General Report – Mining, Tunnelling and Excavations

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1. INTRODUCTION

Given the Conference Theme - "Geotechnical Risk, Identification, Evaluation and Solutions" and the theme of Session 3, "Mining, Tunnelling and Excavations", the twelve papers provided for reporting present a broad spectrum of endeavour and create difficulties in delivering a coherent view. Some papers even bear little relation to the theme of the Session except having incorporated the term of geotechnical risk.

At such Conferences, we should question where our skills have developed in this region, particularly in the 4 years since the conference in Sydney in 1988.

The twelve papers generally can be grouped such that two address coal mine subsidence, albeit from different perspectives, whilst two papers consider stress measurement. A further two papers consider rock mass characterisation with one considering data collection, whilst the other addresses a reliability-based method in assessment of stability and support requirements in jointed rock excavations.

Three papers address aspects of coal mining, and in particular strength criteria, peripheral fractures on the side of roadways and advanced electronic monitoring techniques.

Only one paper addresses tunnel construction, and this is primarily from an historic viewpoint since the construction was nearly 40 years ago.

The two papers on deep excavation appear to be somewhat out of context with regard to the other ten papers of this session.

2. REVIEW OF PAPERS

The paper by Villaescusa addresses the problem of rock mass characterisation. Villaescusa addresses a very specialised subject which will no doubt be of interest to those working in this field. After describing conventional techniques of rock discontinuity data collection, Villaescusa proceeds to recommend a sampling method based on a line intersection criterion due to the considerable reduction in the number of discontinuities required for subsequent mathematical analysis.

Mapping of full traces is recommendedinstead of semi-trace length sampling because of the lognormal nature of trace length distributions.

Data collection and handling has advanced significantly since the 1960's when R D Terzaghi (1965) published a method of reducing orientation bias and as well as the work by Villaescusa at the University of Queensland, a significant development by CSIRO Division of Geomechanics is SIROJOINT, a system able to determine rock mass structure automatically. CSIRO claims the system enables vital data collection concerning the structural state of the rock mass to be determined in a rapid and cost effective manner.

As with Villaescusa, Brox has drawn upon research work conducted at Imperial College, and presents an interesting approach to a quite difficult problem in the design stage using a reliability-based prediction rather than a "rule of thumb".

Brox suggests the method is becoming increasingly accepted in geotechnical engineering, and develops the concept through the identification of potentially unstable blocks. The author then proceeds to quantify potentially unstable blocks and describes in limited detail the statistical and probabilistic evaluation of stability and support requirements. In order to develop support requirements in the concept stage of a project it is admirable to attempt to develop techniques with a rational basis rather than resort to "rules of thumb", which often have an undue degree of inherent conservatism. Nevertheless the statement of Section 3.1 of this paper that "no direct consideration is given to the influence of in situ stress or the cohesive and frictional components of strength along joint surfaces" surely incorporates an intangible degree of safety.

The case studies presented by Brox represent a quantitative assessment of the method and the predicted bolt lengths for the respective cases (in Table 1) of the paper correspond reasonably with the recommended/installed lengths. However, the predicted bolt spacings for the chamber and slope differ significantly from the recommended/applied spacing but the author does not elaborate on the reasons for this divergence. It would be useful if the author had provided a justification for the statement that the reliability-based approach may be more applicable for assessing rock support requirements for rock masses that are characterised with closely spaced jointing where there is a strong likelihood of instability.

It would also be useful if the method for selecting the recommended/installed bolt lengths and spacing had been described so that the relativity of approaches could be assessed.

In the design development stage of an underground project, the understanding of the stress field and the changes liable to be induced by excavation are now generally within our grasp. Enever et al present examples of recent stress and hydraulic jacking measurements carried out by CSIRO Division of Geomechanics in three Ausrtralian states for the design of pressure tunnels. The paper highlights the stress variability associated with structural and topographic features, and their impact on tunnel lining requirements for the prevention of leakage. The paper indicates empirical design criteria for depth of cover, incorporating topographic effects have been used successfully for many years, and the authors state direct stress measurements are necessary for modern numerical analytical methods, but the key justification for the stress measurements and hydraulic jacking tests by borehole pumping is their direct applicability.

Citing three case studies (King River, Tasmania, Boomerang Creek, NSW and Tully Millstream, Queensland) the authors present a comparison of techniques adopted.

It is significant to note that the hydraulic fracturing performed for the Tully Millstream investigation represented the first civil engineering application of the Minifrac System developed by CSIRO for 38mm diameter holes.

In summing up, it is interesting to note that the authors concluded that since at all sites topography is a major feature, they suggested geological structure has an overriding influence on stress variability, compared to topographical effects.

In contrast to the inference derived from the paper by Brox concerning stresses, Enever et al, conclude that the mapping of structural discontinuities is essential and the orientations of joint and fracture planes should be considered in conjunction with the stress field orientations, since the stress components normal to the planes are the critical factor in assessing the risk of hydraulic jacking. They furthermore conclude that hydraulic pumping of individually isolated, orientated joints is the most direct test of jacking potential.

Another paper on stress measurement has been prepared by Brox et al and relates to the first stress measurements performed in Hong Kong. A significant proportion of the paper reiterates the background behind stress measurement in rock masses and develops the methodology applied (hydraulic fracturing). Brox et al have assumed that σ_3 is vertical and apparently took measurements in a vertical borehole. Whilst the topography of the area under consideration on Tsing Yi Island is not given, it is suggested that the full stress field could usefully be determined by the hollow inclusion cell provided rock conditions permit. This would obviate the need for assumptions regarding the minor or intermediate stress orientation.

Brox et al describe their testing programme at Tsing Yi Island and indicate test results for the pressure-time and flow-rate - time data were typical for Tsing Yi data. As this test programme was a first in Hong Kong, the relevance of this statement is difficult to comprehend how the data could be typical.

Those with some knowledge of the Hong Kong granites can understand the statement that the absolute magnitude of in situ stresses is not of general concern in comparison to the strength of most rocks, the relative magnitude of the minimum principal horizontal stress compared to the overburden stress is of major concern in the evaluation of the stability of large span underground excavations.

Once the rock mass characterisation and stress field have been established, strength of the mass assumes importance. Vutukuri and Hossaini have prepared a detailed paper on the statistical assessment of strength criteria for intact coal. They have re-analysed data on coal strength tests published by Hobbs (1964) and Das and Sheorey (1986). Four strength criteria have been described, namely:

- Bieniawski
- Hoek and Brown
- Johnston
- Ramamurthy

and Vutukuri and Hossaini proceed to describe their regression analysis of the triaxial test data. They state that an estimate of the axial compressive stress at failure at any confining pressure can be made if only the uniaxial compressive strength of the intact coal is known.

It is interesting to note that Vutukuri and Hossaini believe the selection of appropriate software for non-linear regression analysis is crucial in the results obtained.

Following in the sequence developed are the papers on mining and underground works. Follington and Medhurst describe a monitoring system which appears to still be in its infancy and is still subject to further development. The concept appears to be excellent in that skilled resources are far more cost effective in being able to interpret data and be relieved of tedious data gathering, often in risk prone areas.

In another field of development, CSIRO Division of Geomechanics are attempting to develop a range of intrinsically safe instrumentation that is compatible and able to address the geotechnical parameters such as convergence and support loads which affect underground coal mine management. A virtue of the system will be the ability to utilise existing mine telephone systems and be able to span up to 2 km from underground telephones.

The adoption of such systems, however, may require attention to the education of management and workforces to realise their potential. Such systems will also need to be sufficiently proven in the field, otherwise their implementation could be retarded.

Bhattacharyya and Belleza have studied the depth and degree of fracturing at the sides of pillars and continuous ribs in roadways at two underground coal mines in New South Wales. The seismic refraction technique was adopted and the end result should lead to the optimum design of pillars based on a knowledge of the support capability of the peripheral fractured zone.

In summing up, Bhattacharyya and Belleza suggested that the differences between results derived by the refraction method were lower than those by the modified uphole method and the latter were estimates. As indicated by the authors, further work in this area is essential.

The authors also suggest that the depth of the fractured zones seems to indicate a relationship with the depth of the seam below the surface. Although this statement has some backing from the work of Wilson (1972) and Barron (1978), it is perhaps too bold a conclusion from limited data.

The paper by Gordon describes the problems which beset the construction of the Homer tunnel near Milford Sound, New Zealand. With the advances in knowledge and methods of stress measurement, the ramifications of rock bursting would now be anticipated. However given that construction proceeded between 1934 and 1953 it was fortuitous that the stress levels were such that catastrophic failures did not occur, because little option on a realignment of the route appeared possible. In the paper Gordon suggests the vertical stress field, given by the gravitational component γZ where γ = unit weight of rock and Z is the depth below surface, may have been a contributing cause, but topographic and denudation effects are probably of greater significance bearing in mind the rocks traversed.

The author also suggests that the stresses were residual, largely horizontal and once released attenuated with time. It is possible that once bursting occurred no further change in the stress field occurred. However this could only be clarified by absolute stress measurement and consideration of the rock mass strength relative to these stress levels.

Two papers relating to mine subsidence have been presented and the first by Stone et al considers centrifugal modelling for total and partial extraction in the Collie field in Western Australia. The model depth considered of approximately 60m cover over the seam is relatively shallow for longwall mining. These authors suggest that to date the prediction of mining induced subsidence has relied on the use of empirical models and little or no attempt has been made to formulate predictive models based on the physical responses of geomechanical materials - soil and rock.

The tests certainly represent an initial study of the applicability of centrifuge modelling to simulate coal extraction beneath relatively soft sedimentary rock. However it should be noted that this only applies to Australian practice and other large-scale physical models for both longwall and shoftwall mining have been tested at Bellambi, NSW by ACIRL from the early 1960's. Furthermore, centrifuge modelling of mining structures is by no means new, although material similitude has been a new area of endeavour.

The greatest contribution that centrifuge testing can make in improving the understanding of subsidence mechanisms is the ability to observe crack pattern development.

The observation that more abundant cracking occurred and extended over a larger area in the longwall model compared with the Wongawilli panel model appears to bear out a similarity to the prototype experience.

The paper by Farquhar and Douglas on the other hand is an interesting case study of the effects of subsidence of old workings on a community. After a thorough search of the limited records still available of 100 year old workings, the authors have assessed the subsidence hazard in a residential area. After adopting a risk assessment, as proposed by Cole (1987), the authors determined a number of properties to be at risk in varying degrees. The authors state that the nature of geotechnical engineering, and particularly the work dealing with abandoned mines and mining subsidence, is such that the amount of data required to allow a reliable statistical analysis of the problem is seldom available or obtainable.

In discussing their Table 1, the authors claim without any appareant justification that there was a greater risk of damage to property than destruction of property and a greater risk of injury than loss of life. Whilst both statements appear logical, the methodology should be developed rather than making subjective assessments.

The final two papers allocated for this session of the Conference relate to deep excavations. The former paper by Goh et al describes the back analysis of a deep excavation in soft clay. The particular case study was the Marina Bay Station on the Singapore MRT development which was constructed by a series of coffer dams followed by submerged excavation of the soil.

The back analysis by the finite element method showed reasonable agreement with field results for deflection. The method also enabled simulation of the effects of soil properties on wall behaviour whilst alternative construction techniques were also considered.

It would be of interest to readers of this paper to know the level of the water table which prompted the decision to flood the coffer dam in order to achieve base stability.

It is also interesting to note that Goh et al advanced their analyses over those presented at the Fifth ANZ Conference in 1988 for Newton Station on the MRT system in an endeavour to develop design guidelines for deep excavations in soft Singapore clays.

The paper by Ressi di Cervia describes the use of diaphragm walls to reduce risk in deep excavation. The paper describes the method in general terms only and does not address specific geotechnical issues nor are the references adequately presented.

3. GENERAL COMMENTS

As a general observation the importance of mining geotechnics has generally been given insufficient attention by way of the number or scope of papers submitted. The contribution of underground mining, particularly to the Australian economy, is very significant and the absence of relevant papers must surely prompt questions such as:

- is the Conference a relevant venue for presentation of such papers?
- is the mining industry lacking adequate geotechnical expertise?
- are practitioners too busy to publish?
- have there been no significant advances in the technologies available to us worth reporting?

Having posed these questions it is believed the following answers apply:

- Such Conferences are the ideal vehicle for such presentations, particularly when the Conference theme is Risk, and mining exploitation does encompass an element of risk.
- The second question must be answered in the negative as some very significant work has been performed in the key production areas.
- The third question is probably answered in the affirmative. To present a paper can be an onerous task, and furthermore in the competitive world in which we practise, any mining company obtaining the technical "edge" is loathe to relinquish it to competitors.
- The fourth question is definitely answered in the negative as we see the imminent introduction of the Mark 2 Robbins Mobile Miner at Pasminco, Broken Hill, and the advances in rock cutting with road headers in stronger, more abrasive rocks such as on the Sydney Harbour Tunnel land tunnels.

4. REFERENCES

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