

A list of countries for principle rock engineering projects includes:

- # *United Kingdom: Rock structure assessment for A82 Loch Lomond Road Cutting, M1-M62 Motorway Interchange, Hinkley Point "C" Nuclear Power Station foundation investigation, M4-Bryn Glas By-Pass Road Cutting, Plymouth Tank Farm Inspections*
- # *Egypt: Suez Rock armour quarry design*
- # *United Arab Emirates: Fujairah Rock armour quarry design*
- # *Australia: Port Hedland Harbour Rock Dredging Investigations.*
- # *Mauritius: Assessment of Rock Slopes and tunnels for Port Louis Ring Road*
- # *Pakistan: Swabi Scarp Water Supply Project (10km of new and refurbished rock tunnels), Indus Highway Project, Bridge Foundation Report*
- # *India: Bombay Sewerage Project (twin three kilometre marine outfall tunnels and two IPS 35m diameter, 45m deep rock shafts)*
- # *Malaysia: Bakun Dam Access Road slope design advice (including 80m high rock cutting reinforcement design)*
- # *Hong Kong: Risk analysis and slope protection design for Ting Kau rock slopes on Tuen Mun Highway.*
- # *Iran: Kerman Water Supply, technical assessment studies for dam and 64km tunnel construction.*

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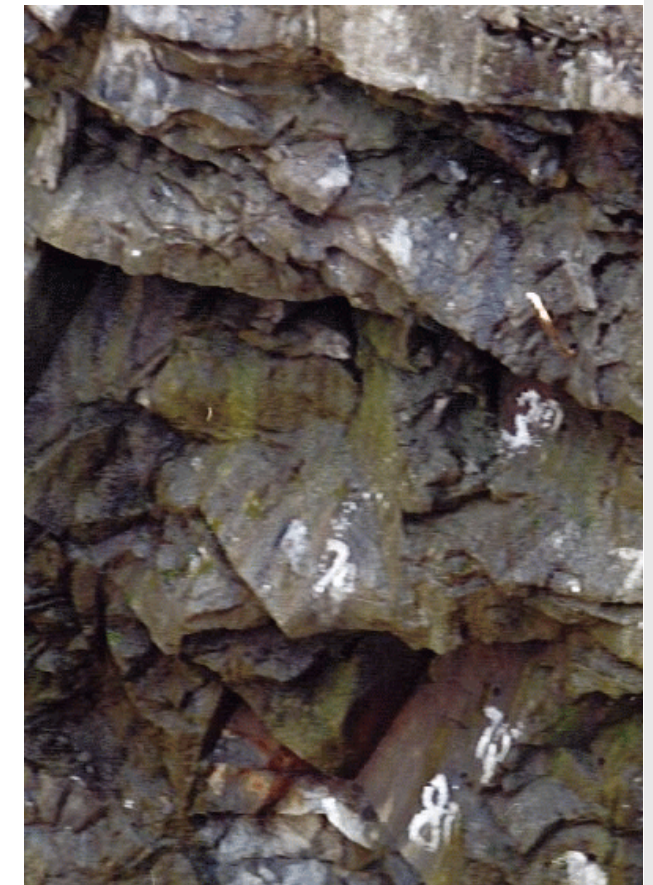
Rock Engineering for Foundations, Slopes and Tunnels

Rock mechanics has been a major aspect of work for Antonio Associates for many years and major projects have been completed in all parts of the world.

Rock engineering projects for highway cuttings, foundations and underground structures and the excavation of rock or the design of permanent structures in rock requires a thorough understanding of:

- # *all rock types and full rock structure,*
- # *in-situ stress history and induced changes,*
- # *rock material strength and joint strength,*
- # *optimum and effective reinforcement,*
- # *the effects of water, and,*
- # *an understanding of how these measurements are applied to the large scale engineering project.*

Despite the fact that many rock materials are stronger than the concrete of most structures, engineering projects in rock require thorough consideration. Only in very particular circumstances can a rock mass be analysed in a similar way to soil. When deep underground or when the size of discontinuities, faults and large joints in most rock masses are of a similar scale to the engineering design, is when other design methods can be used which follow the principles of rock mechanics.



Antonio Associates has provided expert support to projects for the design of rock foundations, rock cuttings, water supply tunnels, rail and road tunnels, quarries and rock-filled embankments.

PLANE FAILURE ANALYSIS

Typically, on large projects, geological site surveys, including field mapping and coring is required to provide basic field data for initial design.

SLOPE HEIGHT	30	H	m
FACE PLANE DIP	63	af	deg
FAILURE PLANE DIP	49	ap	deg
DENSITY OF ROCK	26	dr	kN/m ³
DENSITY OF WATER	9.8	dvw	kN/m ³
DEPTH OF TENSION CRACK (≠12.42m)	7	z	m
DEPTH OF WATER IN TENSION CRACK	7	zw	m
SELECT (FACE OR UPPER) SLOPE MODEL	U	FIU	upper
if zw=z is used for the general to case, the Factor of Safety for dry, wet and saturated slopes is also calculated. For TC=0, dry and saturated slopes are calculated			
ANCHOR LOAD		T	kN
ANCHOR LOAD ANGLE		Tap	deg
CRITICAL ACCELERATION (Az/Ah=2)			
COHESION OF PLANE	10	c	kPa
ANGLE OF FRICTION FOR PLANE	35	phi	deg
COMP STRENGTH JOINT	80,000	Gcj	kPa
JRC (BARTON)	6	JRC	

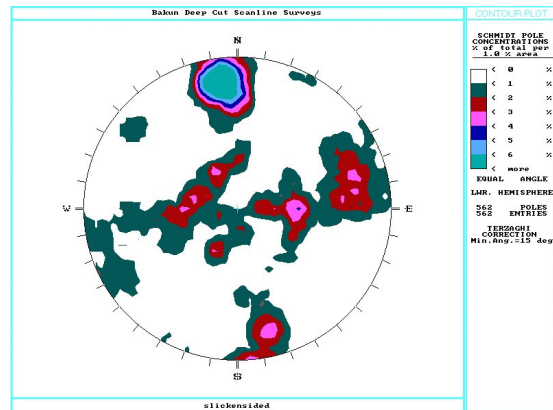
W	Wn	Ws	W uppl
3,665	2,398	2,759	3,665
A	U	V	W face
30	1,046	240	4,221
Tn kN/m ²			max z
			12.42
			apC
			49.00
			zoc
			7.03
			b-to
			4.71

	dry	wet	sat
F	0.72	0.64	0.39
TANphi	0.70	0.70	0.70
n	2,398	2,217	1,172
ca	305	305	305
Sn	79	73	98
QcJ/Sn	1,017	1,100	2,081
tA	3,187	2,969	1,968
tangential	2,759	2,916	2,916
F	1.16	1.02	0.57

SLOPE STABILITY FACTOR OF SAFETY	
USING C, PHI STRENGTH CHARACTERISTICS	
FOR DRY SLOPES	0.72
FOR SLOPES WITH WET TC	0.64
FOR SATURATED SLOPES	0.39
USING BARTON STRENGTH CHARACTERISTICS	
FOR DRY SLOPES	1.16
FOR SLOPES WITH WET TC	1.02
FOR SATURATED SLOPES	0.57

calculation warnings and flags	
upper	
tension crack exists on upper slope, 4.71m from crest	
TC depth within limits and TC is 100% full of water	
water level in TC is OK	
CRITICAL VALUES for DRY slopes: ap=49deg, zoc=7.03m, b=1.03m	

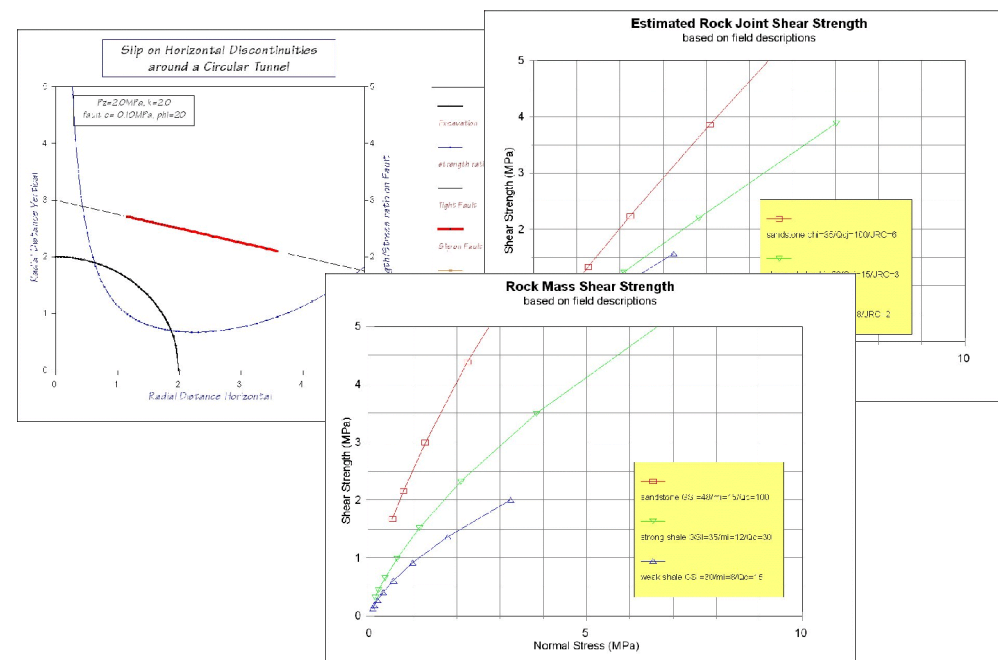
Rock structure is assessed with controlled sampling techniques using scanline surveys and stereographic projection methods may be used for presentation and as design tools.



Surface or underground design must reflect the interplay of rock strength and rock structure and often a statistical approach is used to provide working designs.

Obtaining some knowledge of in-situ stress is often a greater concern than rock strength for underground excavations. Weak layers or weak joints may fail and cause local deformation of good quality rock in other areas of the opening.

Using field observations, field testing, simple or in some cases highly sophisticated laboratory testing techniques, the basic relationships between rock mass and rock material strength can be assessed and utilised in the design.



Rock engineering projects require a thorough understanding of the interplay of mass and material properties.