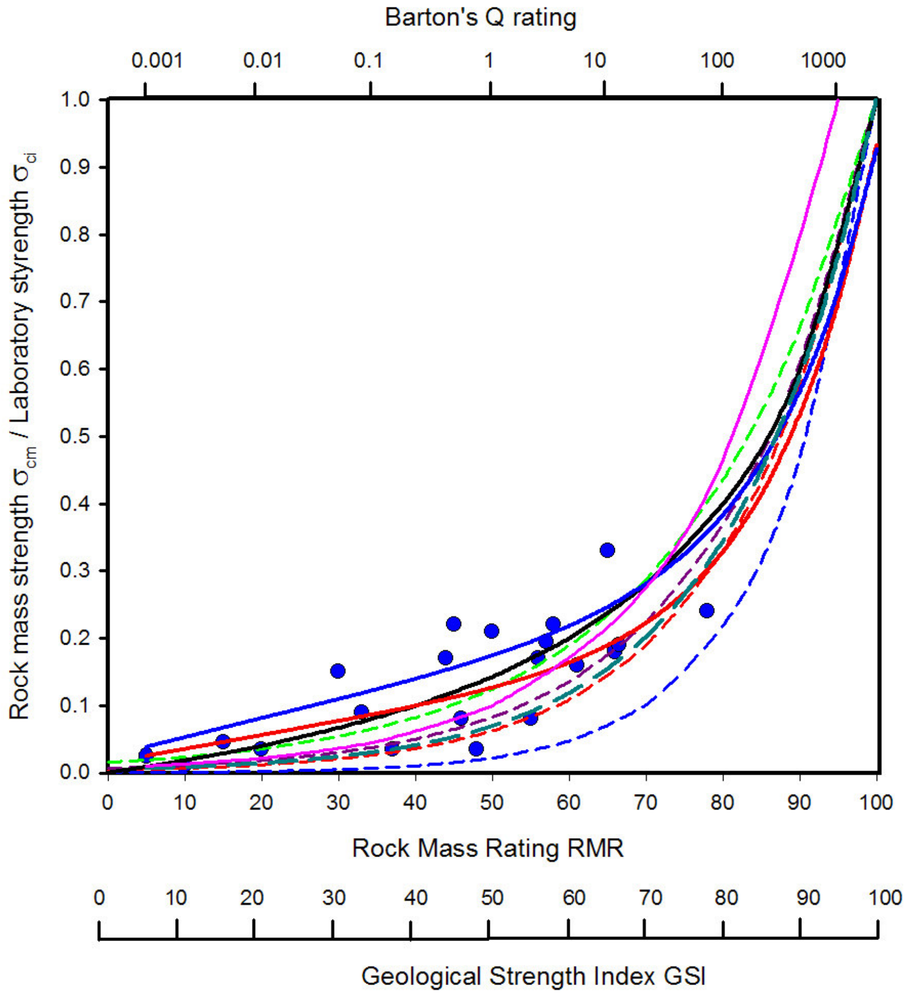
Discussion paper # 4

Estimates of rock mass strength

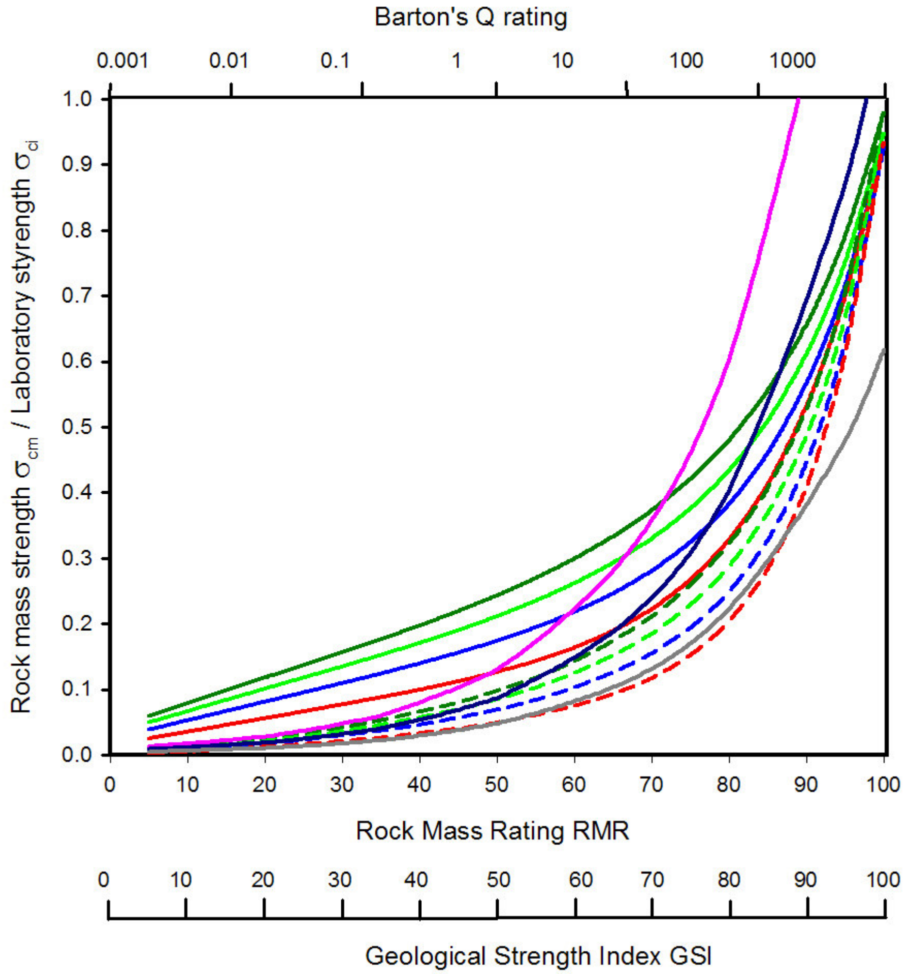
In the preliminary stages of a rock engineering design the need for approximate estimates of rock mass strength frequently arises. Several authors have published empirical estimates of rock mass strength, based on rock mass classification systems. These estimates, together with available data from in situ measurements, are summarized in Figure 1. Hoek et al (2002) and Barton (2000) have extended these empirical relationships to allow for different intact rock strength values and for disturbance due to blast damage and stress relaxation. These extended relationships are summarized in Figure 2. All of these relationships are intended to provide initial estimates of the rock mass properties and they should be used with caution in engineering design. In critical cases it is strongly recommended that the estimates should be confirmed by in situ measurements or by back analysis of excavation behaviour. The use of RMR values of less than 20 and Q values of less than 0.01 for making these estimates is not recommended because of the dominant role of RQD in these classifications and the difficulty of determining its value for very poor quality rock masses. It is recommended that only directly determined values of RMR, Q and GSI should be used for making these estimates and that equations relating these classifications should not be used.

Evert Hoek April 2004



●	In situ tests from construction sites in Turkey	Aydan, O and Dalgic,S, 1998
red dashed line	$\sigma_{cm}/\sigma_{ci} = \sqrt{\exp((RMR-100)/9)}$	Hoek, E and Brown, E.T., 1980
blue dashed line	$\sigma_{cm}/\sigma_{ci} = \exp(7.65\,((RMR-100)/100))$	Yudhbir and Bieniawski, Z.T., 1983
green dashed line	$\sigma_{cm}/\sigma_{ci} = \exp((RMR-100)/24)$	Kalamaris, G and Bieniawski, Z.T, 1993
teal dashed line	$\sigma_{cm}/\sigma_{ci} = \exp((RMR-100)/20)$	Sheorey, P.R. 1997
purple dashed line	$\sigma_{cm}/\sigma_{ci} = \exp((RMR-100)/18.75)$	Ramamurthy, T, 1986
black solid line	$\sigma_{cm}/\sigma_{ci} = (RMR/(RMR+6(100-RMR)))$	Aydan, O and Dalgic,S, 1998
blue solid line	m_i = 10, for confined conditions with D = 0	Hoek et al, 2002
magenta solid line	$\sigma_{cm} = 5\gamma(Q\,\sigma_{ci}/100)^{(1/3)}$, $\gamma = 2.6$, $\sigma_c = 100$ MPa	Barton 2000, Singh 1993

Figure 1: Estimates of the ratio of rock mass strength to the strength of small laboratory samples based upon rock mass classifications.



red solid line	m_i = 5, for confined conditions with D = 0	Hoek et al, 2002
blue solid line	m_i = 10, for confined conditions with D = 0	Hoek et al, 2002
light green solid line	m_i = 15, for confined conditions with D = 0	Hoek et al, 2002
dark green solid line	m_i = 20, for confined conditions with D = 0	Hoek et al, 2002
red dashed line	m_i = 5, for disturbed conditions with D = 1	Hoek et al, 2002
blue dashed line	m_i = 10, for disturbed conditions with D = 1	Hoek et al, 2002
light green dashed line	m_i = 15, for disturbed conditions with D = 1	Hoek et al, 2002
dark green dashed line	m_i = 20, for disturbed conditions with D = 1	Hoek et al, 2002
magenta line	$\sigma_{cm} = 5\gamma(Q\,\sigma_{ci}/100)^{(1/3)}$, γ = 2.6, σ_c = 100 MPa	Barton 2000, Singh 1993
dark blue line	$\sigma_{cm} = 5\gamma(Q\,\sigma_{ci}/100)^{(1/3)}$, γ = 2.6, σ_c = 30 MPa	Barton 2000, Singh 1993
grey line	$\sigma_{cm} = 5\gamma(Q\,\sigma_{ci}/100)^{(1/3)}$, γ = 2.6, σ_c = 5 MPa	Barton 2000, Singh 1993

Figure 2: Rock mass strength predictions by Hoek at al, 2002, and Barton, 2000

References

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[1] This paper together with the Windows program RocLab can be downloaded from www.rocscience.com.