Code of Practice: Strata Control in Underground Mines
Jim Galvin

I have previously submitted a number of comments in regard to the WHS Regulation that are also relevant to the Code of Practice in Underground Coal Mines. This submission relates to Section 3.1 of the Code of Practice in Underground Coal Mines and specifically to the following text:

"Characterisation requires a widely appreciable and appropriate estimate of rock mass strength that can be related to the in situ stress environment, such that the response of the rock mass can be predicted. For example, the Coal Mine Roof Rating, or CMRR system (Molinda and Mark, 1994) , is used widely to characterise the immediate roof strata, focusing on the bolted horizon. It also entails an understanding of the level of variability of the rock mass, including the impact of lithological changes and geological anomalies (for example, faults and dykes)."

The CMRR is a form of rock mass classification system. It is effectively an extension of the Rock Mass Rating System developed for the tunnelling industry by Richard Bieniawski in the 1970s. Many eminent rock mechanics engineers do not subscribe to rock mass classification systems, including CMRR, having the merits and capabilities credited to CMRR in the above statement and with the manner that CMRR is used in many instances.

Rock mass classification systems are scoring schemes which attempt to characterise the quality or competence of a rock mass by assigning a numerical rating to factors thought to affect the stability or behaviour of the rock mass, and summing these to produce a single numerical index. A number of secondary schemes have been developed which endeavour to correlate rock mass indices with field experience in areas such as excavation span, stand up time, ground support requirements, pillar safety factor, caveability, fragmentation, and slope stability. This type of approach is not mechanistically based and has been superseded to some extent by the advent of powerful numerical analysis methods, prompting the development of modified classification systems which provide rock mass ratings that are more useful as input into these models.

Rock mass classification schemes which endeavour to encapsulate the complexity and diversity of a natural rock mass in a single numerical index are attractive and offer advantages because of their simplicity; because they cause rock mass properties to be evaluated in a systematic and continuous manner; and because they can be calibrated to previous experience. However, they have shortcomings and must be used with care (Galvin, 2014). In general:

- Most give little or no consideration to:
    - the characteristics of the surrounding rock mass;
    - impacts which might arise from deformation and mobilisation of the surrounding strata during mining;
    - single geological features, such as an unfavourably orientated plane of weakness or a thin stratum with poor mechanical properties, the behaviour of which is the dominant factor causing structural failure.
    - stress anisotropy;
    - the influence of mining direction.

- Not all of the critical factors which control ground response in a mining environment may be incorporated into the rating system; for example, the number of joint sets or the dip of joint sets.

- Adjustments which are made to account for the influence of mining are often of a subjective nature.

- The systems are suited primarily to situations where failure is controlled by sliding and rotation of intact pieces of rock at low to moderate stress levels. They do not cater for situations where failure is associated with squeezing, swelling, spalling or pressure bursts, or where failure develops progressively.

- The numerical value of the resulting rock mass index can be highly dependent on the local knowledge and experience of the person assessing the rock mass.

Hence, rock mass behaviour mechanisms and failure modes are largely ignored in rock mass classification systems and all important controlling aspects may not be fully evaluated. Two quite different rock mass structural settings or rock mass behaviour mechanisms, for example, can have the same rock mass classification index. Similarly, a change in a critical factor will not be reflected in a classification index unless this factor is explicitly included in the classification rating scheme. Caution is required, particularly with design procedures that rely on direct correlations to rock mass ratings.
(Hoek & Brown, 1980) pointed out the dangers involved in blindly adopting the provisions of the Q system. (Hoek et al., 1995) emphasised the importance of understanding that the use of a rock mass classification scheme does not (and cannot) replace some of the more elaborate design procedures. This advice was reinforced by (Hartman & Handley, 2002), stating that it must be understood a classification system can give the guidelines but the geologist or engineer must interpret the finer details. (Brady & Brown, 2006) noted that whilst a rock mass classification approach is superficially attractive, it has a number of serious shortcomings and must be used with extreme care. It does not always fully evaluate the important aspects of a problem and, if applied blindly without supporting analysis of the mechanics of the problem, can lead to disastrous results. Subsequently, (Pells, 2008)expressed concern at the inappropriate and sometimes dangerous manner in which rock mass classification systems are used to quantify behaviour. Pells was particularly critical of the design of tendon support systems on the basis of rock mass classification systems, noting that they provide little or no idea of the loads the reinforcement is supposed to carry or the shear and tensile displacements the bolts are expected to encounter.

Some rock mass classification systems are no longer just being used as a point of reference to past outcomes but also as primary determinant of mechanism of behaviour, even of strata to which they do not relate in some cases. In underground coal mining, examples are to be found in ground support design and pillar system design. The determination of roof support patterns is critically dependent on the orientation of joint systems, the orientation and magnitude of horizontal stress, the direction of drivage, and the presence of very weak individual units, none of which feature in the derivation of rock mass ratings on which some support designs are being based.

In the case of coal pillar system design, rock mass competence has implications for both pillar system strength and pillar system working stress (load) determinations. The only technically sound way that the selection of a pillar system design safety factor could be based directly on a rock mass rating is if all of the primary parameters that determine pillar system strength and working load are incorporated into the rock mass rating system and weighted in a manner consistent with their individual contribution to determining pillar system strength and load.

The issue is concerning because of the risks that can be associated with the inappropriate use of rock mass classification systems in underground mining, especially when used as a basis for mine design and operating procedures. These systems do not constitute rigorous analysis, should not be correlated directly to mechanisms of behaviour, and should not be used in isolation.

Against this background, I suggest that it would be wise not to single out any specific rock mass classification system and/or, if reference is to be made to such systems, to alert to the end user to the limitations of these systems.

Hoek, E., & Brown, E. T. (1980). *Underground Excavations in Rock*. London: Inst. Min. & Metall.

Hoek, E., Kaiser, P. K., & Bawden, W. F. (1995). *Support of Underground Excavations in Hard Rock*. Rotterdam: A.A. Balkema.

Hartman, W., & Handley, M. F. (2002). The Application of the Q-Tunnelling Quality Index to Rock Mass Assessment at Impala Platinum Mine. *J. Sth. Afr. Inst. Min. Metall, 102*(3), 155-165.

Brady, B. H. G., & Brown, E. T. (2006). *Rock Mechanics for Underground Mining* (Third ed.). Cordrecht: Springer.

Pells, P. J. N. (2008, April). *What Happened to the Mechanics in Rock Mechanics and the Geology in Engineering Geology?* Paper presented at the 6th Int. Sym Ground Control in Mining and Civil Engineering Construction, Capetown.

Galvin, J.M. (2014). *Ground Engineering in Underground Coal Mining: Principles and Practices.* Cordrecht; Springer. (In press)

Regards

Jim

Emeritus Professor J Galvin