The Editor,
Prof. Marc Panet,
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Dear Sirs,

Water and stress are fundamental to rock mass *characterization* and *classification.*

A recent report from a rock mass classification workshop held in Australia in 2000, which was reported by Palmstrøm, Milne and Peck in your ISRM News Journal (August 2001, 6,3 : 40-41) may leave the impression that the subject of rock mass classification has been definitively debated, and that an important conclusion has been reached for the profession to follow. Regrettably, this desirable goal has clearly not been achieved in this forum, as we will try to demonstrate. Of concern, perhaps only to the undersigned, is the fact that the developers of two of the principal classification methods under discussion, were not able to give possible alternative points of view. Perhaps this *will be permitted* in the pages of your ISRM News Journal.

The key dilemma is whether the 'internal' and 'external' so-called boundary conditions of water and stress should be permitted in a rock mass characterization scheme. The latter might be RMR, Q or the more recent RMi of Palmstrøm. The problem is particularly relevant here, since RMi does *not* include water and stress, and this new but complex method *was* represented by its developer in Melbourne.

Firstly, one can address rock mass *classification* for preliminary empirical design of rock mass reinforcement and tunnel support. Here it seems to be generally agreed that water and stress parameters are 'allowable', and in fact are necessary components of the classification. Their possible wide-reaching effects in excavation design are clear, and many users understand the necessity of, for instance, Jw and SRF in the Q-system. The close correlation between the six-parameter Q-value and the necessary quantities of B + S(fr), were shown by Grimstad and Barton, 1993, in a major Q-system support-recommendation update, which now includes some 1260 case records.

Secondly, there is the problem of rock mass *characterization* of relevant rock units at appropriate depths for a future rock engineering project. Prior to excavation, the 'virgin' rock mass qualities and correlated design parameters like deformation modulus, may be required as input data for modelling. The correct interpretation of seismic velocities obtained from shallow refraction seismic, or from deeper reaching VSP, or from focussed cross-hole seismic velocity tomography, and their conversion to tentative rock qualities at depth is also an important goal of this site *characterization* stage.

The report of the GeoEng2000 Workshop on rock mass classification by Palmstrøm, Milne and Peck, reproduced in your ISRM News Journal, leaves one in no doubt that the majority opinion from this forum was, suprisingly, that use of RMR or Q in site *characterization* should be with the truncated versions that have been promoted by various authors. In the case of Q this would mean Q', the first four parameters only, thus excluding the coupling with water and stress. The RMi is already 'truncated', so fitted the 'workshop opinion' perfectly. The suggested exclusion of these 'boundary conditions' in site *characterization* is in fact far from what is desirable in our rock engineering profession, which we will try to demonstrate using the following simple reasoning.

Firstly, when rock mechanics engineers back-calculate a deformation modulus (M) from measured tunnel or cavern deformations, or when they do the same beneath an instrumented plate jacking or loading test, in each case using a pre-installed MPBX device, there will usually be the effects of both water and redistributed in situ rock stresses within the interpreted modulus. The water may even have a dual role in softening joint coatings or discontinuity fillings (where stresses are not too high), and in reducing the effective stresses. These effects will be important whatever the depth, both within the excavation disturbed zone and beyond the EDZ.

If the furthest MPBX anchor points are sufficiently deep, perhaps the (almost) undisturbed deformation modulus for the particular depth and rock unit can be recorded. The resulting modulus (or moduli) obviously include the internal and external boundary conditions referred to above, and will be relevant to the particular effective stresses acting across the various joint sets.

Secondly, when a geophysicist calculates arrival times and seismic attenuation, perhaps from VSP or cross-hole seismic velocity tomography, he is not asked to somehow exclude the effects of water pressure and rock stress, i.e. their all-important coupling in the form of effective stress. The Moho velocity discontinuity is also not corrected for stress and fluid pressure effects, much deeper in the Earth's crust.

If our rock mass *classification* and rock mass *characterization* methods are to correlate readily with such measurements of modulus and velocity, both close to and distant from an excavation, which must surely be an important goal in our subject, then the adverse effects of water and the usually positive effects of rock stress on these measurements *must* be accounted for in the chosen method.(In fact water will first have a positive effect on Vp when the water table is reached – going downwards).

In the recent Q-system correlation routines described by Barton, 1995 and 1999, it is shown how depth of measurement (or effective stress) alters the Q – M and Q – Vp correlations. However, it is fundamental that ratings for Jw and SRF are included in these correlations, since the first four parameters in the Q-system can only give an incomplete, uncoupled description of the rock mass, as emphasised by Barton, 2002.

Water ‘softens’ clay-bearing discontinuities, and clay-bearing faults ‘soften’ the rock mass, both of which have greatest effect when excavation occurs. Our Vp and M estimations will tend to reflect both these effects, either if measurements are carried out within an excavation disturbed zone, or from outside the EDZ. Values of Vp and M will usually be distributed as knee-shaped curves close to the excavations and are specifically the end result of coupled behaviour, with blast damage as a complicating factor.

Finally a word about the volumetric joint count Jv, suggested many years ago by Palmstrøm as an alternative to RQD. This factor is often promoted by the undersigned in helping to estimate RQD when evaluating the Q-value in the absence of core data. These two measures of the degree of jointing were compared in an exaggerated diagram in the GeoEng 2000 Workshop report. Due to the good engineering sense of Deere, the ‘universally used’ RQD range of 0 to 100% actually covers most of our rock engineering *problems*, while Jv cannot be evaluated accurately with only core data. In glaciated or exposed steep terrain, and once underground, Jv may however be very useful.

Contrary to the stated opinion by the workshop co-reporters, highly anisotropic rock *is well described* by its joint spacing! On the contrary, conversion of Jv to a block size may be impossible in such cases. RQD stretches into a zone of much smaller ‘block sizes’ than shown by Palmstrøm, but of course RQD is 0% throughout this lower range. In fact this is important information too, when combined with other descriptive parameters. Furthermore, are we really so concerned if block volumes are 1000, 10,000 or 100,000 m^3 ? Even the ‘smallest’ of these must be ‘very good quality,’ even for producers of dimension stone.

Contrary to the opinion expressed in the workshop report, the ratio RQD/Jn is a very sensitive indicator of relative block size. Its extreme range is 200 to 0.5, and it clearly distinguishes between rockburst-prone massive rock and ‘normally’ jointed or crushed, altered rock, as shown by Grimstad and Barton, 1993. Very suprisingly, Palmstrøm et al. 2001, actually state that *RQD and Jn* (the all-important number of joint sets) *and joint spacing* ‘do a poor job of quantifying block size’. This indeed is a new way of thinking!

In conclusion, those who call for truncated *characterization*, as occurs automatically with RMi, are simultaneously rejecting the influence of coupled behaviour in several of the important parameters that we try to measure during site characterization. They are doing the profession and themselves a disfavour, as they will not be able to correlate correctly with the real-world response of rock masses, which is often highly coupled. Deformation moduli and seismic velocities do not correlate with jointing parameters alone, but with the complex non-linear response of these properties to the ‘internal’ and ‘external’ boundary conditions, which often give anisotropic as well as depth-dependent properties, as emphasised by Barton 1999 and 2002. It is therefore illogical not to include both stress and water, both in characterization *and* classification. Contrary to the Palmstrøm et al. assertion that the Q-value requires *fewer* parameters for *characterization*, the undersigned would assert that RMi requires *more* parameters, both for *characterization* and *classification*!

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References

Palmstrøm, A., Milne, D. and Peck, W. 2001. The reliability of rock mass classification used in underground excavation and support design. GeoEng2000 Workshop, Discussion Leaders, ISRM News Journal, Vol. 6, No. 3, August, 2001.

Barton, N. 1995. The influence of joint properties in modelling jointed rock masses. Keynote lecture, Proc. 8th ISRM Cong., Tokyo, 3, 1023-1032, Balkema, Rotterdam.

Barton, N. 1999. General report concerning some 20th Century lessons and 21st Century challenges in applied rock mechanics, safety and control of the environment. Gen. Rept., Theme 1, Proc. 9th ISRM Cong., Paris, 3, 21p, Balkema, Rotterdam.

Barton, N. 2002. Some new Q-value correlations to assist in site characterization and tunnel design. Submitted to the Int. J. Rock Mech.& Min. Sci., 2001.

Grimstad, E. and Barton, N. 1993. Updating the Q-system for NMT. Proc. of the Int. Symp. on Sprayed Concrete – Modern Use of Wet Mix Sprayed Concrete for Underground Support, Fagernes. Eds. Kompen, Opsahl and Berg, Norwegian Concrete Association, Oslo.