Review of longwall Mining Experience at South Bulga Colliery

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Abstract:
In Australia many longwalls operate under massive sandstone roofs and are subject to periodic weighting. Operators have to commit large amounts of capital investment to establish a longwall mine the selection of roof supports is one of the largest. If this selection is not made correctly then operation on the longwall may never be profitable. South Bulga has some of the largest supports made by Joy mining in the world and has experienced loss in production due to rapid convergence. This paper outlines the geotechnical issues surrounding the operation of South Bulga Colliery’s longwall.

Key Words:
Periodic Weighting, Low stress, massive sandstone and Longwall

Introduction
South Bulga Colliery is one of Australia’s most productive Longwall mines. Longwall production started in October 1994. Mining conditions are very favourable due to the competent roof. This benefit is however a double edged sword. While the longwall has excellent gate and face stability it is subjected to cyclic loading. To date this cyclic loading has stopped production from the longwall three times. In each of these cases the height had to be regained over 30 supports. There have been an additional 8 events which have resulted in rapid convergence. In each of these cases the Longwall has been able to advance in to stable ground before the convergence reached a point that would not allow the shearer to pass through the face. This paper reviews the information available to a new mine when designing longwall supports and what monitoring techniques can be used once a longwall has started production to allow the development of management plans to minimise the risk of lost production due to rapid convergence.

Location and regional geology

The mine is situates in the Northern Coalfield of the Sydney basin 23 km south east of Singleton. The current seam being extracted is the Lower Whybrow seam in Whittingham coal measures. The longwall operates at depth ranging from 160 m at the start to 40m at the take off position. The roof strata above the Lower Whybrow are variable across the Saxonvail lease. In the area of the current longwall panels the immediate roof is a massive sandstone with a strength of 40-80 Mpa and a modulus of 13 Gpa. The presence of carbonaceous laminae in this strata varies within the mining area.

The interburden between the Upper and Lower Whybrow Seams varies in thickness from 36 to 10 metres across the lease, with the thicker section at the face start line.

The strata above the Upper Whybrow consists of sandstone laminated with shale, siltstone and the occasional coal seam. The Laminated siltstone above the Upper
Whybrow are often stronger than those below, however they contain numerous carbonaceous bedding planes. Figure 1 and table 1 show a typical bore hole section and an analysis of the roof strata close to the area of rapid convergence that stopped the longwall 5 on the 21 April 1998.

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<th>Unit</th>
<th>Rock Type</th>
<th>Height m</th>
<th>Bedding Planes/m</th>
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<td></td>
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<td>6-7</td>
<td>&gt;50</td>
<td></td>
</tr>
<tr>
<td>Lower Abbey Green</td>
<td>Coal</td>
<td>1-2</td>
<td></td>
<td></td>
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<td></td>
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</tr>
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</table>

Table 1

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**STRATIGRAPHIC SECTION BOREHOLE No.97**

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**Figure 1**
Key Geotechnical
- South Bulga Colliery operates in an extremely low stress regime with a Horizontal to Vertical stress ratio of 1/2. This was not known at the time of design and a higher ratio closer to the regional trend would have been assumed:
- The thickness and nature of the Upper Whybrow to Lower Whybrow interburden varies over the lease. The thickness increases to the south and there is an increase in the number of carbonaceous laminate bands to the East
- Subsidence is supercritical on a 200m wide longwall at the lower depth of cover.

Support design
Design for the roof supports was based on appraisal of Mining conditions by ACIRL and SCT as to the expected mining conditions. These predicted:
- The caving height would be 3.5 to 6 metres. Breakage of strata above the initial caving may occur leading to periodic weighting
- Widening the face from 200 metres to 250 metres would not create additional significant geotechnical problems
- No significant floor problems were expected
- Supports should have a capacity of 100 tonnes per square metre
- Set to yield ratio of over 80%
- Systematic support monitoring to ensure maximum support efficiency

The first four panels were 200 metres wide equipped with one hundred and seventeen 940 tonnes two leg supports. Face control is via Joy mining's L110 system. This provides a fully automated face and monitoring system. Data from the gate end computer is then captured by the mines Citect system. The original mine layout allowed for the face width to be increased to 250 metres at Longwall 4. This was delayed until longwall five when thirty one 1150 tonne supports were purchased. Prior to manufacture the roof supports were fully tested over 50,000 cycles to 120% of full load. This testing has been invaluable as all weaknesses were found at the design phase and no supports have suffered significant damage despite the three major weightings. These weightings completely closed the lemniscate linkage.

History of Longwall Production and Research
Longwall 3
In 1996 South Bulga Colliery set a new Australian productivity record of 24,000 per man year. This was due to well matched equipment and a dedicated work force. This result masked an underlying problem that was first recognised in August 1996. The first rapid convergence event was recorded soon after the start of longwall three. Face standards were not perfect at this time and this event was attributed to face alignment. Since this time on a straightening cut is carried out every shift. Cyclic weighting was present for the rest of the panel. Normally these weightings manifested themselves as weeping yield valves. A regular pattern developed relating to about 20 metres of advance. At this time the mine was committed to a 250m wide face in longwall 5. With the improvement in computer modelling and the additional information gained from mining the first two longwalls SCT were commissioned to construct at Flac simulation of the caving characteristics of the Lower Whybrow seam. This model confirmed that cyclic weighting was taking place at about 20 metre intervals. The model also showed another shearing process occurring at the base of the Upper Whybrow seam. This shearing extended in
front of the longwall face position and then started to propagate down towards the mining seam. Occasionally the face would mine into this fracture zone. Validation of this computer model was carried out by the installation of two sets of wire line extensometers installed at 22 and 21 Cut-through. In addition data collected from the chock monitoring system was processed. By analysing the rate of pressure rise, times of weighting could be identified. This data was then correlated with Deputies observations. The outcome of all this work was to show that cyclic weighting occurred on average every 20 metres. At irregular interval larger rates of pressure rise were noted.

A decision was made to purchase the largest supports possible for the face extension. The only constraint placed on Joy Mining in designing the supports was that they had to have the same profile as the original supports to ensure a straight caving line.

**Longwall 4**

Longwall 4 started 400 metres inbye of Longwall 3. This would create a high stress zone in the tail gate as the two goafs came level. To determine whether extra support would be needed the actual virgin stresses were measured. It is this information that revealed the lack of horizontal stress. The longwall past this region of higher stress without any change in the gate road conditions. Approximately 100 metres past this point the first of the three face stopping events occurred (marked by line one in figure 2). Thirty supports from mid face to the tail gate converged to a point at which the shearer could not travel underneath. Recovery of the supports took over one week. Once the face moved away from this point conditions returned to normal immediately. No work had to be done to stabilise the face.

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Figure 2

Plan showing sites of major convergence
Line 2 in figure 2 shows the position of the second face stoppage. The area affected this time was around the centre of the face. These two events prompted a complete review of the operation of the longwall. The following points were addressed:

- Hydraulic system: this was performing as designed with no indication of return line pressure causing pilot circuit problem. There were some changes made to the unloader setting to improve face pressure at times of high demand.
- In-support controls were examined to ensure that the supports were giving maximum support density on setting.
- In-support hydraulics investigation of the leg circuit indicated that in about 33% of the legs the none return valve at the base of the major stage was leaking. This would have the effect of reducing the capacity of the leg by up to 50%. The long term remedy for this is to change all the legs and replace them with an improved valve. Investigation into the cause of this failure indicated that the operating height on longwall 1 was at a critical point which would cause the valve to operate each time the supports were moved. The short term solution was to limit the working height and not use the second stage of the supports. This removed the faulty valve from the circuit.
- SCT modelled some different scenarios which showed that periodic weighting would still occur even with a 1400 tonne support on the face.
- Review of all information related to the longwall indicated that cyclic weighting had been taking place since longwall 2. The magnitude of these events had been increasing as time passed. This was put down to deterioration of the non-return valves in the legs. Once the working height was reduced Longwall 4 was completed without any future stoppages.

Longwall 5

Convergence monitors were installed for the first time on this panel to improve the monitoring. As with the use of leg pressure rise it took the third face stoppage before this information showed any pattern that could be recognised. The initial results were only of limited value as there were no off the shelf data processing packages. The system has now been developed to record raw data, total convergence per shear and rate of convergence. Data is recorded every 3 minutes from the ten transducers on the face. Data is then available for trending on any of the Citect terminals at the mine. To allow any future data processing the mine has established a standard of archiving all data recorded at the end of each panel to CD rom. This replaces the original system of over-writing the data on the hard drive.

When the convergence data is reviewed over a large time frame then a pattern can be seen. Prior to the major weighting events when the face is at rest the magnitude of the levels of total convergence increases. At present the only method to avoid production loss is to keep the face moving forward. Having an early warning system enables decisions to be made as to whether it is safe to stop the face for maintenance. The mechanisms involved are such that only 5 shears are needed to move the face into stable conditions.

On April 21st 1998 the third period of lost production and the fifth time rapid convergence occurred on longwall 5. Thirty supports had to be recovered from 37 to 67 chock causing one week's lost production. Surveys of the face showed that the faulty valves in the legs were not in use and so all of the available force was being transferred to the roof. From 41 chock every other support was a new support giving an average
support density of 121 tonnes per metre squared. Another review of events took place to try and establish what was triggering these events.

**Current Status**

After reviewing all the data the following level of weighting can be established.

- Since longwall 3 there have been over 400 cyclic weightings
- Ten recorded periods of rapid convergence
- Three of the ten rapid convergence events have led to loss in production

The question is what causes the rapid convergence and what was the difference in the three events that stopped production too events that do not stop production?

The second part of this question is probably answered by the fact that in each of the three face stopping events there has been a delay in the production process of over one hour. As the only way to recover from the rapid convergence is to move the face forward into fresh ground then a breakdown will let the convergence reach a level that stops the shearer from moving through the face. If this is the case then the risk of a stoppage during a time of rapid convergence is too high even on a well maintained longwall. The answer to the first part of the question is then the key to eliminating lost production due to periodic weighting. The answer is not known to date but lies in one of three areas or combination of them.

**Operational**

Operational errors may lead to a time of rapid convergence becoming a face stopper. They do not account for the 10 rapid convergence events. The use of a face management plan will provide soft barriers to reduce the risk of lost production but not remove the problem. South Bulga has had in place procedures for ensuring good face management is achieved at all times. As history shows these in themselves have not stopped losses in coal production

**Maintenance**

High standards of maintenance can reduce the risk of the longwall stopping during a convergence event. The failure of the non-return valve was thought to be the cause of the problem. After longwall 4 this proved not to be the case and to date no defect has been found to account for the problem. A review of the support selection process showed that periodic weighting was identified as an issue when the size of the supports were chosen. Modelling has subsequently shown that it is not possible to build a support large enough to stop the cyclic loading.

**Geotechnical**

The events have been grouped in one region as shown in figure 2. The reason for this is still unknown. The following factors have been evaluated and cannot point to a reason why the normal cyclic weighting changes.

- Depth of cover
- Ratio of interburden thickness to depth of cover
- Changes in stratigraphy
- Structural features
Conclusions
To date no one can completely explain what is happening and what could be done to stop the rapid convergence.

When faced with major a problem to solve there is a temptation to look for causes which can be easel removed and not address all the issues. This is compounded by the nature of operation at most mine, “I have put out that fire whereas the next.” The result of this approach is that often that the fire re-kindles.

South Bulga Colliery has to try and find a solution to this issue. The next planned phase of data collection is to use 3D seismic technology to record the position and timing of event in the caving cycle. This information along with additional computer simulation it’s hoped will indicate what is driving the extra convergence.

References
SCT Reports for South Bulga Colliery