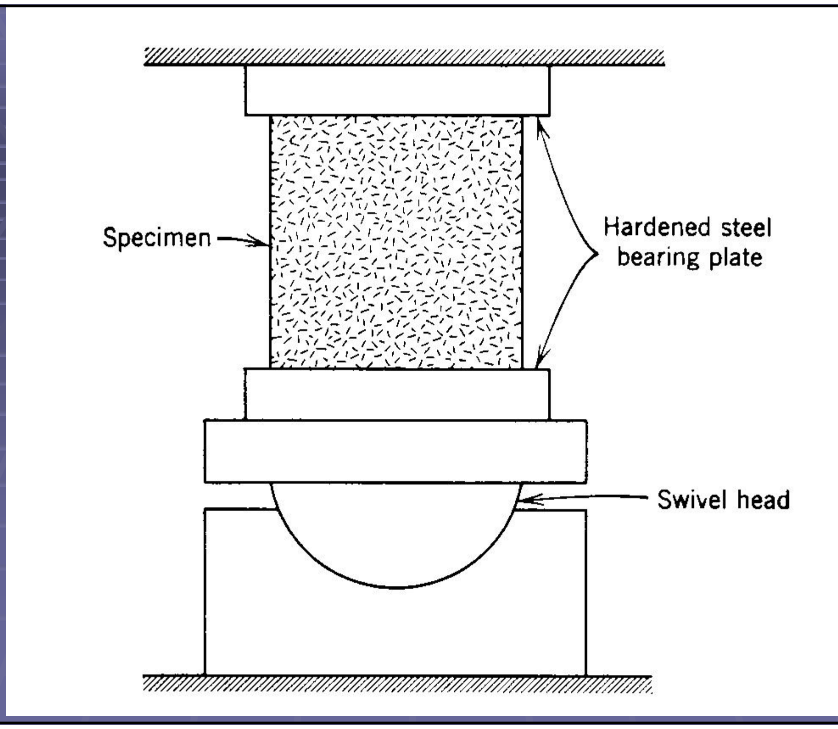
Clase No. 3

- 3.0. Resistencia de la roca intacta
  - 3.1. Concepto de roca intacta y propiedades características.
  - 3.2. Tensores de esfuerzo y deformación.
  - 3.3. Criterios de falla

Ensayo de Compresión Uniaxial



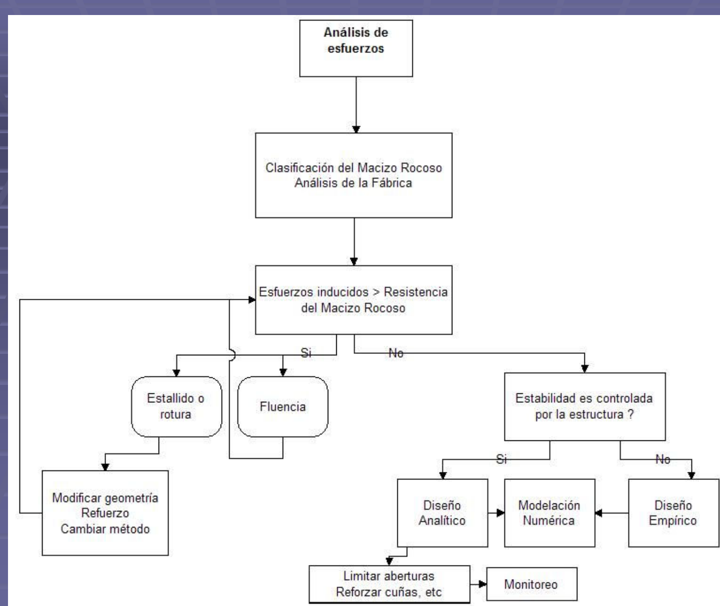
Factores que afectan los resultados

- Caras planas y paralelas de las probetas
- Tamaño de la probeta
- Forma de la probeta
- Contenido de humedad
- Fricción entre probeta y soportes
- Velocidad de carga

Ensayo Triaxial

Criterios de falla

- Falla por Tensión
- Coulomb-Navier
- Mohr Coulomb
- Griffith
- Hoek and Brown

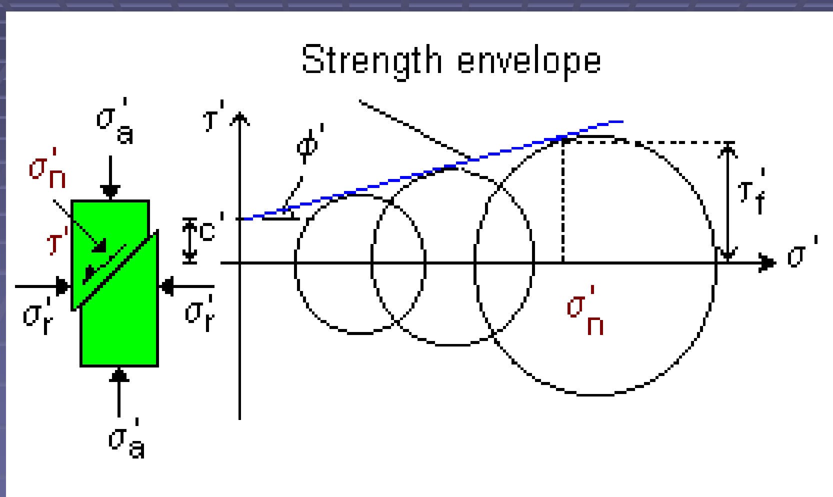


Falla por Tensión

$$\sigma_t = T_0$$

- T0 : Resistencia a la tracción del macizo rocoso

Mohr Coulomb



Hoek and Brown

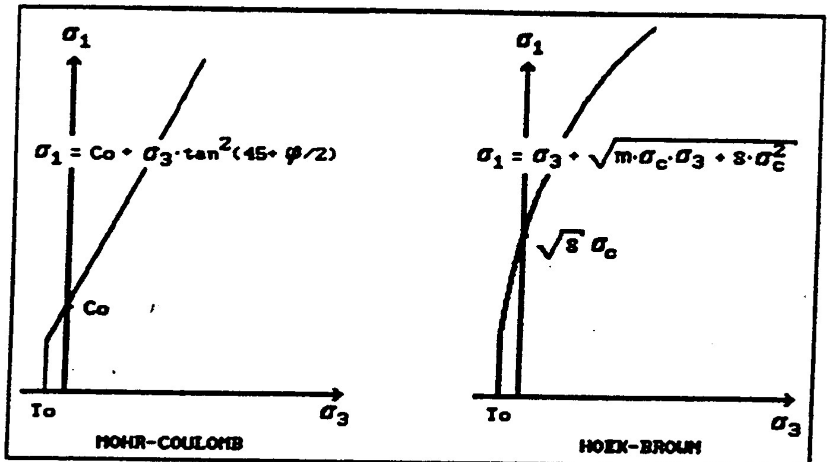
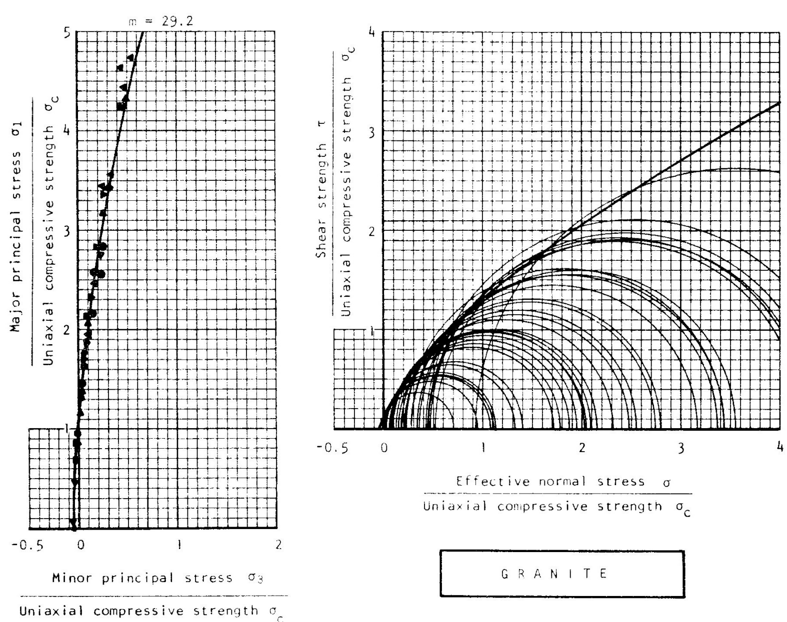
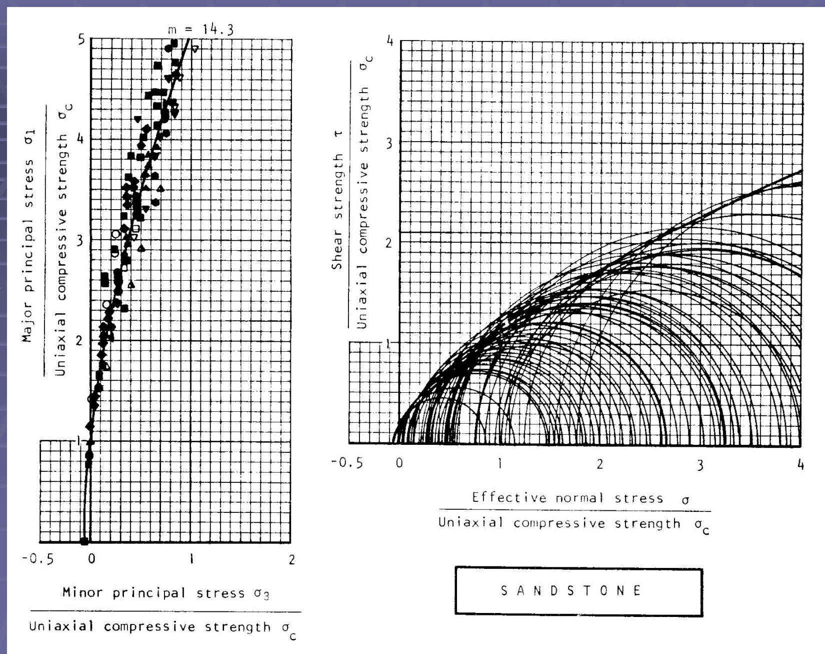


Figure 56 - Failure Criteria





Criterio original Hoek-Brown

$$\sigma_1 = \sigma_3 + \sqrt{m\sigma_3\sigma_c + s\sigma_c^2}$$ (Hoek and Brown, 1980)

m, s = constantes que depende de las características del macizo rocoso

σ_c = Resistencia a la compresión simple

Ejemplos: resistencia a la compresión del macizo rocoso, resistencia a la tracción del macizo rocoso.

APPROXIMATE RELATIONSHIP BETWEEN ROCK MASS QUALITY AND MATERIAL CONSTANTS

Disturbed Rock Mass m and s Values — *Undisturbed Rock Mass m and s Values*

Empirical failure criterion $\sigma_1 = \sigma_3 + (m\sigma_c\sigma_3 + s\sigma_c^2)^{1/2}$ where σ_1 = major principal stress, σ_3 = minor principal stress, σ_c = uniaxial compressive strength of intact rock, *m* and *s* are empirical constants		CARBONATE ROCKS WITH WELL-DEVELOPED CRYSTAL CLEAVAGE *Dolomite, Limestone, and Marble*	LITHIFIED ARGILLACEOUS ROCKS *Mudstone, Siltstone, Shale, and Slate (Normal to Cleavage)*	ARENACEOUS ROCKS WITH STRONG CRYSTALS AND POORLY DEVELOPED CRYSTAL CLEAVAGE *Sandstone and Quartzite*	FINE-GRAINED POLYMINERALLIC IGNEOUS CRYSTALLINE ROCKS *Andesite, Dolerite, Diabase, and Rhyolite*	COARSE GRAINED POLYMINERALLIC IGNEOUS AND METAMORPHIC CRYSTALLINE ROCKS *Amphibolite, Gabbro, Gneiss, Granite, Norite, and Quartz - Diorite*
INTACT ROCK SAMPLES Laboratory-size specimens free of discontinuities	m	7.00	10.00	15.00	17.00	25.00
RMR = 100	s	1.00	1.00	1.00	1.00	1.00
Q = 500	*m*	*7.00*	*10.00*	*15.00*	*17.00*	*25.00*
	s	*1.00*	*1.00*	*1.00*	*1.00*	*1.00*
VERY GOOD QUALITY ROCK MASS Tightly interlocking undisturbed rock with unweathered joints at 1–3 m	RES m	2.40	3.43	5.14	5.82	8.56
RMR = 85	s	0.082	0.082	0.082	0.082	0.082
Q = 100	*m*	*4.10*	*5.85*	*8.78*	*9.95*	*14.63*
	PK *s*	*0.189*	*0.189*	*0.189*	*0.189*	*0.189*
GOOD QUALITY ROCK MASS Fresh to slightly weathered rock, slightly disturbed with joints at 1–3 m	m	0.575	0.821	1.231	1.395	2.052
RMR = 65	s	0.00293	0.00293	0.00293	0.00293	0.00293
Q = 10	*m*	*2.006*	*2.865*	*4.298*	*4.871*	*7.163*
	s	*0.0205*	*0.0205*	*0.0205*	*0.0205*	*0.0205*
FAIR QUALITY ROCK MASS Several sets of moderately weathered joints spaced at 0.3–1 m	m	0.128	0.183	0.275	0.311	0.458
RMR = 44	s	0.00009	0.00009	0.00009	0.00009	0.00009
Q = 1	*m*	*0.947*	*1.353*	*2.030*	*2.301*	*3.383*
	s	*0.00198*	*0.00198*	*0.00198*	*0.00198*	*0.00198*
POOR QUALITY ROCK MASS Numerous weathered joints at 30–500 mm with some gouge. Clean compacted waste rock	m	0.029	0.041	0.061	0.069	0.102
RMR = 23	s	0.000003	0.000003	0.000003	0.000003	0.000003
Q = 0.1	*m*	*0.447*	*0.639*	*0.959*	*1.087*	*1.598*
	s	*0.00019*	*0.00019*	*0.00019*	*0.00019*	*0.00019*
VERY POOR QUALITY ROCK MASS Numerous heavily weathered joints spaced at less than 50 mm with gouge. Waste rock with fines	m	0.007	0.010	0.015	0.017	0.024
RMR = 3	s	0.0000001	0.0000001	0.0000001	0.0000001	0.0000001
Q = 0.01	*m*	*0.219*	*0.313*	*0.469*	*0.532*	*0.782*
	s	*0.00002*	*0.00002*	*0.00002*	*0.00002*	*0.00002*

Criterio modificado Hoek-Brown

$$\sigma_1' = \sigma_3' + \sigma_c \left(m_b \frac{\sigma_3'}{\sigma_c} \right)^a$$

m_b = valor de la constante m para roca fracturada

a =constante para roca quebrada

Criterio de Hoek-Brown generalizado

$$\sigma_1{}' = \sigma_3{}' + \sigma_c \left(m_b \frac{\sigma_3{}'}{\sigma_c} + s \right)^a$$

m_b = valor de la constante m para roca quebrada

a =constante para roca quebrada

$$\sigma_1' = \sigma_3' + \sigma_c \left(m_b \frac{\sigma_3'}{\sigma_c} + s \right)^a$$

where m_b is the value of the constant m for the rock mass

s and a are constants which depend upon the characteristics of the rock mass

σ_c is the uniaxial compressive strength of the intact rock pieces and

σ_1' and σ_3' are the axial and confining effective principal stresses respectively.

For $GSI > 25$ (Undisturbed rock masses)

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

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

$$a = 0.5$$

For $GSI < 25$ (Undisturbed rock masses)

$$s = 0$$

$$a = 0.65 - \frac{GSI}{200}$$

$$m_b = m_i \exp\left(\frac{GSI-100}{28-14D}\right)$$

$$s = \exp\left(\frac{GSI-100}{9-3D}\right)$$

$$a = \frac{1}{2} + \frac{1}{6}\left(e^{-GSI/15} - e^{-20/3}\right)$$

(Modificación, 2002)

Table 6.2: Values of the constant m_i after Hoek et al, 1995.

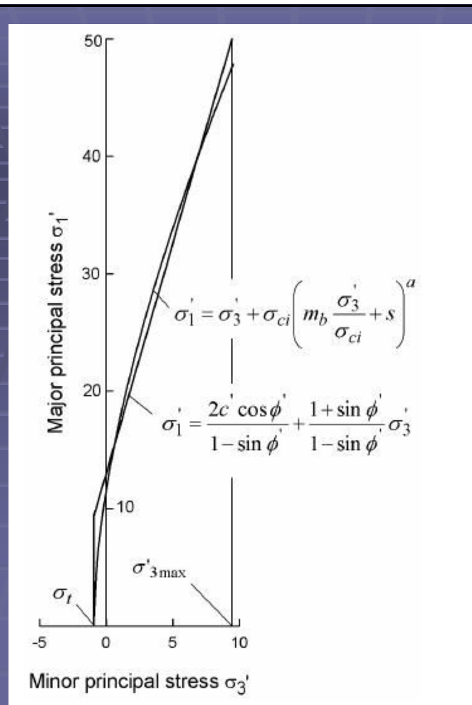
Rock type	Class	Group	Texture: Course	Texture: Medium	Texture: Fine	Texture: Very fine
SEDIMENTARY	Clastic		Conglomerate (22)	Sandstone 19	Siltstone 9	Claystone 4
				← Greywacke (18) →		
	Non-Clastic	Organic		← Chalk 7 →		
				← Coal (8-21) →		
		Carbonate	Breccia (20)	Sparitic Limestone (10)	Micritic Limestone 8	
		Chemical		Gypstone 16	Anhydrite 13	
METAMORPHIC	Non Foliated		Marble 9	Hornfels (19)	Quartzite 24	
	Slightly foliated		Migmatite (30)	Amphibolite 31	Mylonites (6)	
	Foliated*		Gneiss 33	Schists (10)	Phyllites (10)	Slate 9
IGNEOUS	Light		Granite 33		Rhyolite (16)	Obsidian (19)
			Granodiorite (30)		Dacite (17)	
			Diorite (28)		Andesite 19	
	Dark		Gabbro 27	Dolerite (19)	Basalt (17)	
			Norite 22			
	Extrusive pyroclastic type		Agglomerate (20)	Breccia (18)	Tuff (15)	

Ángulos de fricción y cohesión equivalentes

$$\phi' = \sin^{-1}\left[\frac{6am_b(s+m_b\sigma'_{3n})^{a-1}}{2(1+a)(2+a)+6am_b(s+m_b\sigma'_{3n})^{a-1}}\right]$$

$$c' = \frac{\sigma_{ci}\left[(1+2a)s+(1-a)m_b\sigma'_{3n}\right](s+m_b\sigma'_{3n})^{a-1}}{(1+a)(2+a)\sqrt{1+\left(6am_b(s+m_b\sigma'_{3n})^{a-1}\right)/\left((1+a)(2+a)\right)}}$$

where $\sigma_{3n} = \sigma'_{3\max}/\sigma_{ci}$



Ejemplo RocLab