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ANALYSIS OF UNSUPPORTED ROOF SPANS HIGHWALL MINING AT MOURA COAL MINE

John Hoelle [1]

ABSTRACT: Highwall Mining has been conducted at Moura Coal Mine since 1993. During that time period, four different highwall-mining systems have been used. One common constraint with three of the systems was that all drives were 3.6 metres wide and they weredrives are unsupported. The roof conditions vary from pit to pit, seam to seam and within a single reserve block. The roof stability was analysed for each pit and for areas within each pit. The analysis ranged from empirical methods to finite element and numerical analysis. A large amount of geotechnical information was obtained during the exploration program. In most cases a Rock Mass Rating (RMR) system such as the Coal Mine Roof Rating (CMRR) was sufficient for estimating the potential stability of the immediate roof strata.

INTRODUCTION

Moura Coal Mine has had highwall mining conducted on the property from 1993 (auger system) and highwall mining using a continuous miner as the cutting system since 1995. At present there are two different systems operating at the mine. When highwall mining was first being investigated for the Moura Mine, all of the risk assessments highlighted several different geotechnical-related areas that needed to be addressed, which included roof, pillar and floor stability. As a result of these assessments, several methods have been used to evaluate the roof stability.

BACKGROUND

Moura Coal Mine is located in the southern portion of the Bowen Basin just west of Gladstone. The first test mining was in 1959 in a short term open-cut mine in the B seam near Kianga. Open-cut mining started in May 1961 and underground in November 1963. The mine has had a number of open cut pits, underground mines and highwall mining since operations commenced. Presently, active mining is conducted by open cut and highwall mining methods. The active portion of the mine stretches approximately 35 kilometers from north to south with additional reserves both to the north and south. There are seven seams that are mined with thickness ranging from less than one metre to over six metres.

In highwall mining, there is little control over roof stability. The width of the drive is fixed and the azimuth of the drive is controlled within a few degrees. A certain level of exploration can be conducted; however unlike underground mining, there is limited access to the reserve to observe the roof strata and correct any assumptions once mining commences. The size of the pillars can be changed according to geologic conditions. However, the width of the drive is set and adverse conditions in the roof and floor can only be managed to a limited extent. The stability of the roof can be affected to a limited extent by varying the width of the webs or by leaving top coal in the drive.

Since a method of controlling the roof is not available, any analysis should address the following:

- Can the reserve be economically be mined, i.e. is the roof so poor that mining cannot be conducted.
- Will the roof be stable if all of the coal is removed?
- If the immediate roof is unstable, will short-term stability be achieved by leaving coal top? If top coal is required, what thickness of coal will provide stability?

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- If the immediate roof strata is not stable, how far up will caving occur before stability is achieved? The medium term stability is of interest since caving increases the effective pillar height with a subsequent reduction in strength of the pillar. If the immediate roof is unstable, what amount of out-of-seam dilution can be anticipated?
- If the roof is unstable or marginally stabile, can an estimate of the stand-up time be obtained? The emphasis in this evaluation is on the short-term stability since the system should be in a drive for a period of less than two days.

Since highwall mining was a new concept, a number of different methods were investigated in the mid 1990's to analyse roof stability. Three methods have been used at Moura.

- CSIRO developed an analytical method to estimate span stability. This method, Laminated Span Failure Model (LSFM) is very similar to beam analysis. (Shen and Duncan Fama, 1996).
- UDEC, a distinct element code program developed by Itasca.
- Coal Roof Failure Model (CRFM) (Shen and Duncan Fama, 1999) to evaluate the stability of leaving a coal roof in a drive.

In many cases, these various analytical methods require accurate estimates of immediate roof strata properties. Obtaining these geotechnical characteristics can be time consuming and expensive. This requires in-situ and laboratory testing and then determining the parameters for each strata section. The time required for setting up a model can be extensive. In Moura, the pits for highwall mining are over 1000 metres long and have 350 metres depth of penetration. The immediate roof usually changes over the reserve area, requiring either a conservative (worst case) analysis or several different analyses.

Moura Coal Mine was looking for a method of quickly determining whether a particular highwall mining reserve or portion of a particular reserve was going to encounter roof problems. Once a problem area is delineated, then additional analysis may be justified. The roof conditions at Moura vary widely.

- There are seams that have a strong siltstone or fine-grained sandstone roof. These are seams that are easily evaluated and usually are easy to mine.
- Other seams have a claystone immediate roof overlain by a sandstone or siltstone. The thickness of the claystone usually determines the mining difficulty.
- Other seams have roof which consists of claystone inter-layered with coal and shale and then overlain by a stronger strata. These conditions usually create major problems for highwall mining. Strata consisting of a thin strong strata overlaid by a more massive strong strata may be unstable depending on the thickness of the lower seam.

The exploration process routinely obtains both geologic and geotechnical dataas follows:

- RQD - Rock Quality Designation
- FFI - Fracture Frequency Index (number of fractures per metre)
- JRC - Joint Roughness Coefficient
- PLT - Point Load Test, axial and diametral
- Fracture orientations and spacing are obtained during the exploration process and mapping of the highwalls.

Since the information that is obtained is the same data required for use in one of several Rock Mass Rating or Roof Mass Rating systems, these systems can readily be used. The results may then be used to focus on the areas where roof conditions are adverse.

A Coal Mine Roof Rating (CMRR) system (Mark and Molinda, 1996) and a Rock Mass Rating (Bieniawski, 1989) is obtained from each borehole. The CMRR is designed for coal measure strata and the input data required addresses the geotechnical characteristics, therefore the results more closely address the roof stability. The CMRR normally uses the bolted height as the target area. Since highwall mining does not have supported roof, a target of 2.0-metres is used. If the roof strata is weak above 2 metres, major roof stability problems can be expected and the ability to mine the reserve needs to be closely evaluated.

COMPARISON OF TWO PITS

The characteristics of two pits are presented to illustrate the method of analysis and the conditions that may be encountered at Moura.

Pit B was analysed using the UDEC method and two different geologic configurations were modeled. The reserve was mined during two different periods with approximately a year between mining the south and north segments of the pit.

- In the first period the immediate roof was a claystone, overlain by a rider seam overlain by a siltstone (See Figure 1). This sequence was encountered in the southern portion of the pit.
- In the second period there was an immediate roof of siltstone up to 12 metres thick (See Figure 2). This sequence was anticipated in the northern portion of the pit.

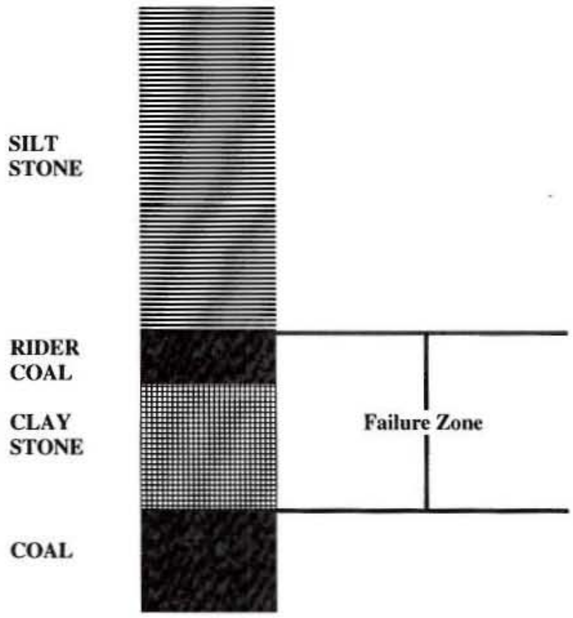

FIG.1 - Analysis of South Pit Roof strata 2 metres thick

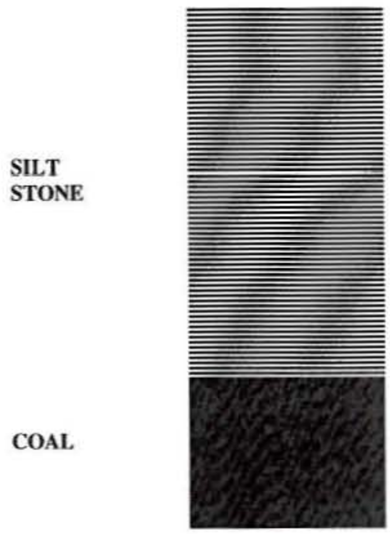

FIG. 2 - Section used for analysis North B Pit Roof strata 1.5 metres thick

Twenty runs were performed and the results indicated that, in the first period, falls from 0 to 0.5 metres through the coal rider seam could be expected. Leaving a coal roof less than 0.3-metres would not stabilise the roof. The results of the analysis of period two indicated a stable roof.

The UDEC system underestimated the severity of the roof instability in the southern portion of the pit. Roof falls up to two metres were encountered and the rider coal seam was usually stable.

Before mining commenced in the second portion of the pit, the boreholes were analysed using CMRR and RMR. The CMRR analysis indicated that portions of the reserve would have roof stability problems and that the roof characteristics were more complex than previously indicated. The results of the CMRR and RMR are presented in Figures 3, 4 and 5 for three selected boreholes.

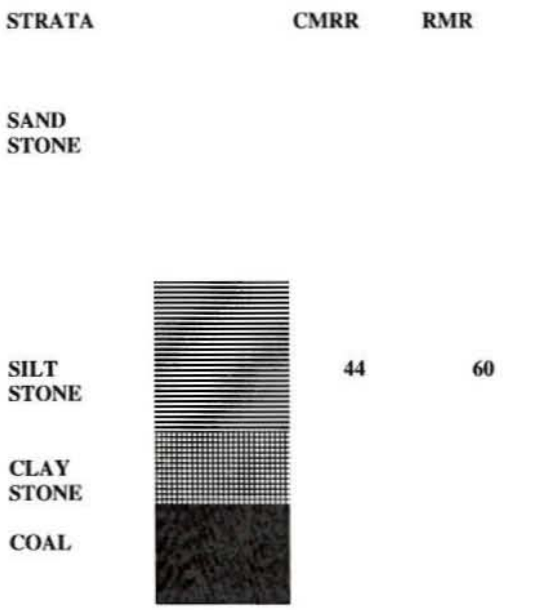

FIG.3 - CMRR for Borehole 29 Roof Strata 2 metres thick

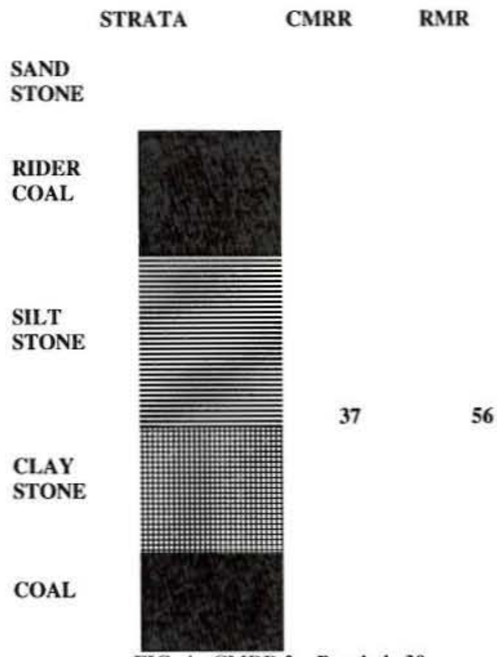

FIG. 4 - CMRR for Borehole 30 Roof strata 2 metres thick

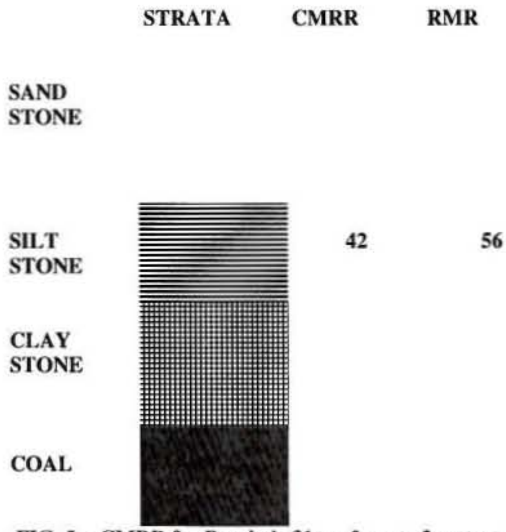

FIG. 5. - CMRR for Borehole 31 roof strata 2 metres thick

Based on these results, the mining was conducted leaving coal top in areas where the claystone was thicker than 0.2 metres. However, severe roof control problems were still encountered in some portions of the pit where the claystone was weaker due to the presence of water.

Before mining the Pit C reserve, the CMRR and RMR were obtained first and the results are presented in Figures 6 and 7. The results indicated a stable roof. However the low CMRR in the mid 40's as well as the sharp discontinuity between the siltstone and overlying sandstone suggested that the siltstone may pull away from the sandstone.

A voussoir beam analysis of Sofianos (Sofianos, 1996, Sofianos and Kapenis, 1998, Seedsman, 2002) was performed and the results indicated that where the thickness of the siltstone was less than 1.5 metres thick and with bedding planes approximately 200 thick, the siltstone was unstable within a short time period after mining. Mining practice indicated that the siltstone was stable for a period of 12 to 20 hours, but once caving started, the siltstone within much of the length of the drive fell with the individual falls limited in extent but continuous.

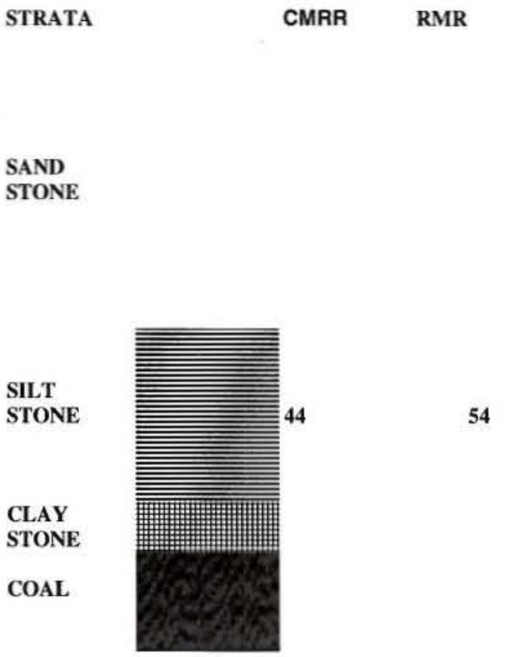

FIG. 6 - CMRR for Borehole 52 Roof strata 2 metres thick

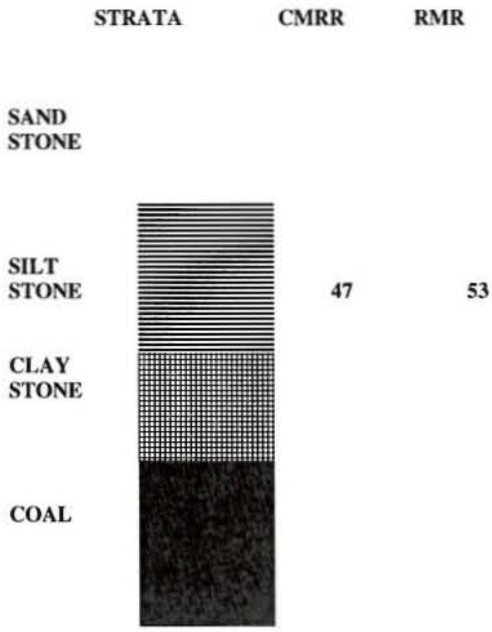

FIG. 7 - CMRR for Borehole 54 Roof strata 1.5 metres thick

CONCLUSIONS

Basic geotechnical data can be obtained during the exploration program. This data can readily be used in rock mass rating programs to evaluate the potential stability of the roof strata of a reserve and allow the focus of subsequent analysis to be on potential unstable areas. Whilst these rating programs are not design programs, the rating numbers are useful in focusing on potential problems areas. The CMRR is especially useful with the programs emphasis on the fracture or bedding plane strength.

REFERENCES

Bieniawski, Z. T., 1989, Engineering Rock Mass Classifications, 251 p (Wiley: New York)

Shen, B., Duncan Fama M.E. 1996. Span Stability Assessment for Highwall Mining – Analytical and Numerical Studies. CSIRO Exploration & Mining Report No. 316F.

Shen B., Duncan Fama, M.E. 1999. A Coal Roof Failure Model for Highwall Mining Span Stability Assessment. CSIRO Exploration & Mining Report 610F.

Duncan Fama, M.E., Shen, B., Adhikary, D., Leisemann, B. E., and Maconocie, A.P., 2000, Geotechnical Design For Highwall Mining of Pit 16B South Highwall and Highwall Mining Appraisal of Pit 16B North, CSIRO Exploration and Mining Report 692C.

Seedsman, R., 2002, Roof Falls onto the Steep Dip Machine in Pit 20C, Seedsman Geotechnics Pty Ltd, Report No. moura02-R2.

Sofianos, A. I., 1996, Analysis and Design of an Underground Hard Rock Voussoir Beam Roof, International Journal Rock of Mechanics and Mining Sciences & GeomechanicAbstracts, p 153-166.

Sofianos, A. I., ands Kapenis, A. P., 1998, Numerical Evaluation of the Response in Bending of An Underground Hard Rock Voussoir Beam Roof, International Journal of Rock Mechanics and Mining Sciences, p 1071-1086.