CONTINUOUS MONITORING OF MECHANISED BREAKER LINE SUPPORTS TO INVESTIGATE ROOF AND PILLAR BEHAVIOUR

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ABSTRACT

A breaker line support (BLS) monitoring system, BLSimon, has been designed and constructed by the CSIRO and installed and commissioned at Laidley No.1 Colliery, Queensland. This system was designed to record hydraulic leg pressure and canopy position measurements and relay these, in real time, to the surface. The system has shown itself to be capable of operating on the BLSs without any adverse affect on production.

Analysis of the results of the monitoring exercise has shown that rate of change of leg pressures on the BLSs could be used as an aid in the prediction of adverse mining conditions. Under favourable mining conditions the supports were observed to initially unload from the set pressure, this unloading reduced with time and by the end of a typical lift cycle had either ceased or reversed slightly. This behaviour was considered to be due to one of four possible causes: the compaction of floor debris, unloading of the floor, and/or unloading of the roof and/or support over. The actual cause can only be determined through detailed monitoring of both roof and support convergence. However, observational data would suggest that compaction of debris and a softer floor material beneath the supports was the most likely cause. The few positive loading rates recorded under these conditions were of short duration and occurred towards the end of individual lifts. Where mining conditions were unfavourable the negative rates of change of pressure, unloading of the support, were reduced throughout a lift, in both duration and magnitude, when compared with favourable mining conditions. Over the same period the positive rates of change were observed to be greater. The rate of change of loading and convergence can be utilised to identify the onset of instability in the lift area. However, before this facility can be utilised by the mine for the reliable prediction of instability more monitored data and sophisticated processing techniques are required.

A mechanism has been postulated for the deformation behaviour of the roof and pillars in a mechanised pillar extraction operation from the continuously monitored data, observational data and results of previous studies.

The 7 m wide fender was observed to yield under abatement stresses before lifting commenced. The stability of these fenders throughout the lifting sequence was considered to be dependent upon the magnitude of their post peak load carrying capability. This is influenced by the post peak stiffness and the extent of roof lowering in the vicinity of the fender.

Difficulties with fender extraction occurred where remnant coal left standing in the goaf caused uncaved goaf to bridge to the mined fender. Difficulties were also experienced where sub-vertical jointing occurred in the roof of the split reducing its ability to bridge effectively.

Despite the relatively short monitoring period, the potential role and application of continuous monitoring in advancing understanding of the rock mass response to mechanised pillar extraction operations has been demonstrated. This understanding now requires enhancement and shows great potential for aiding the optimisation of mechanised pillar extraction operations.

1. INTRODUCTION

In March 1991 two Voest-Alpine ABLs 185/380-540V mechanised breaker line supports were introduced into Laidley No.1 Colliery with the aim of improving the efficiency of pillar extraction operations. A collaborative project between the mine and CSIRO, Division of Geomechanics was initiated, the aim was to improve the understanding of how BLSs would function in the Rangal Coal Measures of Queensland.

CSIRO were to design, gain approval for, install and commission a monitoring system able to monitor the
operational performance of the breaker line supports without interfering with production. Upon commissioning CSIRO undertook a period of intensive monitoring during which time records were kept of mining conditions and activities. Subsequent analyses were undertaken on the data gathered in attempts to identify patterns in the behaviour of the supports and their interaction with the strata.

2. MINE DETAILS

The Latelham No.1 Colliery is located 45km south of the town of Blackwater in central Queensland and is 334km by rail from the port of Gladstone. The mine extracts coal from the Pollux Seam which is the lowest economic seam of the three seams (Artes, Castor and Pollux) of the Upper Permian Rangai Coal Measures. The Pollux Seam has a seam thickness of 3.6m but is worked to an extracted height of 2.8m with 0.8m of coal is left in the roof.

The Pollux Seam is immediately overlain by a 2m thick bed of carbonaceous mudstone which is massive in nature, exhibiting few bedding planes. The mudstone in turn overlain by a 30m sequence of interlaminated siltstones, sandstones and limestones which include the Castor and Arieti Seams at 23 and 36m above the Pollux Seam respectively. The Pollux Seam is characteristically underlain by a 0.1 to 0.3m thick layer of clay cemented siltstone which is often fissured by slickensided planes, joints, crumbly laminations and bedding plane shears.

The colliery is a bord and pillar operation with secondary pillar splitting and Wongawilli extraction panels working down to a depth of 180m. Pillars are typically at 39 x 39 m centres in main roadways and 70m long. Wongawilli splits are driven into the solid. Pillar extraction operations are mechanised using two Voest-Alpine ABLS 185/380-540V breaker line supports and a JOY 12CM 12 continuous miner.

3. MONITORING SYSTEM

The breaker line support (BLS) monitoring system, BLSmon, has been designed to record hydraulic leg pressure and canopy position measurements and relay these, in real time, to the surface. The hydraulic pressures are measured by pressure transducers (500 bar) coupled into the relevant hydraulic circuits on the BLS. Pressure measurements are recorded for the following hydraulic circuits; front legs, back legs, right and left hand stabilising rams and ram/castle link rams. The pressure reading resolution of the system is 0.5 bar. The closure of each of the legs was monitored separately using closure transducers with a resolution of 0.37mm through the system. A more detailed technical description of the system is recorded elsewhere, see Fig.1.

![Fig.1 - Schematic of BLSmon.](image)

Data was transmitted from the BLS unit using a sub-carrier communication system on the 1.0kV trailing cable. The data passed to the distribution transformer from where it was conveyed to the surface computer by a pair of modems via a dedicated I.S. telephone line. Further protection was added to the system in the form of a CSIRO designed Galvanic Barrier which provided D.C. isolation for the telephone line preventing dual earthing of the system.

The surface computer software was written in the "C" language specifically for the BLS monitoring system. The program configured the communication equipment that was used in the system, collected and logged the data from the BLSs onto the laptop's hard-drive. It provided a tabulated data output on the computer screen, along with graphs in real time showing each of the measured parameters against time, for a time span of 2.5 hours. A facility was also provided to enable the operator to store the raw data, in common or condensed spreadsheet format, on floppy discette for later analysis. The latter format was condensed by deleting consecutive data points which were unchanged with time.

4. FIELD MONITORING AND RESULTS

To enable interpretation of data collected by the CSIRO BLSmon System, a period of one week was allocated for underground monitoring at Latelham No.1 Colliery. Field investigations were targeted specifically for the lifting operations within the pillar extraction sequence in 100 panel. Information gathered for the purposes of analysis included:

11th International Conference on Ground Control in Mining, The University of Wollongong, N.S.W., July 1992.
Time and motion data from the operating BLS units,
Detailed geometry of the lifting sequence,
Observations of strata conditions and behaviour,
Caving events, and
Geology.

Both pillar lifting and Wongawillil extraction sequences were monitored. A range of operating conditions were experienced, which aided the evaluation of the monitoring system. These ranged from stable to adverse conditions and included a period of abnormally loading of the BLSs. In total the lifting of five fenders from pre-formed pillars and one 93 m long fender from a Wongawillil were monitored.

The most favourable mining conditions were experienced when lifting the fender from the Wongawillil. The caving line followed behind the supports as mining progressed. The caving process was aided by the fact that an old roof existed adjacent to the Wongawillil panel. The monitoring of this sequence gave a pattern for the support performance under stable operating conditions.

Adverse mining conditions were observed during lifting off a pre-formed pillar. At the commencement of lifting the intersection and a large portion of the previous split were still standing. A series of sub-vertical joints were observed in the roof mining parallel to the fender. During the early lifts, a number of small falls of the immediate roof occurred. The goaf falls were observed to be controlled by the sub-vertical joints. As lifting proceeded along the fender, conditions gradually worsened until the fourth lift when leg pressures on the BLS nearest the fender, BLS1, rose sharply and quickly went into yield. The remainder fender in front of the supports was observed to crush. At completion of the fourth lift, the lift caved prior to the goaf side BLS being moved forward this allowed goaf to flash in front of the BLS, see Fig.2.

Lifting of the fender was abandoned at this stage and the BLSs removed. Both the uncaved spans from a stook standing in the goaf and the existence of the sub-vertical joints appeared to contribute to the poor mining conditions. The monitored data from such periods of mining can enable the identification of a pattern of behaviour for the supports.

5. ANALYSIS OF RESULTS OF MONITORING

Fig.2 - Yielding of Remnant Fender Allowing Flashing of Goaf.

An analysis of both the pressure and convergence records indicated that convergence measurements gave limited indication of the response of the BLS units to strata movement. In contrast the pressure records accurately delineated this response. The detailed analysis was therefore focused mainly on the pressure data. Convergence measurements in the split in front of the BLSs and within the BLSs themselves will aid in the definition of their area of influence. This would also give an indication of the behaviour of the fender and roof support during the mining process. The monitoring of convergence on the BLSs will not be abandoned and in fact will play a key role in future monitoring activities tracking any extension of the support legs in response to compaction of soft material beneath the supports.

Comparisons were made between lifts that included the most and least favourable mining conditions that were described in section 4. The front and rear leg pressure records for BLS1 during the lifting of the fender from the Wongawillil, where mining conditions were favourable, can be seen in Fig.3.

The data from BLS1 was chosen as it generally showed more changes due to its closer proximity to the fender. Under these stable operating conditions there was a pattern to the operation of the BLSs. The support was set at the beginning of the lift. In general the leg pressures decreased throughout the lift, the rate of decrease reduced towards the end of the lift. There are a number of potential causes for this behaviour they include, compaction of floor cinders; and/or compaction of the floor, and/or crushing of the roof and/or creeping.
Fig. 3 - Sequence 3, Leg Pressures for BL1.S1.

of the support. The most plausible explanation of this reduction in pressure was considered to be the compaction of a layer of coal debris and softened floor material beneath the support allowing support set pressure in the legs to reduce at a faster rate than the roof beam was loading the support. This hypothesis was further corroborated by observation records and the extraction crews themselves. Towards the end of a lift the rate of material compaction beneath the support was considered to decrease whilst the rate of roof lowering in the vicinity of the support increased. Observational records indicated that good roof control was experienced and that the roof was lowering at a controlled rate during these operations as load was transferred to the stiffer adjacent pillar.

The same set of results were noted for the lift where mining conditions were unfavourable. This support went rapidly to into yield at about 13:10 pm, see Fig. 4.

Fig. 4 - Sequence 25, Leg Pressures for BL1.S1.

Even before yielding occurred changes in the operation of the supports were noticeable. In contrast to the sequence previously discussed there was no recorded pressure reduction for the front and back legs as lifting proceeded. Towards the end of each lift, even before the lift in which yielding occurred, a marked rise in pressure was noted on these legs.

It was concluded from analysis of the leg pressure records that the rate of loading was an important factor. For this reason the leg loading rates were plotted for both sequences, the data for the near legs over the corresponding sequences are presented in Figs 5 and 6.

Fig. 5 - Sequence 3, Loading Rate Records for BL1.S1. (Rear Legs)

Fig. 6 - Sequence 25, Loading Rate Records for BL1.S1. (Rear Legs)

The stabilising rams and lemniscate pressures did not react significantly until the supports were close to yield. When all the legs went into yield the right hand stabilising rams increased in pressure on BL1.S1, reacting to strata movement. The lemniscate linkage did not significantly change during mixing. The reaction of the stabilising rams and lemniscates was interpreted as indicating that the roof lowered over a the partially extracted fender.

Although the above analyses have concentrated on the best and worst mining conditions observed during the monitored period, the same general conclusions, as noted above, were obtained for other fenders. It was clear from the monitoring exercise that there was great potential for the use of the rate of loading, in conjunction with rate of convergence, to be used to identify periods of instability. An insufficient range of conditions have been monitored.
to accurately assess critical rates for these parameters. Additionally, the data was found to be affected by 'noise' due to operational procedures, such as setting and moving of the BLSs, this acted to mask some aspects of the strata response to the BLSs and requires filter out.

6. STRATA RESPONSE

The monitoring of the BLSs, observations and analysis of previous work carried out at Lubeck No.1 Colliery by CSIRO and other workers enabled the strain response during pillar extraction to be postulated. Before driving splits, the pillars, at 39m centres, were stable even when carrying abutment loads. Stress measurements carried out previously by the CSIRO have indicated that the 7m wide fenders isolated by splitting yield under the imposed abutment stress. Observations made during this project would support this conclusion. Although the fenders were unable to carry the full load imposed upon them, for the reasons described above, they did carry a significant load thereby enabling mining to continue. This can be explained by reference to an idealised load deformation curve for a pillar, see Fig.7. Pillars can carry load even after they have fully yielded. This capacity to carry load is termed the post peak strength of the pillar and is a problematic parameter to estimate. The magnitude of the post peak load carried by a pillar is dependent upon the amount of roof convergence in the vicinity of the pillar. The closer that fenders are to stiffer (i.e. larger) unmined or partially mined pillars left in the goaf, then the less the roof converges in the vicinity of the fender and the more post peak load they carry. As the fender is lifted, the adjacent roof converges more and the load carrying capability of the remnant fender is reduced. This load has to be transferred to the stiffer unmined and partially mined pillars under normal operations. The extent of unanced mine goaf also influences the amount of roof lowering adjacent to the fender. The greater the unanced span the more deformation experienced by the fender and the less load it can carry. Uncaned roof spans are related to the remnant size of unmined stalls and pillars. Previous studies of pillars where yielding was initiated have also indicated the importance of the post peak deformation response of strata.

Under normal operating conditions the BLSs were considered to aid the bridging of the immediate roof to stiffer adjacent pillars. Potential problem areas with respect to the operation of the BLSs have been observed at the mine and can be explained with reference to pillar and roof behaviour.

Where sub-vertical joints were present in the immediate roof they appeared to reduce the ability of the roof beam to bridge over to the stiffer pillar.

7. CONCLUSIONS

The monitoring system was successfully designed, installed and commissioned and did not interfere with coal production. It proved to be capable of surviving the hazardous mining environment, providing continuous data over the monitoring period. Some problems were experienced with the convergence sensors due to the adverse physical environment, further work is required to overcome these problems.

During the intensive monitoring period both stable and poor mining conditions were recorded, including a period of abnormal loading of the BLSs. The range of conditions encountered aided the evaluation of the practicality and effectiveness of the CSIRO BLS monitoring system.

Under stable conditions the leg pressures on the BLSs were seen to decrease throughout an individual lift, the rate of decrease reducing towards the end of a lift. There were considered to be a number of possible causes responsible for this behaviour including: compaction of floor debris, and/or compaction of the floor, and/or crushing of the roof and/or creeping of the support. The mechanism considered to be most plausible was that the reduction in leg pressure due to the compaction of both debris and softened floor material beneath the support allowed the leg pressure to reduce at a faster rate than the roof beam was loading the support.
Towards the end of a lift the rate of compaction decreased, whilst the rate of roof lowering in the vicinity of the support increased. Under these stable mining conditions the roof was observed to be lowering at a controlled rate as load was transferred to the stiffer adjacent pillar.

During and before abnormal loading of the supports a different operating cycle was recorded. The negative rates of change of leg pressures were significantly less in both magnitude and duration than in the typical stable cycle. In contrast positive rates of change of leg pressure were recorded over most of the fender. Indeed high positive rates of change of leg pressure were observed over significant time periods as early as the second lift of a fender. While the BLS legs were in yield the stabilising rams reacted in manner which suggested that the roof was lowering into the waste perpendicular to the long axis of the split. The laminate ram did not react, this was considered to corroborate the postulated orientation of roof beam tilt.

Analysis of the data revealed that it was possible to identify features in the leg pressure records which were considered to be related to the onset of adverse mining conditions. To date an insufficient range of conditions have been monitored to fully prove the hypotheses outlined and also accurately assess critical rates for those parameters. Additionally the data was found to be affected by ‘noise’ due to operational procedures, such as the setting and moving of the BLSs, this aimed to mask some aspects of the strata response to the BLSs and requires filtering out. More sophisticated processing is required to determine critical rates. These techniques are currently under development at the CSIRO.

Understanding of the mechanisms involved in mechanised pillar extraction at Laleham No.1 Colliery will aid in future operation of BLSs and the prediction of problems in advance of individual splits. Continuous monitoring of BLS operations is able to provide unique information regarding supports/strata interactions and is therefore an valuable aid to the optimisation of mechanised pillar extraction.

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REFERENCES


