Discussion paper # 4

Estimates of rock mass strength
and deformation modulus

In the preliminary stages of a rock engineering design the need for approximate estimates of rock mass strength and deformation modulus frequently arises. Several authors have published empirical estimates of these properties, based on rock mass classification systems. These estimates, together with available data from in situ measurements, are summarized in Figures 1 and 3. 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 Figures 2 and 4. 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.
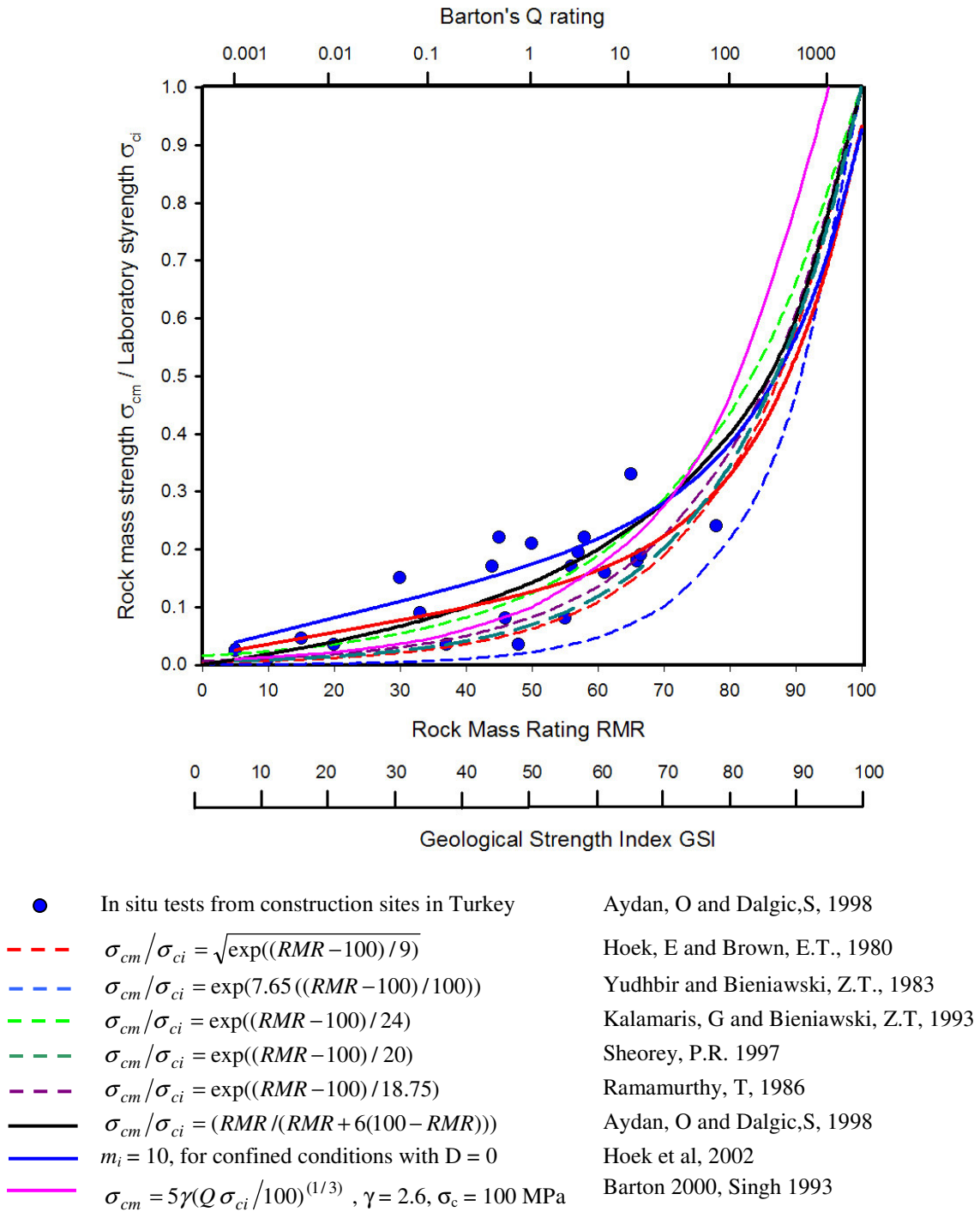
Evert Hoek   April 2004

	In situ tests from construction sites in Turkey	Aydan, O and Dalgic,S, 1998
- - -	$\sigma_{cm}/\sigma_{ci} = \sqrt{\exp((RMR-100)/9)}$	Hoek, E and Brown, E.T., 1980
- - -	$\sigma_{cm}/\sigma_{ci} = \exp(7.65((RMR-100)/100))$	Yudhbir and Bieniawski, Z.T., 1983
- - -	$\sigma_{cm}/\sigma_{ci} = \exp((RMR-100)/24)$	Kalamaris, G and Bieniawski, Z.T, 1993
- - -	$\sigma_{cm}/\sigma_{ci} = \exp((RMR-100)/20)$	Sheorey, P.R. 1997
- - -	$\sigma_{cm}/\sigma_{ci} = \exp((RMR-100)/18.75)$	Ramamurthy, T, 1986
——	$\sigma_{cm}/\sigma_{ci} = (RMR/(RMR+6(100-RMR)))$	Aydan, O and Dalgic,S, 1998
——	$m_i = 10$, for confined conditions with D = 0	Hoek et al, 2002
——	$\sigma_{cm} = 5\gamma(Q\,\sigma_{ci}/100)^{(1/3)}$, $\gamma = 2.6$, $\sigma_c = 100$ 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.
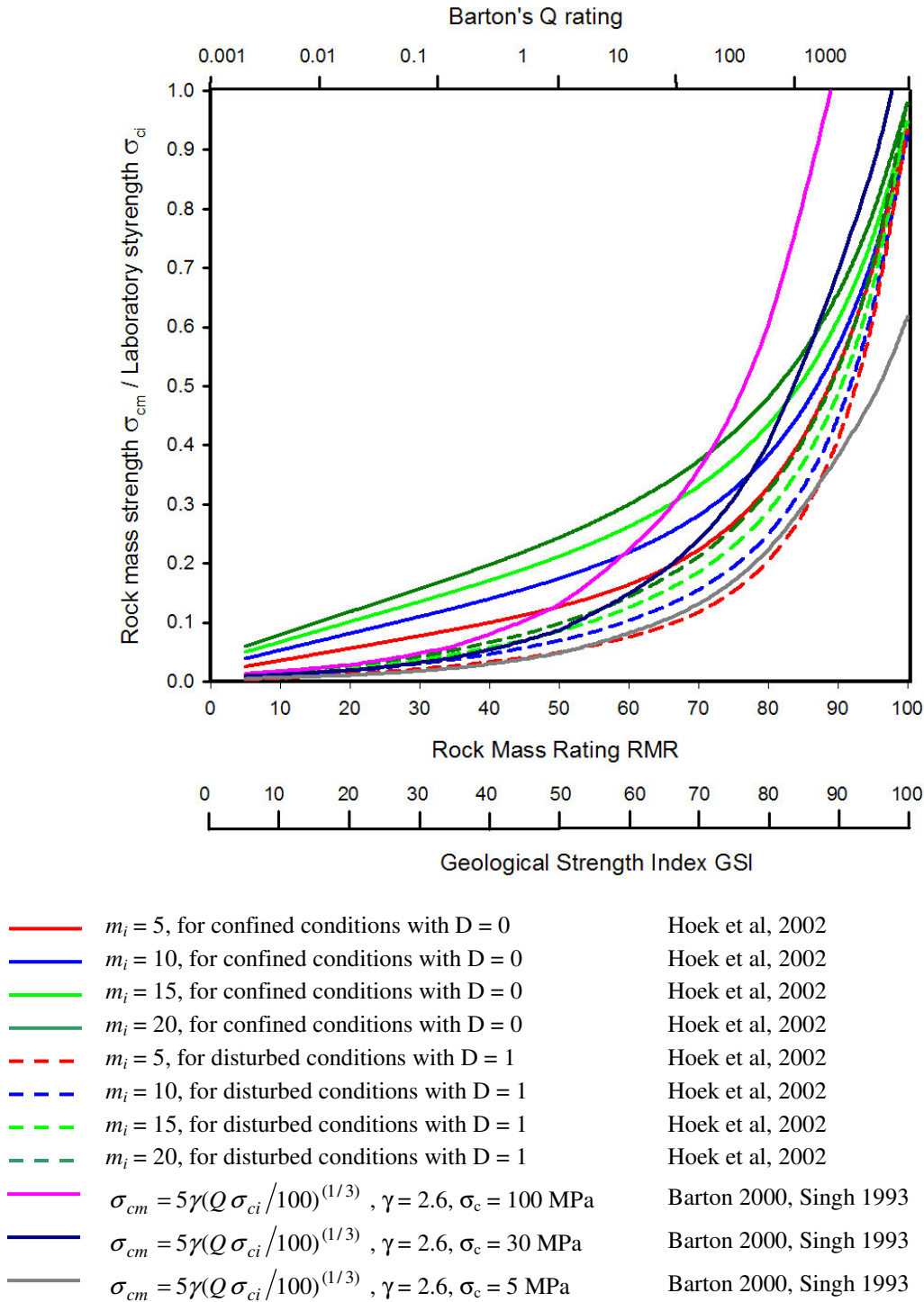
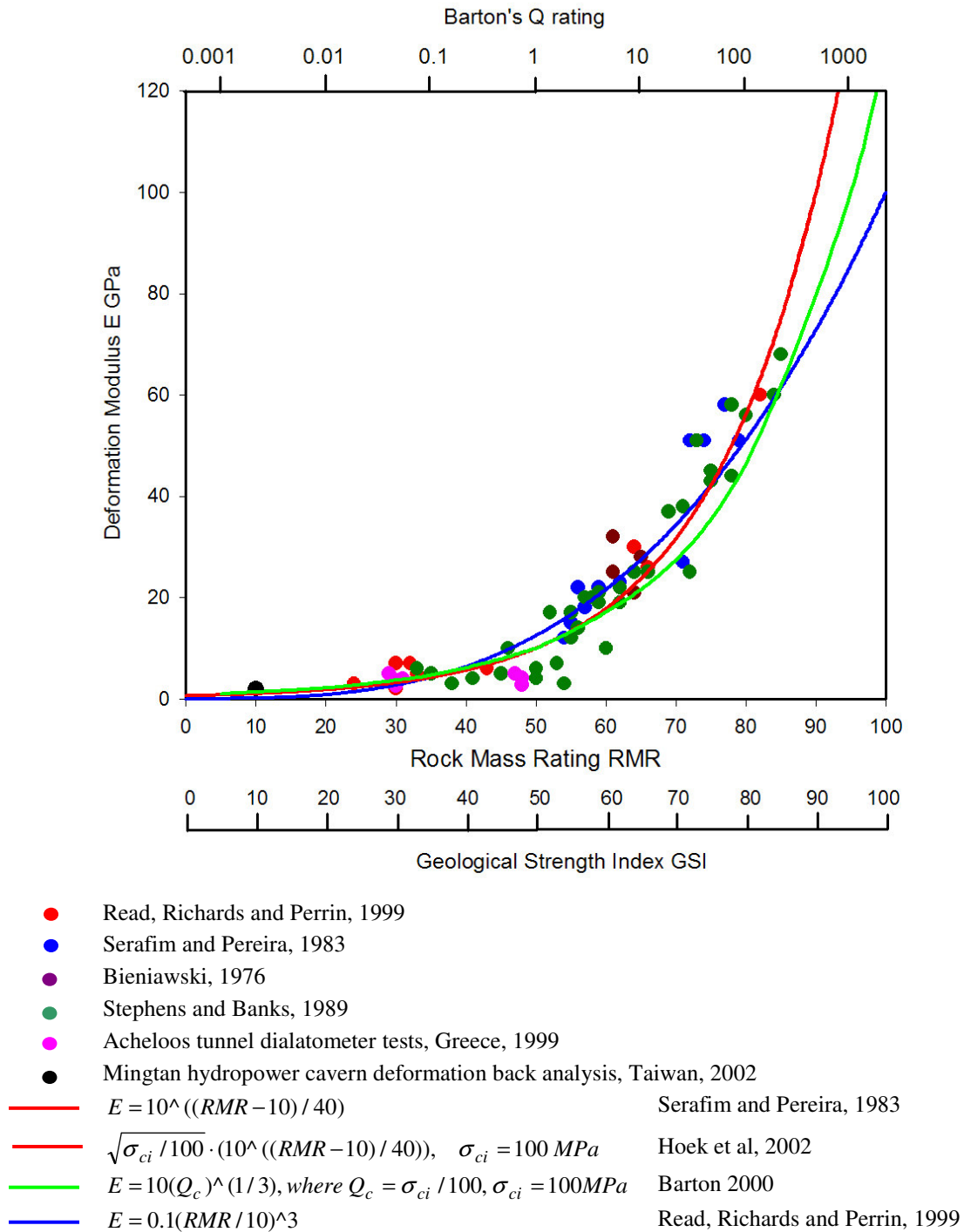Figure 2: Rock mass strength predictions by Hoek at al, 2002, and Barton, 2000

Figure 3: Deformation modulus field measurements and empirical estimates.
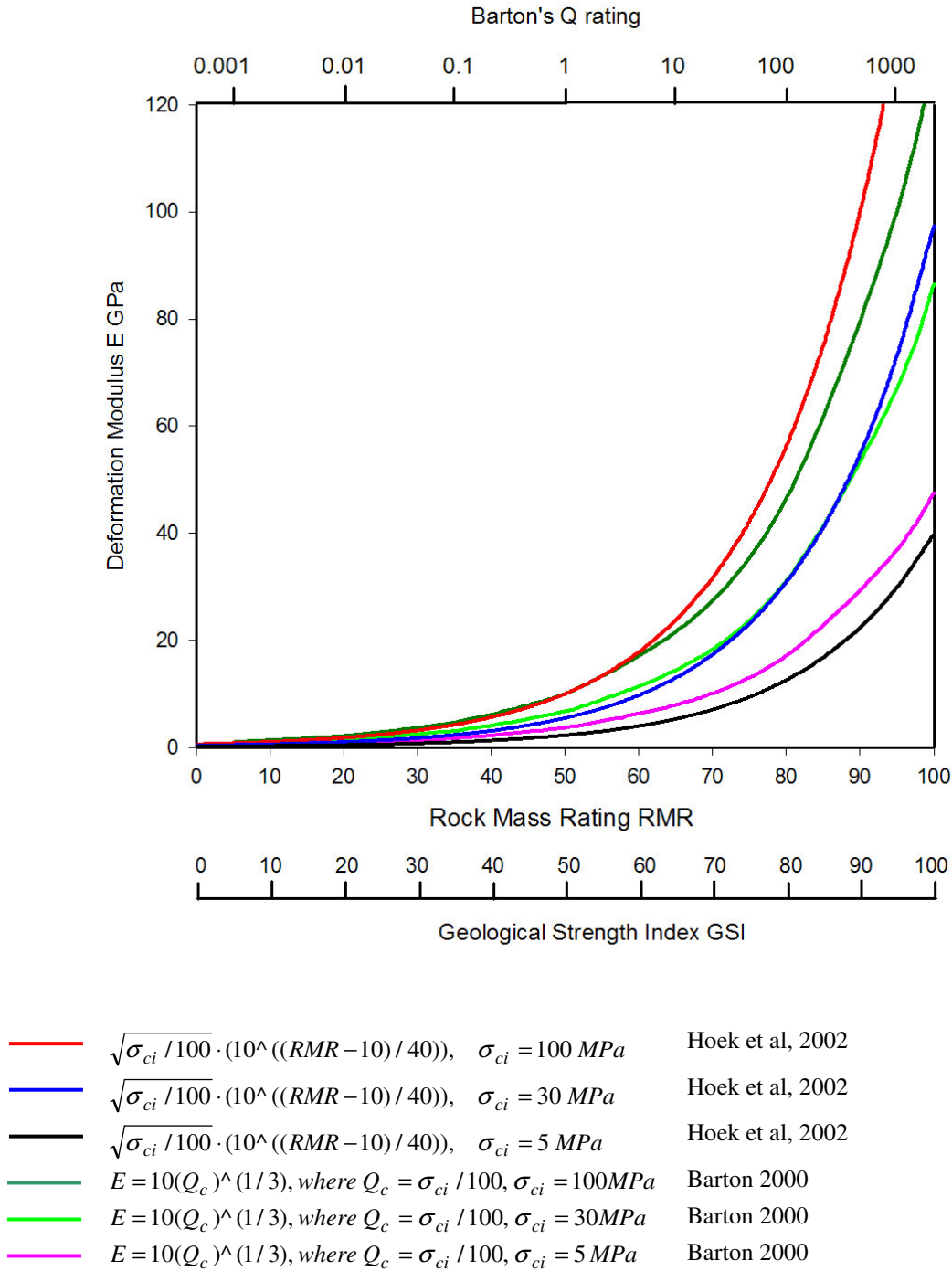
Barton's Q rating

Figure 4: Estimates of rock mass deformation modulus by Hoek, Carranza-Torres and Corkum, 2002 and by Barton, 2000, for different values of the intact rock strength σ_{ci}.

References

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