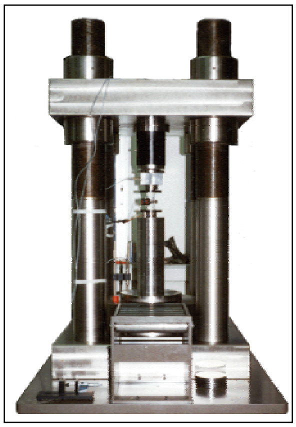
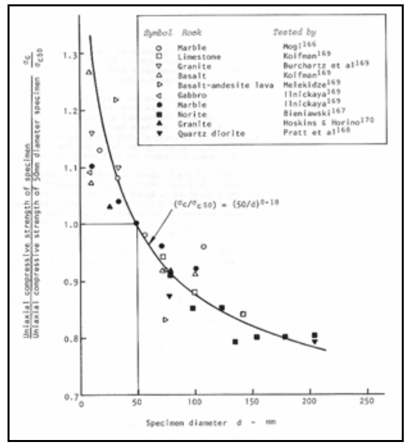

Rock properties


Rock properties:
1) “Intact” rock
2) Discontinuities
3) Rock mass

"Intact rock strength": Uniaxial Compression Test



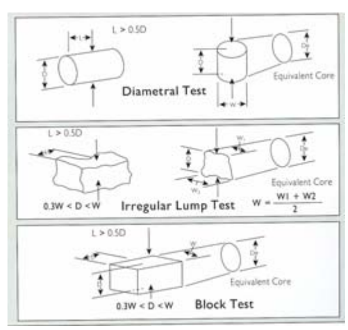
Scale effect:

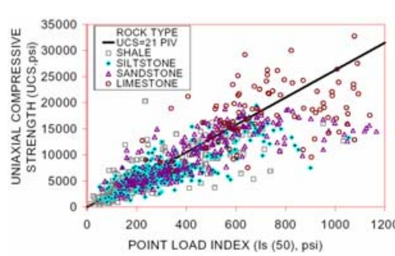


Hoek and Bray (1977)

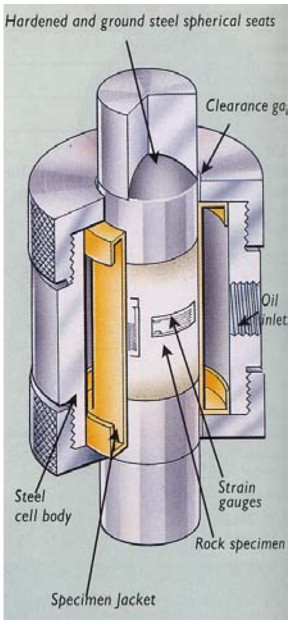
Point Load Test

(Franklin, 1973)



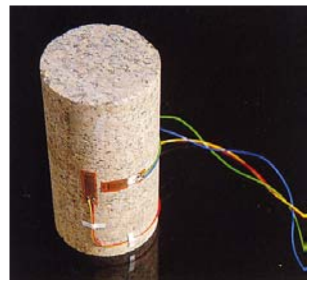


Rusnak J, Mark C., 2002



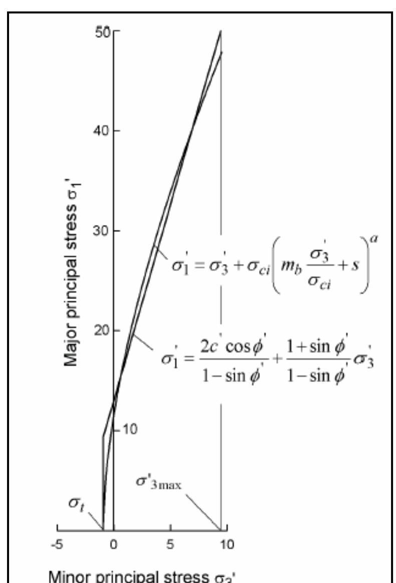
Triaxial test (Hoek Cell)

(Hoek and Franklin, 1976)

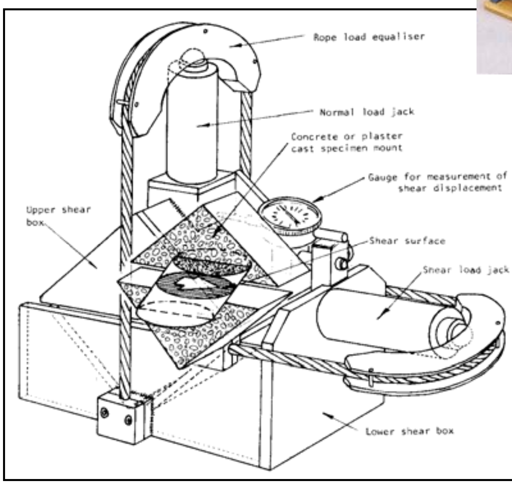


Hoek-Brown strength criterion (1980)

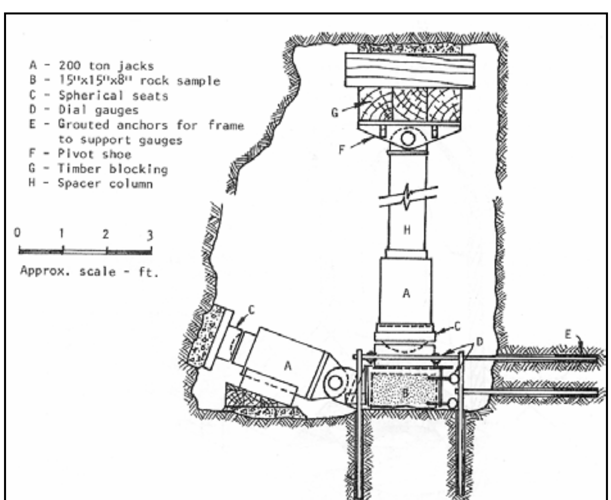
$$\sigma_1' = \sigma_3' + \sigma_{ci}'(m_b \frac{\sigma_3'}{\sigma_{ci}'} + s)^a$$



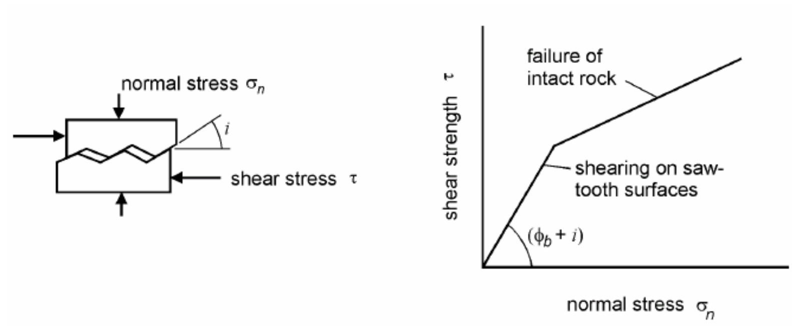
Shear strength of rock discontinuities: Hoek field shear box



"In situ" direct shear test



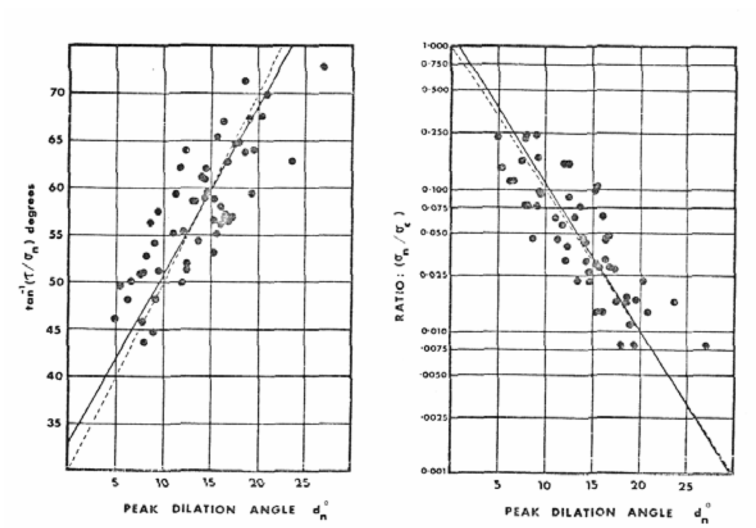
Shear strength of discontinuities in rock



$$\tau = \sigma_n \tan(\phi_b + i)$$

Patton (1966)

“Multiple modes of shear failure..”



Barton (1973)

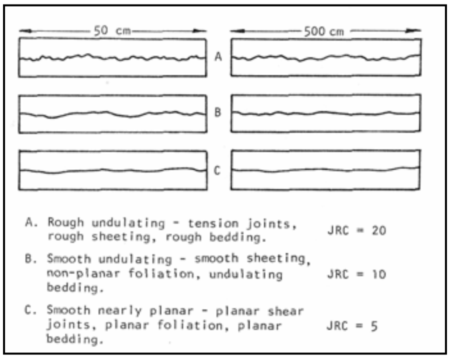
σ_c=uniaxial strength

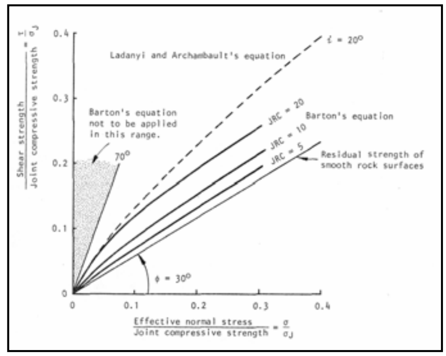
σ_n=normal stress

Barton, N., 1973. Review of a new shear strength criterion for rock joints. Engineering Geology, 7:287-332

Barton's shear strength criterion (1973)

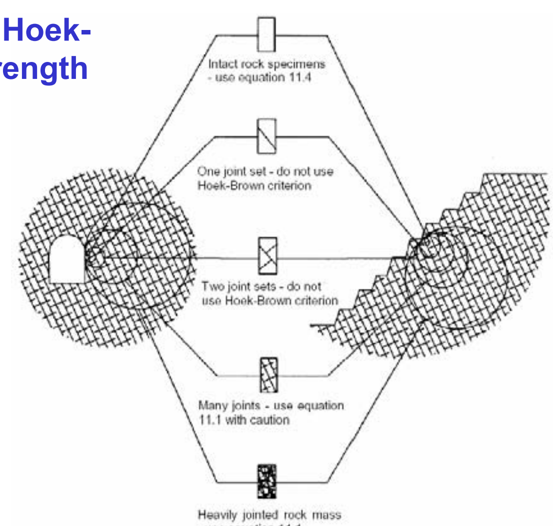
$$\tau = \sigma_n \tan[\phi_b + JRC \log_{10}(\frac{JCS}{\sigma_n})]$$





Rock mass strength:

empirical Hoek-Brown strength criterion



Uniaxial Compressive Strength

"Hammer Test"

Table 1: Field estimates of uniaxial compressive strength of intact rock.[3]

Grade*	Term	Uniaxial Comp. Strength (MPa)	Point Load Index (MPa)	Field estimate of strength	Examples
R6	Extremely Strong	> 250	>10	Specimen can only be chipped with a geological hammer	Fresh basalt, chert, diabase, gneiss, granite, quartzite
R5	Very strong	100 - 250	4 - 10	Specimen requires many blows of a geological hammer to fracture it	Amphibolite, sandstone, basalt, gabbro, gneiss, granodiorite, peridotite , rhyolite, tuff
R4	Strong	50 - 100	2 - 4	Specimen requires more than one blow of a geological hammer to fracture it	Limestone, marble, sandstone, schist
R3	Medium strong	25 - 50	1 - 2	Cannot be scraped or peeled with a pocket knife, specimen can be fractured with a single blow from a geological hammer	Concrete, phyllite, schist, siltstone
R2	Weak	5 - 25	**	Can be peeled with a pocket knife with difficulty, shallow indentation made by firm blow with point of a geological hammer	Chalk, claystone, potash, marl, siltstone, shale, rocksalt,
R1	Very weak	1 - 5	**	Crumbles under firm blows with point of a geological hammer, can be peeled by a pocket knife	Highly weathered or altered rock, shale
R0	Extremely Weak	0.25 - 1	**	Indented by thumbnail	Stiff fault gouge

* Grade according to Brown (1981).
** Point load tests on rocks with a uniaxial compressive strength below 25 MPa are likely to yield highly ambiguous results.

m_i coefficient

(measure of shear strength of the intact rock)

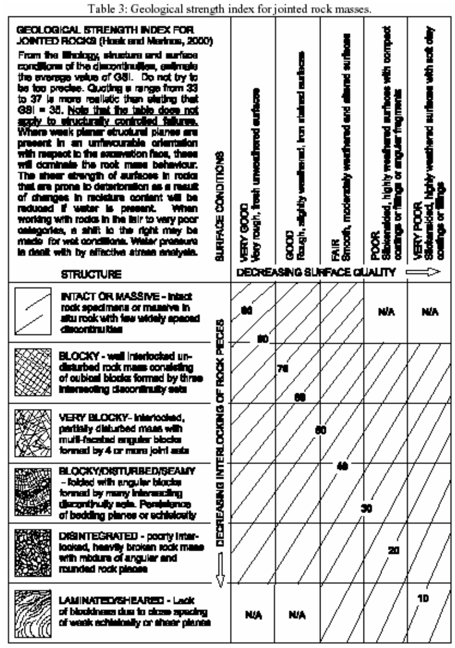
Table 2: Values of the constant m_i for intact rock, by rock group[4]. Note that values in parenthesis are estimates. The range of values quoted for each material depends upon the granularity and interlocking of the crystal structure – the higher values being associated with tightly interlocked and more frictional characteristics.

Rock type	Class	Group	Texture: Coarse	Texture: Medium	Texture: Fine	Texture: Very fine
SEDIMENTARY	Clastic		Conglomerates * Breccias *	Sandstones 17 $\pm$ 4	Siltstones 7 $\pm$ 2 Greywackes (18 $\pm$ 3)	Claystones 4 $\pm$ 2 Shales (6 $\pm$ 2) Marls (7 $\pm$ 2)
SEDIMENTARY	Non-Clastic	Carbonates	Crystalline Limestone (12 $\pm$ 3)	Sparitic Limestones (10 $\pm$ 2)	Micritic Limestones (9 $\pm$ 2)	Dolomites (9 $\pm$ 3)
SEDIMENTARY	Non-Clastic	Evaporites		Gypsum 8 $\pm$ 2	Anhydrite 12 $\pm$ 2	
SEDIMENTARY	Non-Clastic	Organic				Chalk 7 $\pm$ 2
METAMORPHIC	Non Foliated		Marble 9 $\pm$ 3	Hornfels (19 $\pm$ 4) Metasandstone (19 $\pm$ 3)	Quartzites 20 $\pm$ 3	
METAMORPHIC	Slightly foliated		Migmatite (29 $\pm$ 3)	Amphibolites 26 $\pm$ 6	Gneiss 28 $\pm$ 5	
METAMORPHIC	Foliated**			Schists 12 $\pm$ 3	Phyllites (7 $\pm$ 3)	Slates 7 $\pm$ 4
IGNEOUS	Plutonic	Light	Granite 32 $\pm$ 3 Granodiorite (29 $\pm$ 3)	Diorite 25 $\pm$ 5		
IGNEOUS	Plutonic	Dark	Gabbro 27 $\pm$ 3 Norite 20 $\pm$ 5	Dolerite (16 $\pm$ 5)		
IGNEOUS	Hypabyssal		Porphyries (20 $\pm$ 5)		Diabase (15 $\pm$ 5)	Peridotite (25 $\pm$ 5)
IGNEOUS	Volcanic	Lava		Rhyolite (25 $\pm$ 5) Andesite 25 $\pm$ 5	Dacite (25 $\pm$ 3) Basalt (25 $\pm$ 5)	
IGNEOUS	Volcanic	Pyroclastic	Agglomerate (19 $\pm$ 3)	Breccia (19 $\pm$ 5)	Tuff (13 $\pm$ 5)	

* Conglomerates and breccias may present a wide range of m_i values depending on the nature of the cementing material and the degree of cementation, so they may range from values similar to sandstone, to values used for fine grained sediments (even under 10).
** These values are for intact rock specimens tested normal to bedding or foliation. The value of mi will be significantly different if failure occurs along a weakness plane.

“Geological Strength Index (GSI)”

Table 3: Geological strength index for jointed rock masses.



“Generalized Hoek-Brown strength criterion for rock masses

(1995)

$$\sigma_1' = \sigma_3' + \sigma_{ci}'(m_b \frac{\sigma_3'}{\sigma_{ci}'} + s)^a$$

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

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

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

“Rocklab” (download from www.rockscience.com)