EARLY DAYS OF ROCK MECHANICS AND STRATA CONTROL

BY JIM ENEVER

EARLY DAYS OF ROCK MECHANICS AND STRATA CONTROL

Jim Enever

Principle Scientist
CSIRO Petroleum

ABSTRACT: BHP/AIS's Rock Mechanics and Strata Control (RM & SC) Group was formed in the late 1960's to address a range of issues then facing BHP/AIS's underground coal mining operations. Building on a local tradition of innovative rock mechanics and a global body of research targeted at sedimentary strata behaviour, RM & SC tackled a number of critical areas and made substantive contributions in all of these. Alan Hargraves, as the leader of the group, had a significant influence on all activities, as well as continuing personal research in the area of seam gas management. A direct line can be traced from the initiatives implemented by Alan at RM & SC and many of the modern advances in coal mine geomechanics.

INTRODUCTION

When BHP/AIS decided to set up a small research and technical advisory group in the late 1960's, it was Alan Hargraves who Con Martin (the then Superintendent of Collieries) prevailed on to head it up. Alan had already enjoyed a fruitful relationship with BHP/AIS in the area of outburst prediction/control and gas drainage. I had the privilege of joining this group in its infancy in 1970 soon after it was established. During my two years or so with RM & SC I was part of an expanding sphere of activities covering gas related problems, mining subsidence, roadway support, longwall mechanics, chain pillar design, slope stability and the underlying basic rock mechanics. What follows is a personal recollection of my time at RM & SC and the impact of RM & SC on subsequent developments.

ROCK MECHANICS AT THE END OF THE 1960's

By the end of the 1960's rock mechanics had been around as an identifiable discipline for about 15 years. Much of the early developmental effort for the discipline had occurred in Australia, notably through the agency of the Snowy Mountains Scheme and the efforts of the Hydro Electric Commission in Tasmania. Australia's major metalliferous mining operations had formed separate rock mechanics groups.

Globally, rock mechanics as applied to the underground coal mining industry had made notable steps through the efforts of groups such as the United States Bureau of Mines, UK National Coal Board, the Bergbau Forschung in Germany, the Chamber of Mines in South Africa and the various research institutes of the Eastern European Block. Important work was also being conducted at various universities. Collectively, these efforts had raised the level of understanding of the mechanics of sedimentary strata behaviour to a point where solutions could be conceived to a range of problems then facing the coal mining industry.

In Australia, ACIRL had come into existence in the 1960's to apply this learning to the Australian black coal industry on a broad front. Outside of ACIRL, focussed research efforts were going on at a number of universities. To BHP/AIS the moment appeared ripe for the formation of a small group who could build on this background to address a range of problems facing BHP/AIS's operations.

THE AUSTRALIAN COAL INDUSTRY AT THE END OF THE 1960's

By the end of the 1960's, continuous mining was widely in use throughout Australia, with associated issues of compatible roadway roof support practice. The instance of secondary extraction had increased to a point were problems were being encountered with the impact of mining subsidence on surface structures and other infrastructure. Longwall and shortwall operations were increasing in frequency, with the pressing need for a better understanding of the mechanics of caving and design approaches for face supports for Australia's relatively strong (compared to Europe) and highly stressed roof sequences. Design of optimum coal pillar dimensions was an on-going issue, particularly in conjunction with longwall and shortwall operations, in an attempt to maximise recovery. With the increase in coal production rates through the 1960's, problems associated with the management of seam gas became more and more critical. Spontaneous outbursts were sufficiently frequent to pose a real hazard, while increased rates of gas emission into workings was taxing contemporary ventilation practice.

By 1970, all of these issues had become significant for BHP/AIS's underground operations. At the same time, the impending expansion of surface coal mining suggested the need for an attack on potential problems of slope stability. This then was the scene facing the fledgling Rock Mechanics & Strata Control group when I started work there as a new graduate in 1970.

ROCK MECHANICS AND STRATA CONTROL

General Structure

During my time at RM & SC, the group was broadly structured to address the specific issues outlined above. To support these focussed efforts, a capability was developed in the areas of instrumentation and numerical modelling.

Roadway Roof Support

Work in this area concentrated primarily on the introduction of resin roof bolting to routine practice. At the time, resin bolting was a new technology requiring fostering and the establishment of basic operating criteria. Much of the effort went into pull-out testing of different resin/bolt/installation procedure combinations to determine yield and ultimate load capability. A wide range of combinations was investigated to establish suitability for a range of roof conditions and mining practice. Monitoring of roadway convergence and roof strata deformation was used as a measure of the success or otherwise of different patterns of bolting and bolt lengths. The outcome of this work program was the establishment of an empirically based set of guidelines for the use of resin bolts.

Subsidence

At the time of my arrival at RM & SC, an intensive program of subsidence monitoring had been instigated over areas of total extraction on the NSW north and south coasts. This program was continued and expanded during my time at RM & SC to produce a substantial database allowing the nature of subsidence in Australia's stronger/stiffer (compared to other countries) strata environment to be investigated. Survey results were converted to vertical and horizontal strains and related to parameters such as depth of cover and extraction width. This information was compared with similar data from other countries (notably the UK and US) to establish similarities and differences, and thereby the applicability of design procedures based on these overseas databases to Australian conditions.

Mechanics of Caving

Early attempts at mechanised longwall mining in Australia used equipment based essentially on UK practice. This equipment was found generally to be inadequate for Australian conditions. Design of powered support systems in the UK and other European countries, was, at the time, based on an understanding of caving mechanics developed from observations made in the relatively soft, "freely" caving, environments of these countries. Under these conditions, caving tends to occur regularly as extraction advances and the bulking behaviour of the caved material ensures that most of the load is carried through the goaf rather than via the face supports. The stiffer/stronger roof sediments typical of Australian coal basins tend, however, to cantilever out behind the face line, caving periodically and with a lower bulking factor, with commensurate higher loads on face supports. This style of behaviour was beginning to be appreciated at the time I joined RM & SC. The need for an appropriate means of selecting face support capacity for the new generation of longwalls then coming on stream, as well as the innovative shortwalls being pioneered by BHP/AIS at the time, dictated the need for an improved understanding of caving mechanics.

A program of face load monitoring and associated strata deflection monitoring was insigated to explore the relationship between strata behaviour and face support loading. This was complimented by detailed observations of the nature of the caving process occurring in the goaf. Information like this eventually provided a basis for the rational selection of support capacity for Australian conditions.

Chain Pillar Performance

To investigate the loading regimes on longwall chain pillars, a program of stress monitoring was instigated to study the magnitude and spatial distribution of the vertical load patterns occurring in chain pillars as the extraction line approached and passed. The aim of this work was to develop a means of optimising the size of chain pillars to meet the potentially conflicting needs of short term roadway protection and long term yielding to ensure that goaf loading remains as uniform as possible to avoid adverse stress abutments being developed.

A simple hydraulic cell was developed in-house to facilitate this monitoring. A large number of these were installed in a variety of geometric configurations and the behaviour of chain pillars tracked in time and space. Information of this type was important in the ultimate development of an approach for chain pillar design.

Seam Gas Management

The pioneering work undertaken by Alan on seam gas emission prediction and the prediction of outburst potential was incorporated into the activities of RM & SC from its inception. The Hargraves Emission Meter continued to be deployed widely and experience built up from its use in a variety of environments. In my time at RM & SC, innovative work was undertaken in longhole in seam drilling for pre-drainage, and surface holes for goaf drainage. A more complete account of Alan's contributions to seam gas management practice in Australia will be covered elsewhere in this colloquium.

Slope Stability

At the time of my stay with RM & SC, slope stability had not become the major issue that it became later on as the importance of surface mining increased. Initial aspects focussed on the major role of engineering geology in rock slope stability, through the pursuance of a number of case studies.

Numerical Modelling and Instrumentation

In the early 1970's the Finite Element Method (FEM) of Stress Analysis had been around for a number of years, although its application to problems in geomechanics was still relatively new. Up to that time, "modelling" in the coal mining context had generally meant either the application of some form of analogous analytical solution, or the use of a physical model. The advantages offered by numerical stress analysis had become obvious to those involved in the area. With this in mind, a program was instigated at RM & SC to introduce the FEM method. This involved a combination of refinement of existing packages and development of original software

A range of instrumentation was developed during my time at RM & SC to compliment the various efforts outlined above. Of note were remote convergence meters and pillar load monitoring cells. Major effort was devoted to the development of a capability for *insitu* stress measurement, both from underground and from the surface. In the underground context, the overcoring technique was employed in conjunction with a soft inclusion strain measurement cell. From the surface, emphasis was placed on the use of the anelastic strain recovery (ASR) technique.

The Impact of Alan Hargraves

Apart from his personal contribution in the area of seam gas management, Alan was a major influence in all the areas outlined above. His vision and success in selecting appropriate personnel opened the way for the evolution of the integrated effort that became RM & SC. Alan's insight contributed significantly at various times to the progress of efforts in all areas

SUBSEQUENT YEARS

During my on-going association with the Australian coal industry in the thirty or so years since my departure from RM & SC, I have witnessed the growth of coal mining geomechanics into a mature branch of engineering with a high level of acceptance by the industry. It is interesting to reflect on how the initiatives instigated by Alan at RM & SC, have progressed over the intervening years:

- the development of highly effective roadway support systems, tailored to specific situations and based on a sound understanding of the mechanics involved, and an ability to design support arrays objectively;

- the development of an ability to realistically predict mining induced subsidence, based on a sound understanding of the fundamental mechanics involved;
- the attainment of a comprehensive and detailed understanding of the mechanics of longwall caving, and the ability to reliably specify face support requirements;
- the arrival at a process to design optimum coal pillar dimensions to meet conflicting needs;
- dramatic advances in the technology of seam gas drainage and the management of seam gas, as well as the underlying understanding of coal seams as gas reservoirs;
- the emergence of the routine application of modern slope stability principles to surface coal mining;
- the widespread use of a number of numerical modelling techniques to address a range of problems, completely replacing alternate modelling methods;
- the general acceptance of *insitu* stress measurement as an essential component in investigations for new mining operations and the development of solutions to specific operating problems.