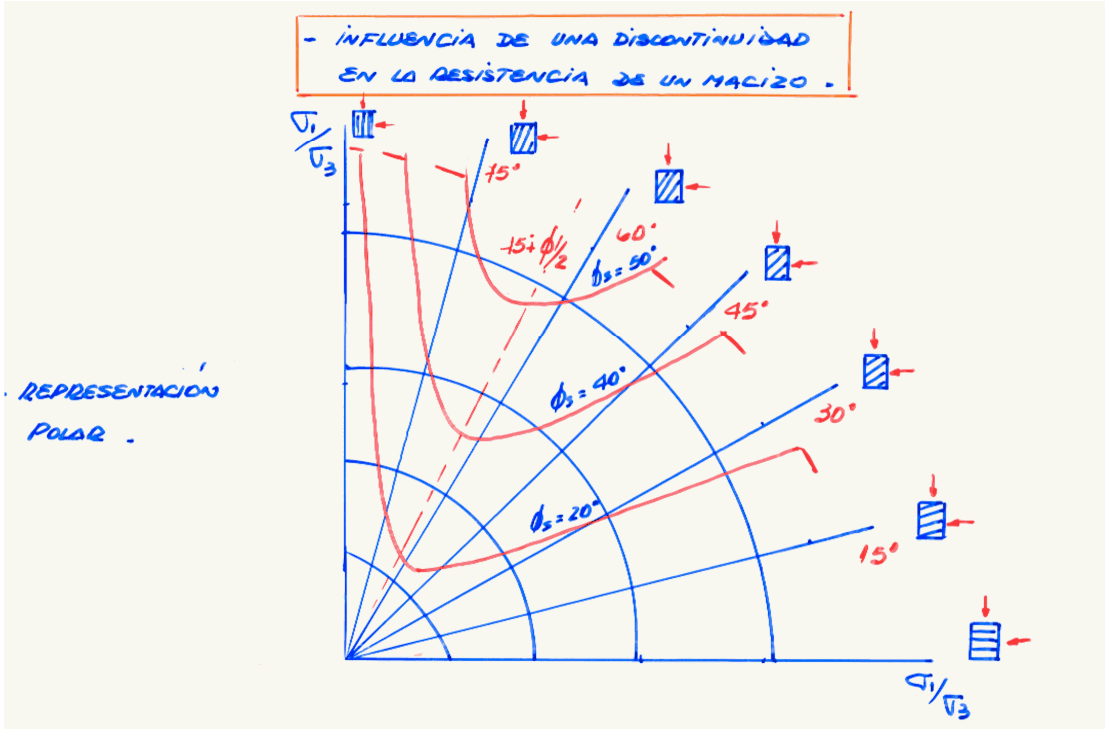
RESISTÊNCIA DAS DESCONTINUIDADES



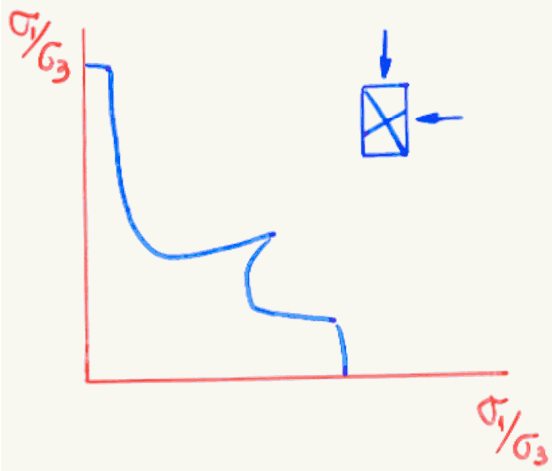
Resistência

Influência das descontinuidades na resistência de um maciço rochoso





Resistência

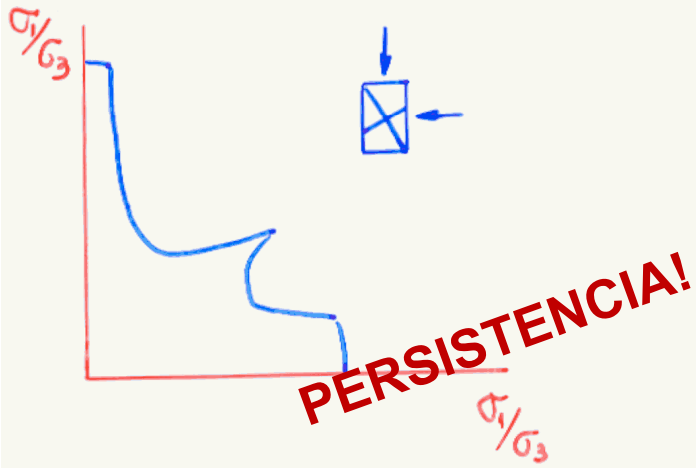


- CASO DE DOS DISCONTINUIDADES -

"Según aumenta el nº de discontinuidades de un macizo (4 ó más), éste se vuelve isotrópico en lo que respecta a su resistencia y deformabilidad"

"La anisotropía se presenta con menos de tres familias de discontinuidades o cuando uno de ellos tiene propiedades mecánicas muy diferentes a los otros".

Resistência



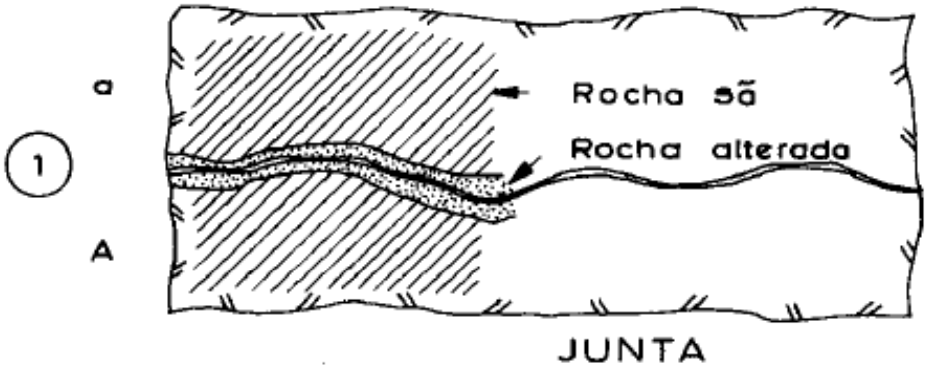
PERSISTENCIA!

- CASO DE DOS DISCONTINUIDADES -

"Según aumenta el nº de discontinuidades de un macizo (4 ó más), éste se vuelve isotrópico en lo que respecta a su resistencia y deformabilidad"

"La anisotropía se presenta con menos de tres familias de discontinuidades o cuando uno de ellos tiene propiedades mecánicas muy diferentes a los otros".

Resistência



PARÂMETROS IMPORTANTES

JCS (or σ_c)

JRC

ϕ_r (or ϕ_b)

ALTERADA

SÃ

S (RESISTÊNCIA)

R (RUGOSIDADE)

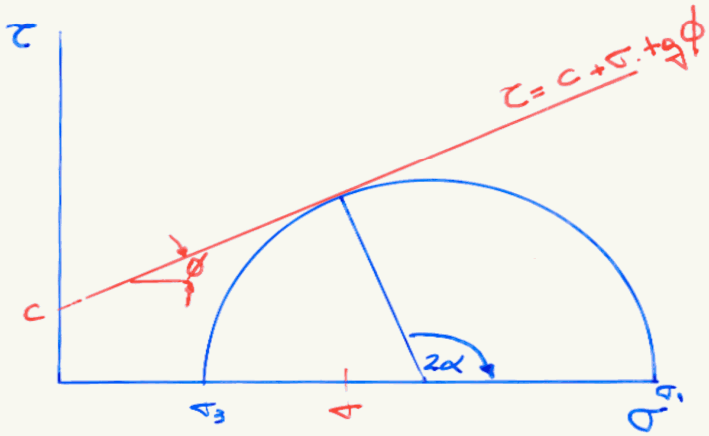
ϕ_r (ATRITO)

Resistência

CRITÊRIOS DE ROTURA

- CRITERIOS DE ROTURA -

- Mohr - Coulomb -



- Se produce rotura por corte cuando la tensión tangencial en un plano sea:

$$\tau > c + \sigma . tg\phi$$

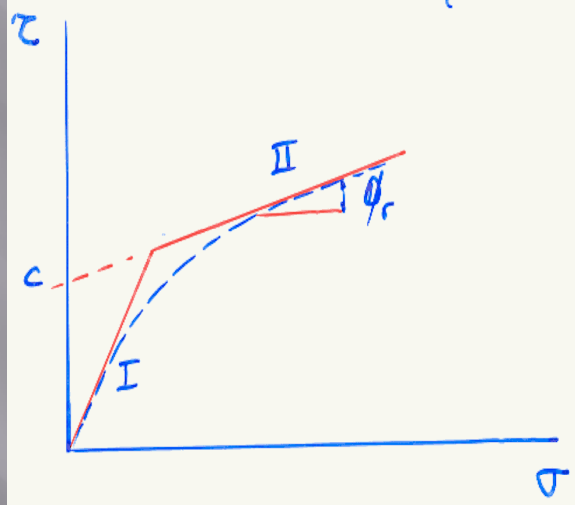
- $\alpha = 45 + \phi/2$

- LA ROTURA SE DA EN PLANOS PARALELOS A σ_2

- La rotura depende de las tensiones extremas σ_1 y σ_3
- La orientación de los planos de rotura depende sólo de ϕ.

Resistência

- F. PATTON (1966)



- Envolventes curvas indican cambios en el modo de rotura.
- Para superficies rugosos propone criterio bilineal:

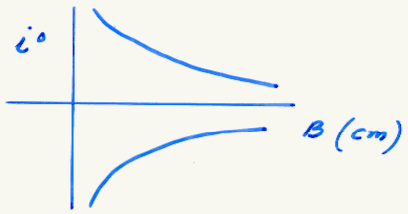
$$\text{I}: \quad \tau = \sigma_N \cdot tg[\phi_r + i]$$

$$\text{II}: \quad \tau = c + \sigma_N \cdot tg\, \phi_r$$

i: DILATANCIA

Resistência

– FECKER y RENGERS (1971)



* PERSISTE EL PROBLEMA DE CUÁL SERÁ LA RUGOSIDAD CRÍTICA.

– BARTON (1973)

$$i = JRC \cdot \log\left(\frac{JCS}{\sigma_N}\right)$$

Resistência

Barton (1973)

$$i = JRC \, Log \, (JCS / \sigma n)$$

$$Tp = \sigma n \, TAN \, (\Phi b + JRC \, Log \, (JCS / \sigma n))$$

Φb ángulo de atrito básico para superficies planas inalteradas;
JRC coeficiente de rugosidade;
JCS resistência da parede da diaclasa.

Resistência

Barton (1973)

$i = JRC \, Log \, (JCS / \sigma n)$

$Tp = \sigma n \, TAN \, (\Phi b + JRC \, Log \, (JCS / \sigma n))$

JRC - JCS

Φb ângulo de atrito básico para superficies planas inalteradas;
JRC coeficiente de rugosidade;
JCS resistência da parede da diaclasa.

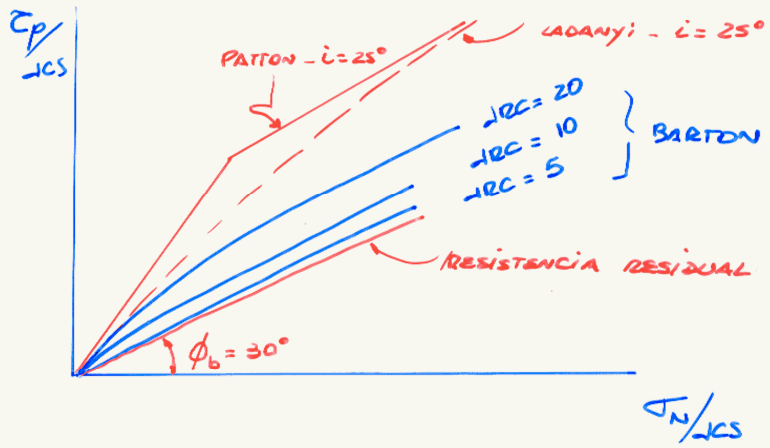
Resistência

Descontinuidades em Rocha

BARTON (1973)

9

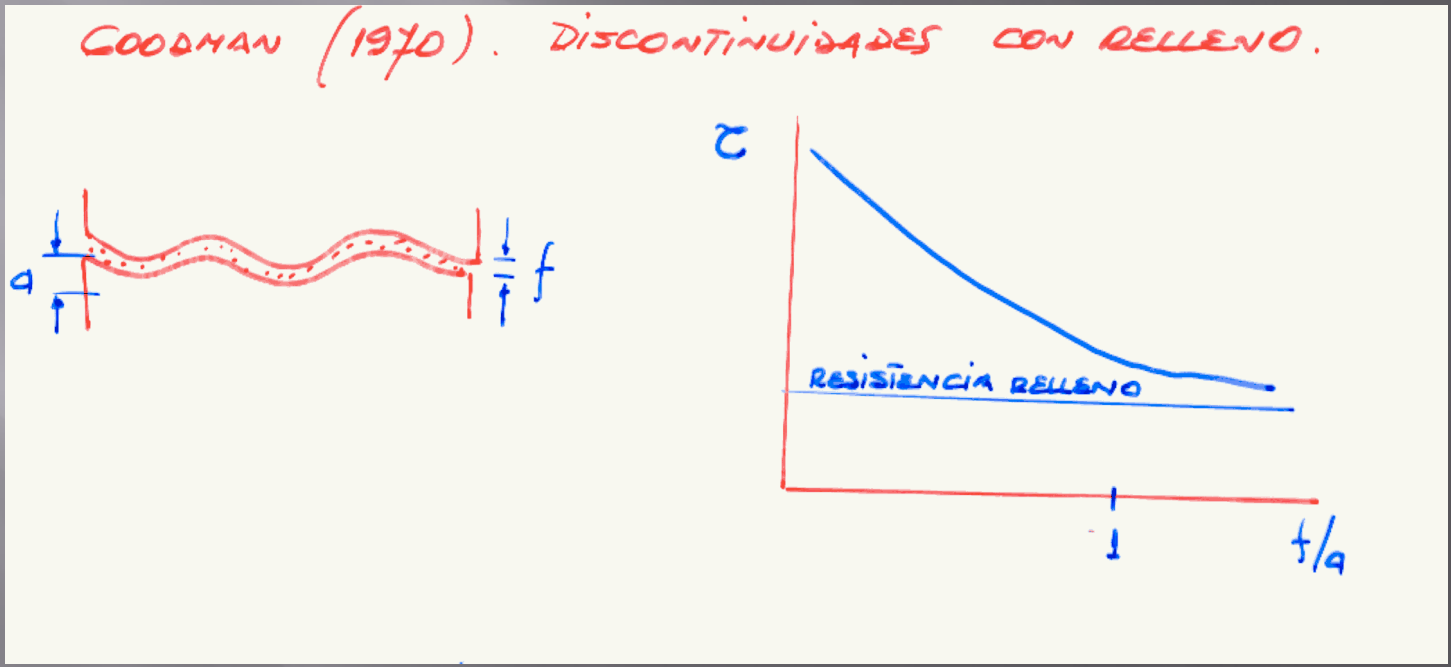
$$\tau_p = \sigma_N \cdot \tan\left(\phi_b + JRC \cdot \log\left(\frac{JCS}{\sigma_N}\right)\right)$$



- ESQUEMA COMPARATIVO -

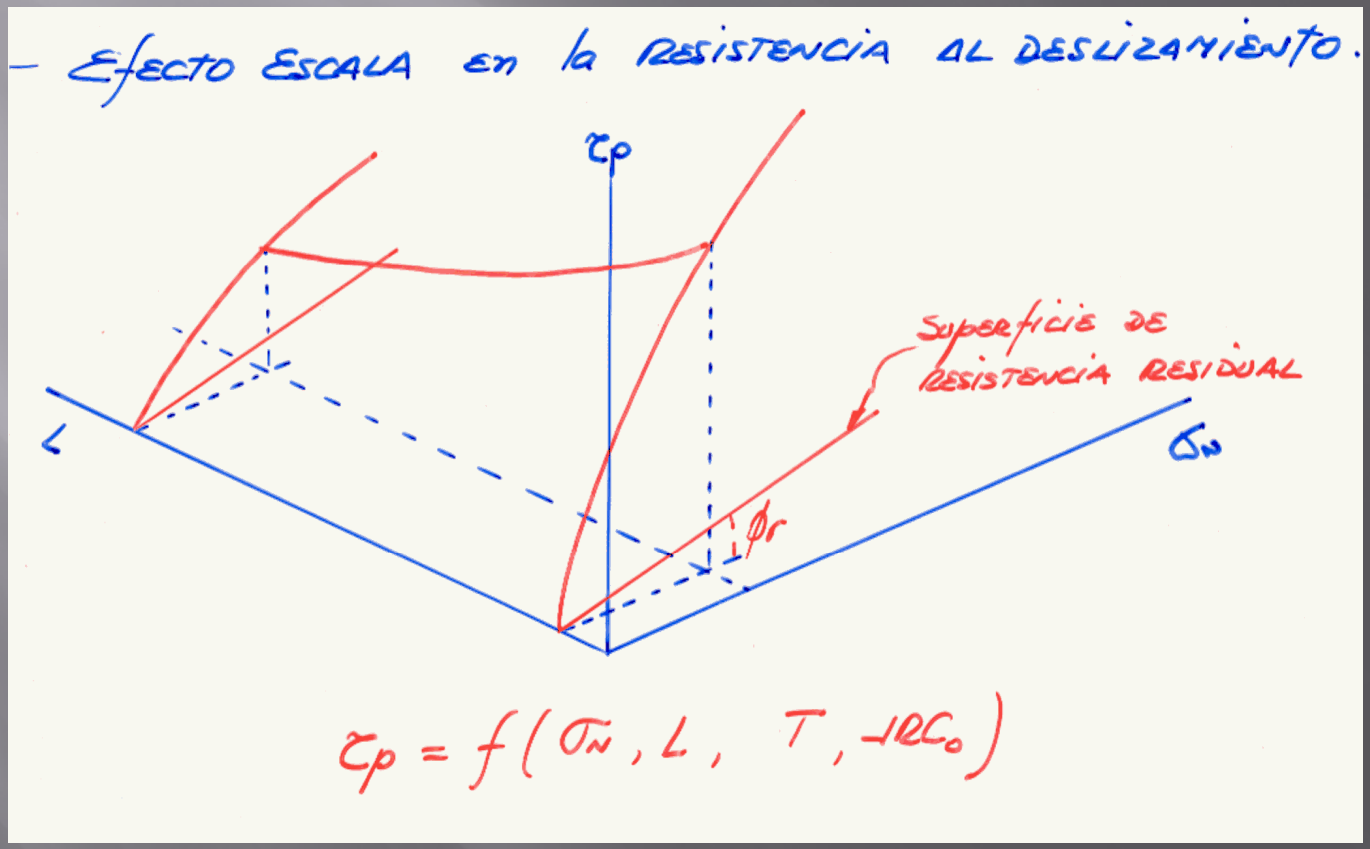
Resistência

INFLUÊNCIA DO ENCHIMENTO



Resistência

EFEITO DE ESCALA



Resistência

ENSAiOS IN LABO

Resistência

ENSAiOS IN SITU

Resistência do Maciço Rochoso

$$\sigma'_1 = \sigma'_3 + \sigma_c (m_b \sigma'_3 / \sigma_c + s)^a$$

(Critério de Rotura Generalizado de Hoek – Brown)

$$\sigma'_1 = \sigma'_3 + \sigma_{ci} (m_i \sigma'_3 / \sigma_{ci})^{0.5}$$

(Para rocha intacta)

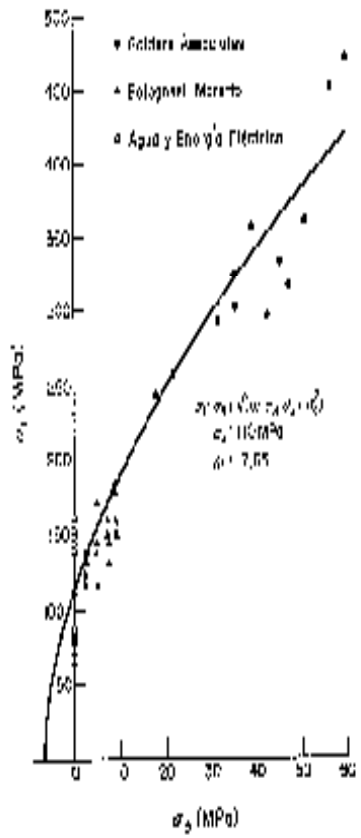


Figure 8 Hoek–Brown failure criterion derived from uniaxial and triaxial compression tests

Resistência do Maciço Rochoso

$$\sigma'_1 = \sigma'_3 + \sigma_c (m_b \sigma'_3 / \sigma_c + s)^a$$

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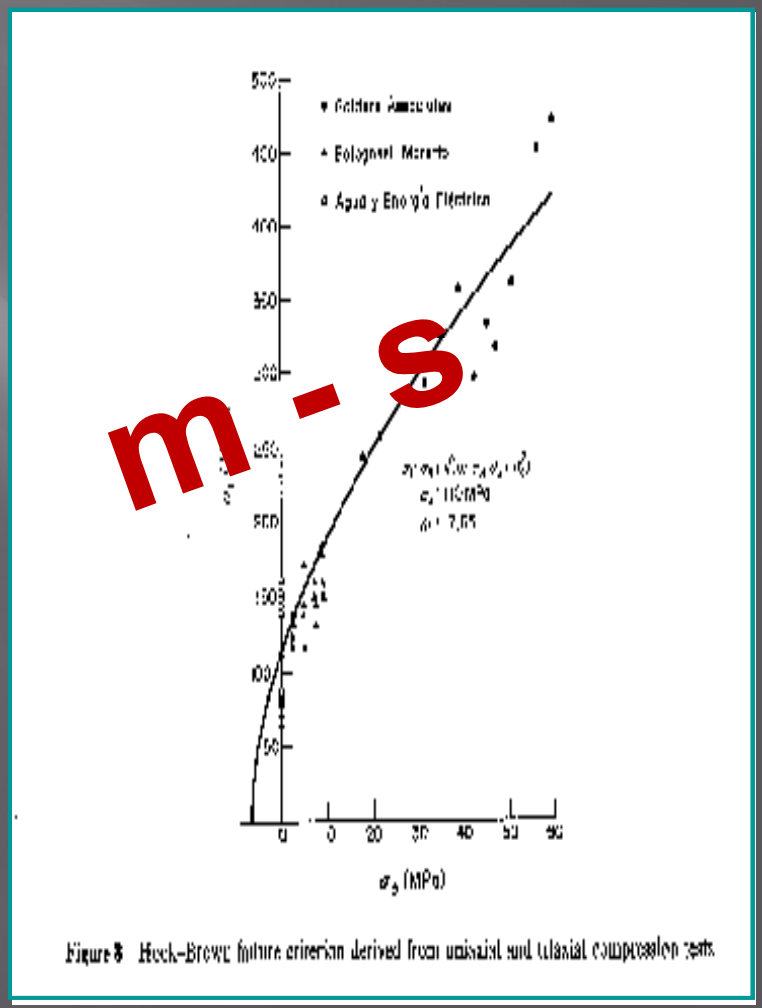


Figure 8 Hoek–Brown failure criterion derived from uniaxial and triaxial compression tests

Resistência

GSI: Geological Strength Index

$$m_b / m_i = \exp\left(\frac{GSI - 100}{28}\right)$$

GSI > 25

$$s = \exp\left(\frac{GSI - 100}{9}\right)$$

$$a = 0.5$$

GSI < 25

$$s = 0$$

$$a = 0.65 - GSI/200$$

(Hoek et al 1995)

Zonificação

2 problemas:

1. netamente geotécnico, escolha de parâmetros

Zonificação

2 problemas:

1. netamente geotécnico, escolha de parâmetros
2. estatístico: distribuição dos parâmetros e valores característicos.

Zonificação

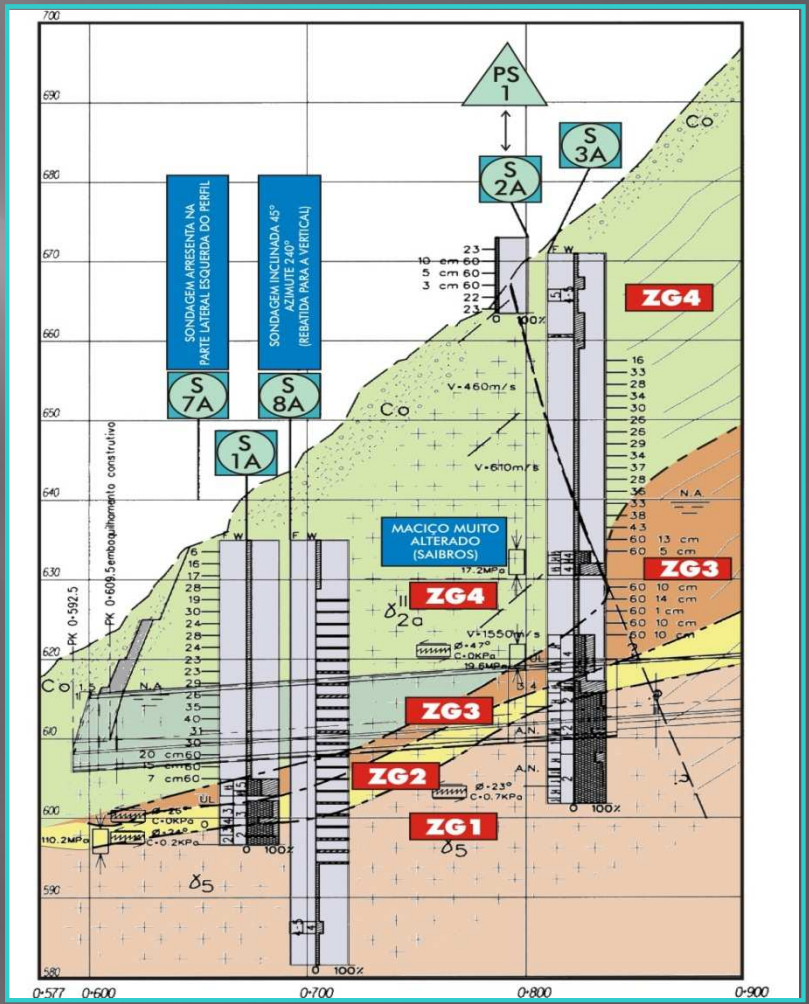
Los índices utilizados en la zonificación, en regla general, deben ser:

1. Simples, representativos y fácilmente verificables durante la construcción:

   a. Tipo litológico
   b. Grado de alteración
   c. Grado de fracturación

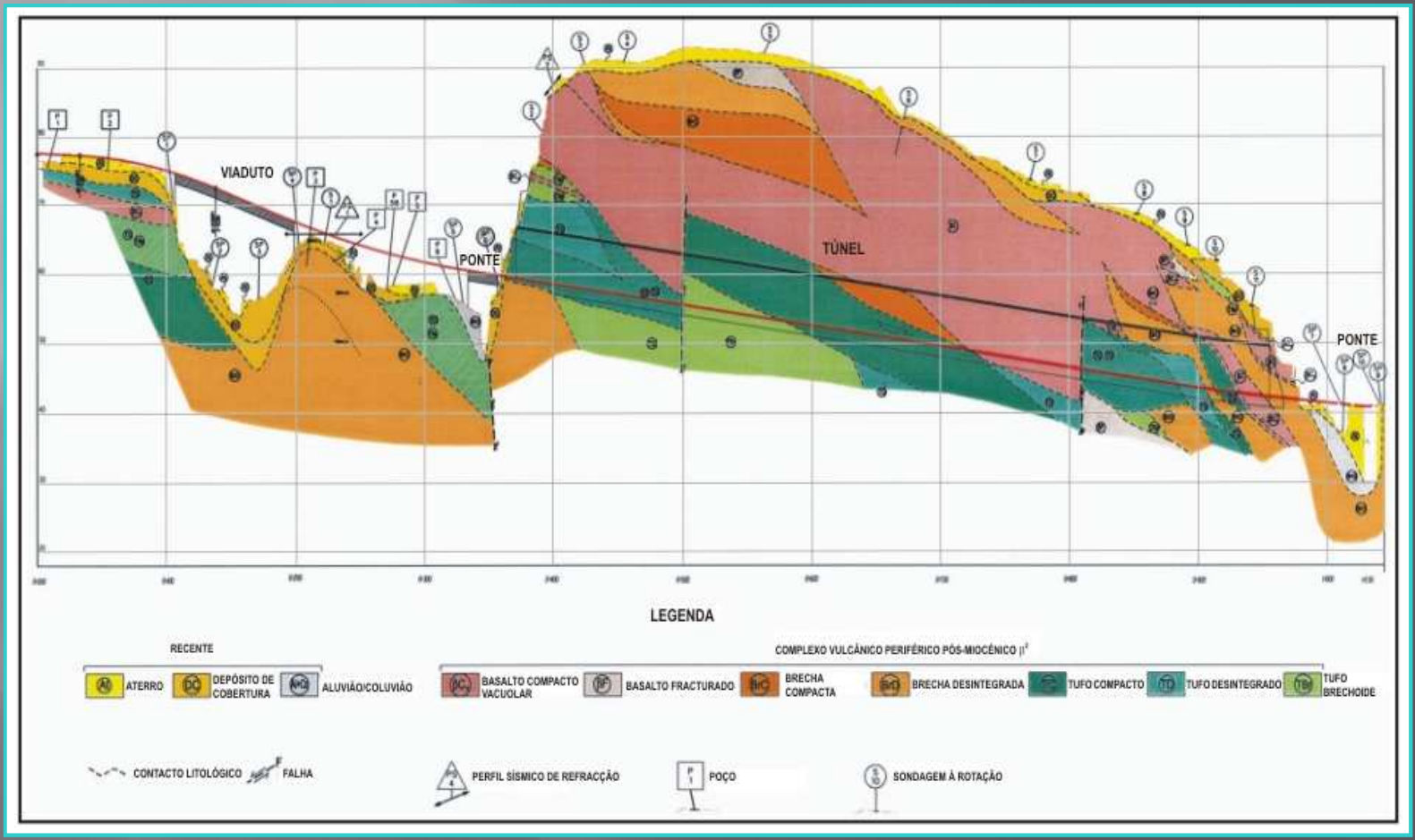
Zonificação

Em saprolitos graníticos saturados



Zonificação

Em maciço volcânico



Zonificación

Maciço volcánico

Zona	RMR	Material	W	F	RQD (%)	γ (kN/m³)	σci (MPa)	GSI	mi	mb	S	ϕ (º)	c (kPa)	E (GPa)	Carga de terreno (m)
ZG1	>60	βC - BrC	1-2	2-3	>60	25	100	70	28	4,70	0,0106	50	500	15	2
ZG2	41–60	BrC - βF	3-4	3-4	>30	22	15	45	19	0,72	0,0002	40	90	1,5	4
ZG3	25-40	TC	3-4	-	-	20	5-8	25-35	15	1,03	0,0002	30-35	60-80	0,5-1	8
ZG4	<25	TBr	4-5	-		19	8	20	14	0,80	0,0001	40	35	0,5	10
		BrD	4												
		TD (5m)	4			19	2,5	18	13	0,70	0,0001	35	10	0,25	
		TD(25m)										25	35		
		DC / Aterro	4-5			19						20	15	0,02	

Zonificação

Zonificação

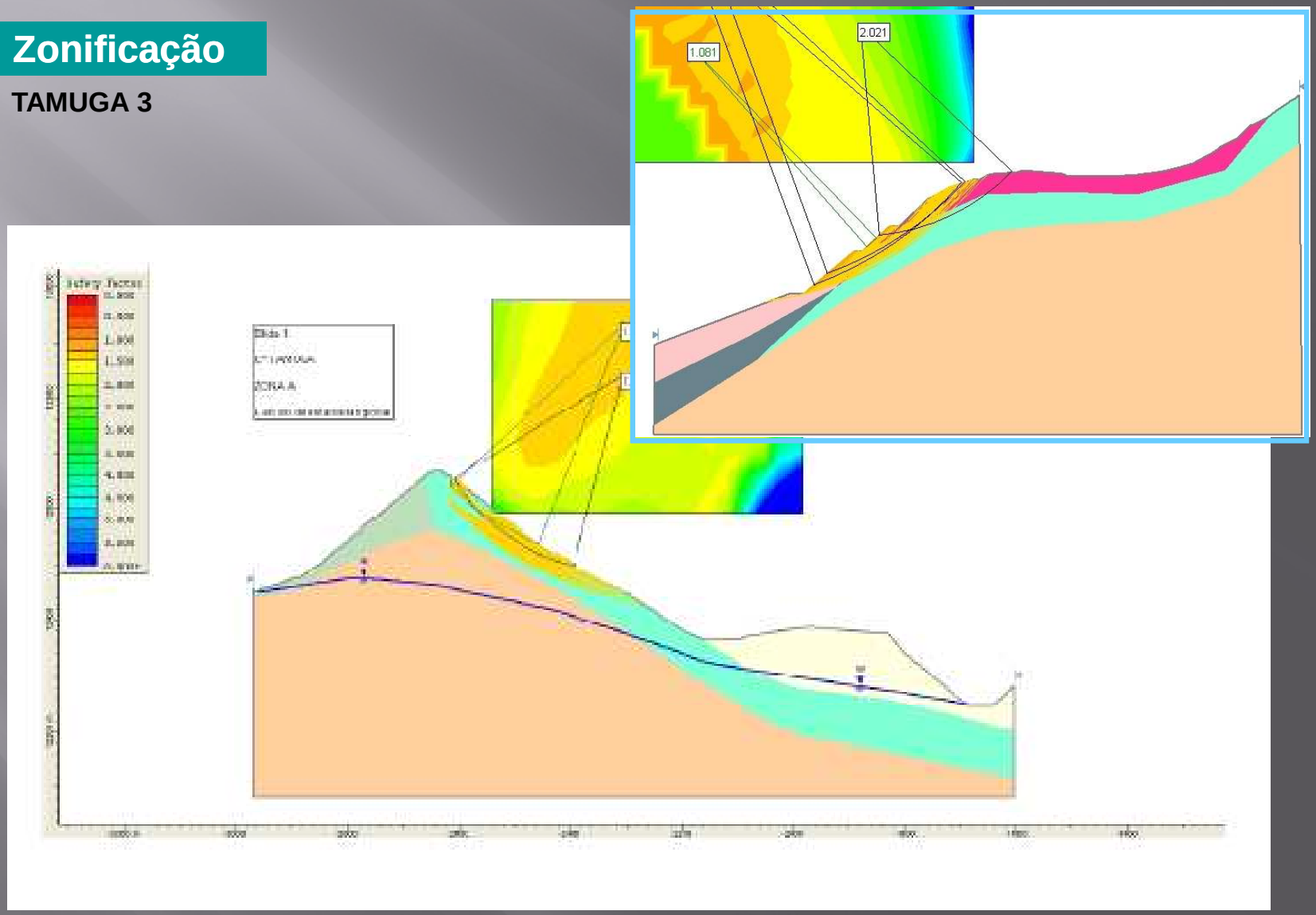
ZONAMENTO GEOTÉCNICO DO Cº TAMUGA

MACIÇO	GSI	*Φ* (º)	*c* (kPa)
M - I	25	40	40
M - II	40 -50	50	100
M - III	60 - 70	55	500
M - VII	20	40	30

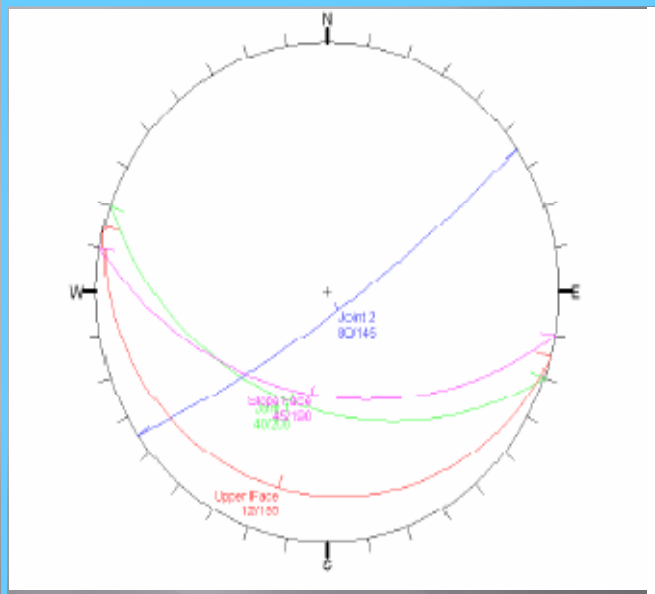
Estrato	*a.Superficial M-IV*	*b.Intermedio M-V*	*c.Profundo M-1*	*d.Firme M-3*
ϕ º - c (kPa)	35º- 0	45º - 0	40º-40	*55º- 500*

Zonificação

TAMUGA 3



MEGADESLIZAMENTOS



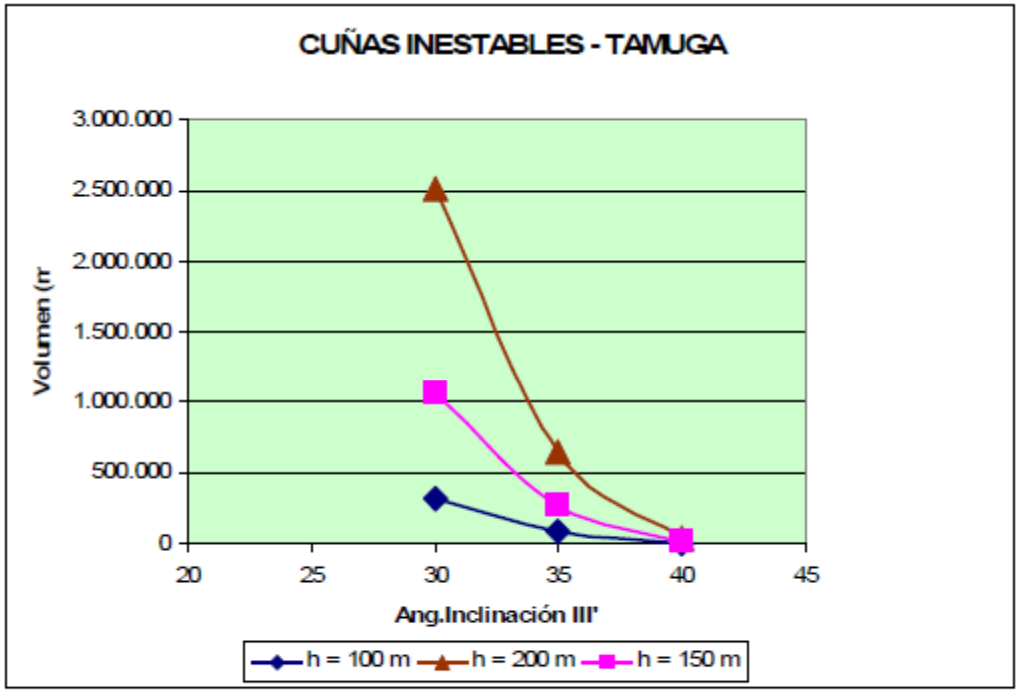
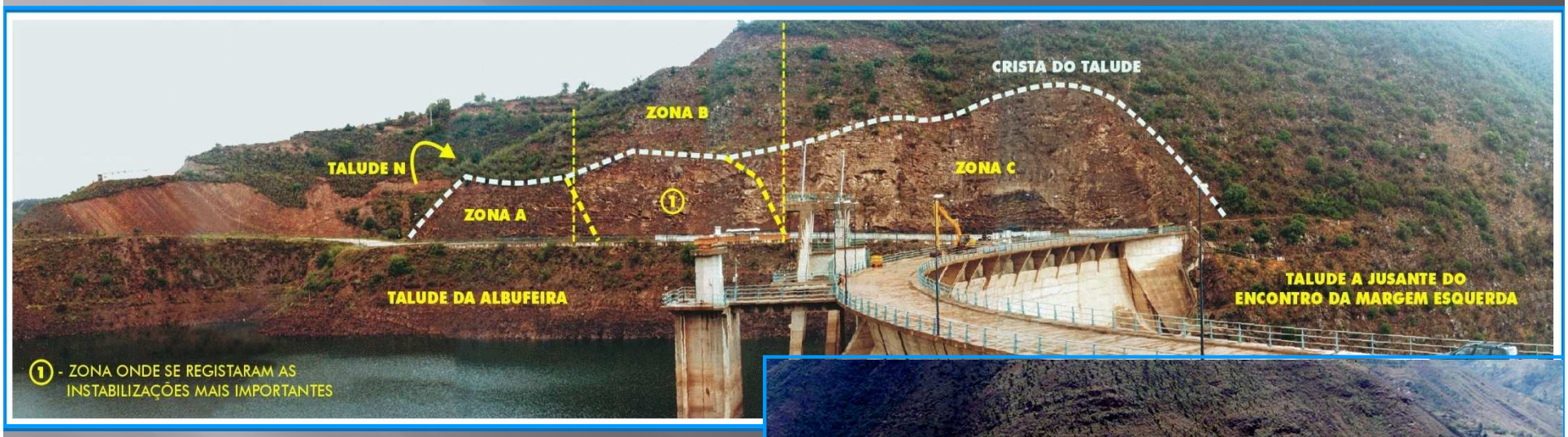
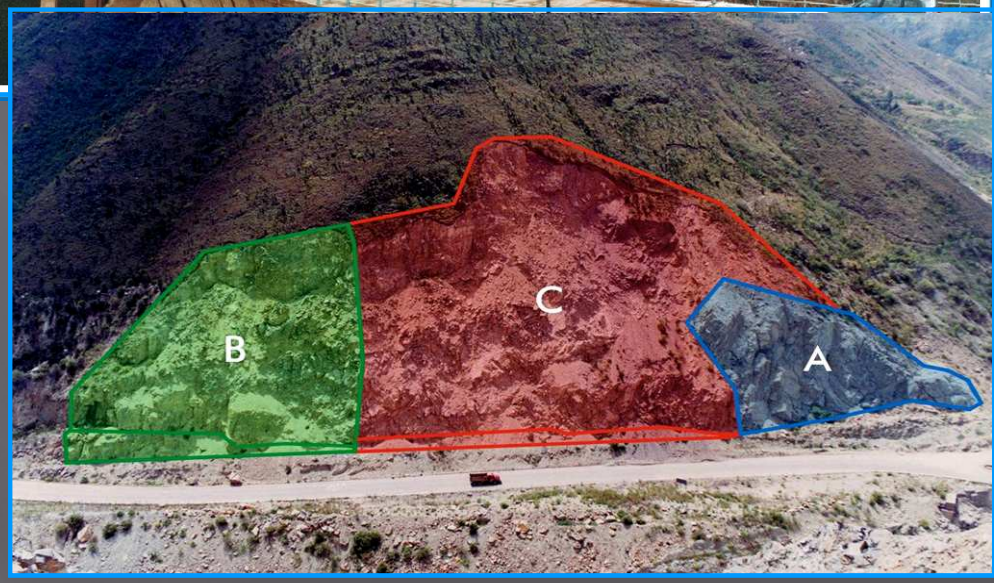


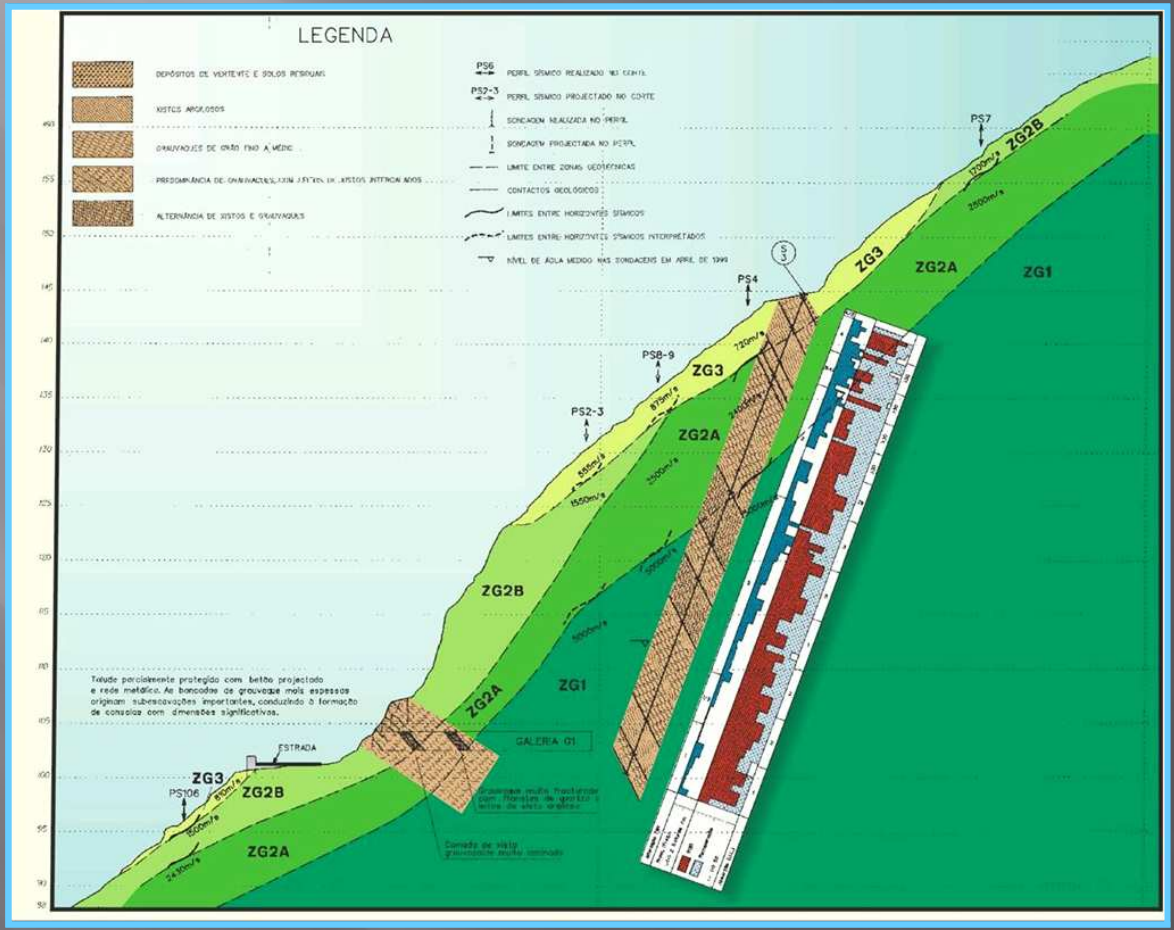
Figura 7- Análisis paramétrico de la variación del volumen de cuñas potencialmente inestables en función del ángulo de inclinación de III' y de la altura sobre el talud.

ZONAMENTO


CRISTA DO TALUDE
ZONA B
TALUDE N
ZONA C
ZONA A
1
TALUDE DA ALBUFEIRA
TALUDE A JUSANTE DO ENCONTRO DA MARGEM ESQUERDA
1 - ZONA ONDE SE REGISTARAM AS INSTABILIZAÇÕES MAIS IMPORTANTES


B
C
A

Perfil geológico tipo e zonamento geotécnico



ZONAMENTO GEOTÉCNICO

Zona ZG3:

Horizonte superficial, con depósitos de vertente e solos residuais..
Profundidade entre 1 y 3 m
Vl: < 900 m/s
RQD%: 25 – 50
Absorção de água: > 30 UL

Zona ZG2B:

Rocha muito fracturada e alterada
Horizonte mais superficial
Profundidade máxima: 10 m
Vl: 1100 – 1600 m/s

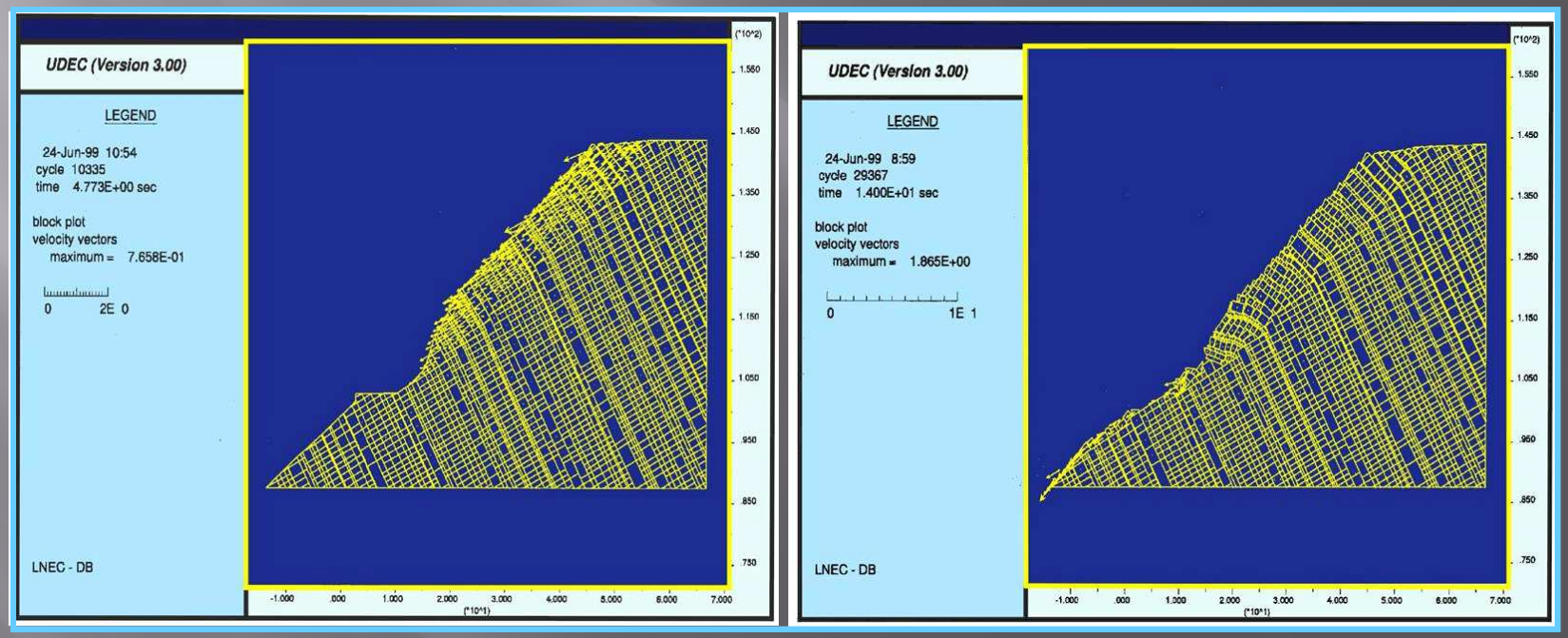
Zona ZG2A:

Horizonte inferior
Vl: 2000 – 2300 m/s
RQD%: 25-50 %

Zona ZG1:

Rocha de boa qualidade
Vl: >3400 m/s
RQD%: > 50%

Modelação da deformação progressiva do talude a partir de um mecanismo de toppling.



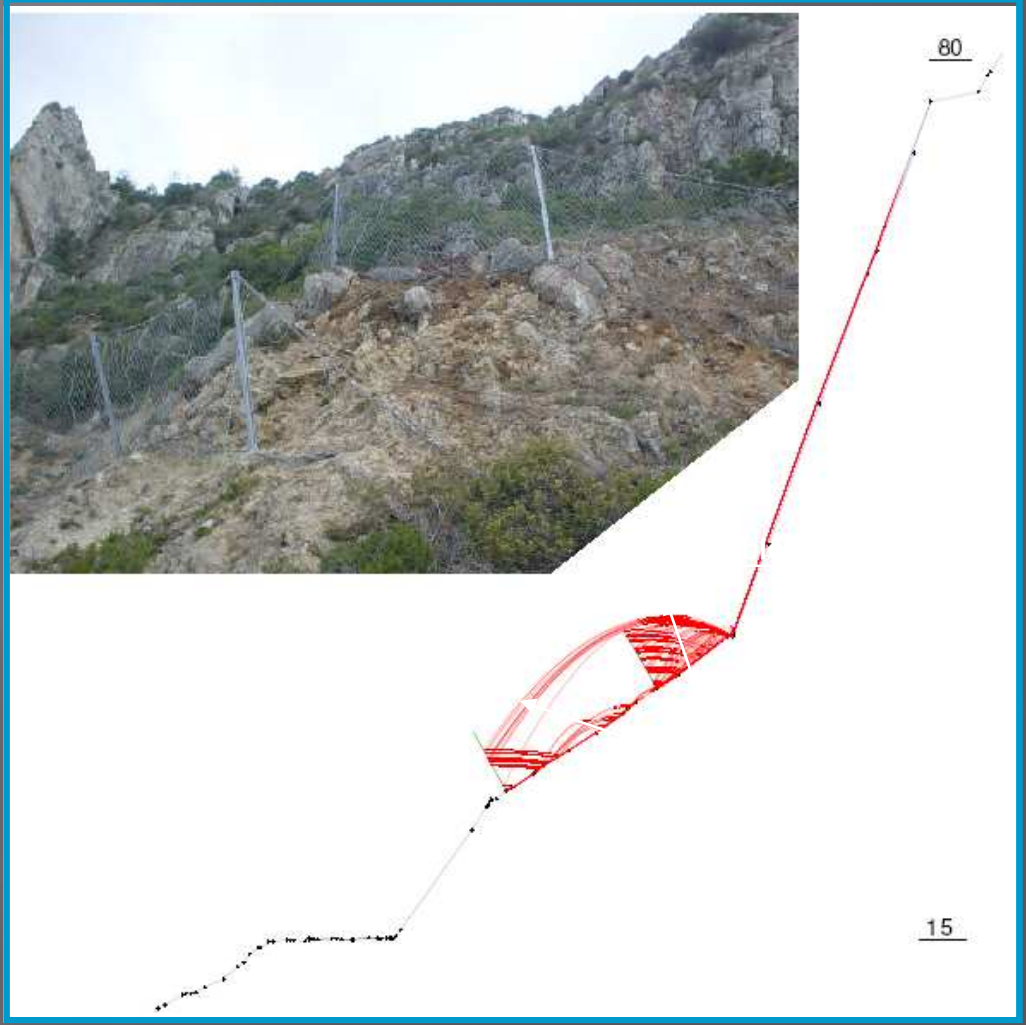
Explorações a Céu Aberto: Novos desenvolvimentos

Ordem dos Engenheiros

Bloco de rocha de ~10 tn

DYNAMIC BARRIERS

The location of the dynamic barriers and assessment of the required energy absorption capacity was approached by analysis of blocks trajectories, resorting to numerical models.



ANALISE CINEMÁTICA DE QUEDA DE BLOCOS

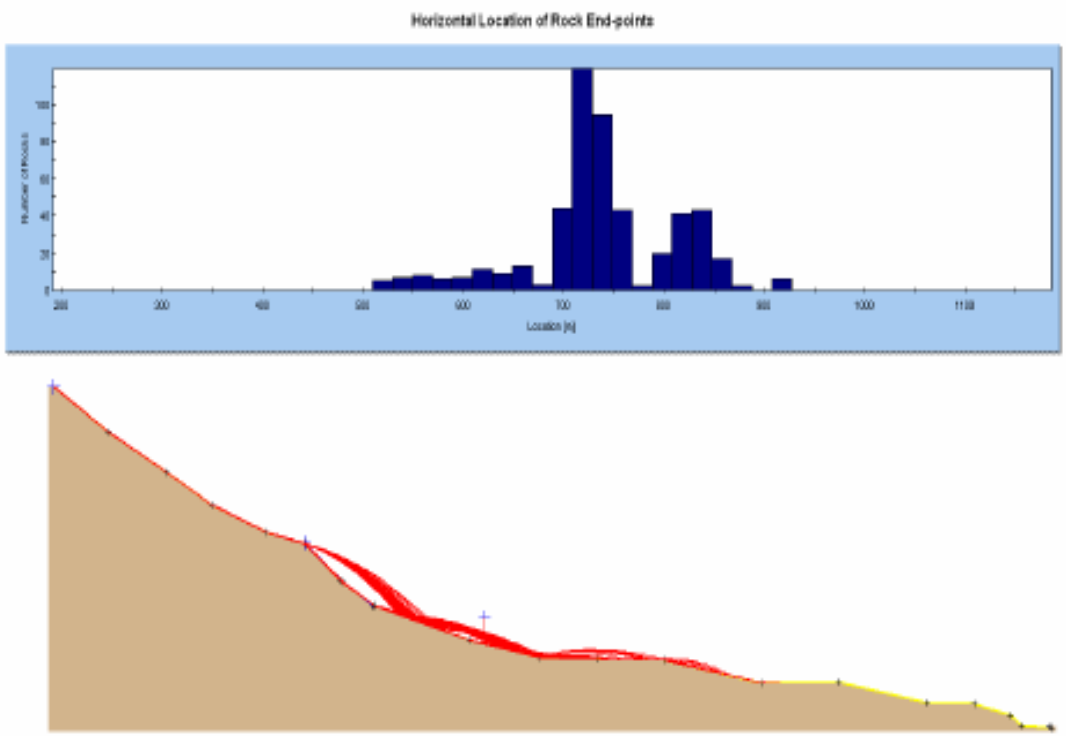
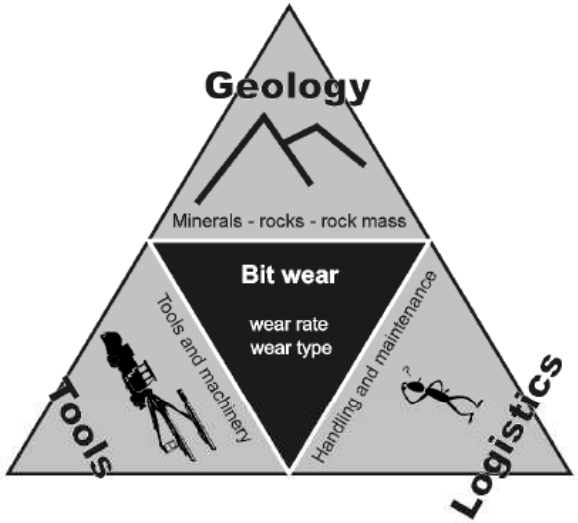
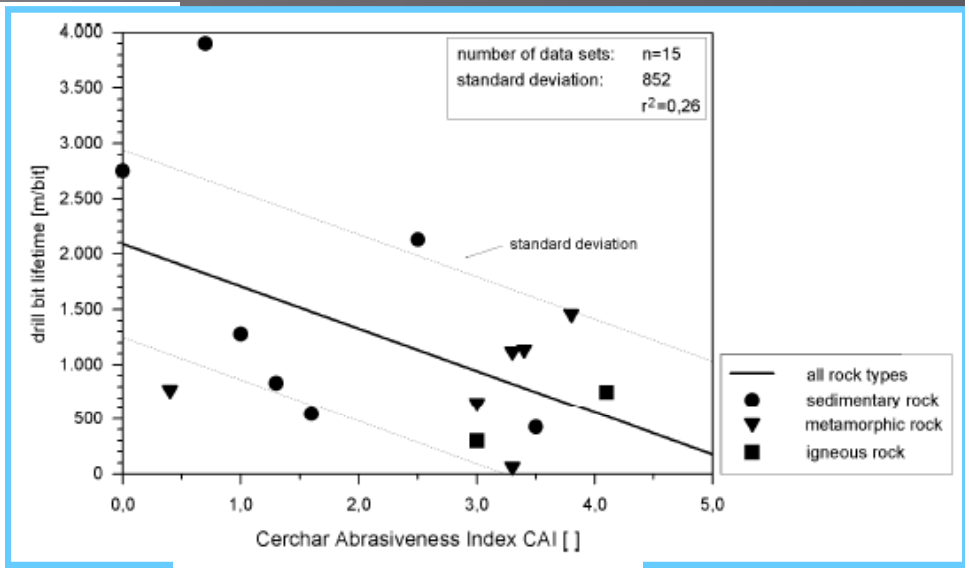


Figura 13 – Rango de alcance de bloques de roca desprendidos de la cresta del Tamuga

DESGASTE



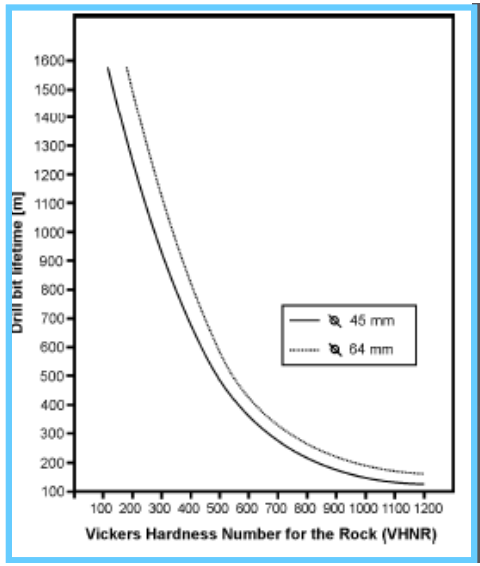


Geology	Tools	Logistics
rock properties *(mineral composition, rock strength, grain size, grain shape)*	tool characteristics *(carbide composition, button shape, button number, steel composition)*	maintenance
joint features *(spacing, orientation, aperture, roughness)*	flushing *(fluid, number & geometry of flushing holes and flutes, flushing pressure)*	tool handling
weathering / alteration of rock	feed and rotating velocity	supporting methods
water situation	temperatures	
composition of rock mass *(homogenous / inhomogenous)*		
stress situation *(stress direction, stress level)*		

FROM:

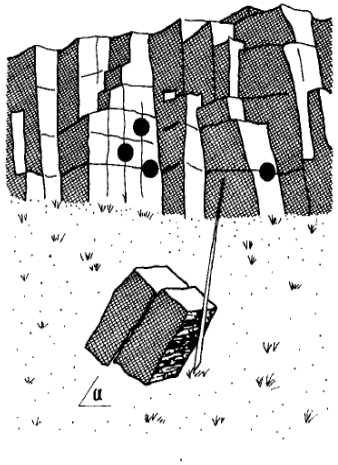
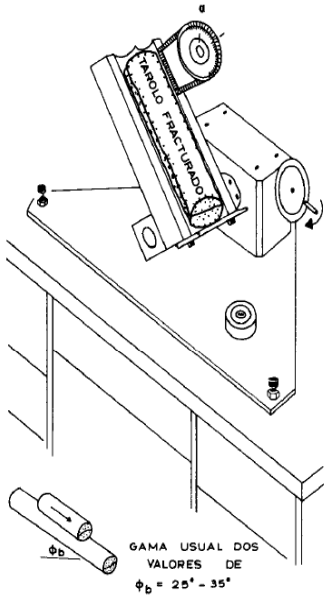
PREDICTION AND CLASSIFICATION OF TOOL WEAR IN DRILL AND BLAST TUNNELLING

Ralf J. Plinninger[1], Georg Spaun[1] and Kurosch Thuro[2]



Obrigado pela Atenção

MARÇO 2011

Resistência

Description	Profile	J_r	*JRC* 200mm	*JRC* 1 m
Rough		4	20	11
Smooth		3	14	9
Slickensided				
	Stepped	2	11	8
Rough		3	14	9
Smooth		2	11	8
Slickensided				
	Undulating	1.5	7	6
Rough		1.5	2.5	2.3
Smooth		1.0	1.5	0.9
Slickensided				
	Planar	0.5	0.5	0.4