PREDICTION OF LONGWALL SUPPORT LOADING AT SOUTHERN COLLIERY, QUEENSLAND

By
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ABSTRACT

Roof conditions at Southern Colliery, the second longwall mine to be established at German Creek, were found to be much stronger and more massive than at the earlier longwall mine on the lease. Investigations were made to ascertain the level of face support required for longwall extraction under the changed geological conditions.

Geotechnical information was provided from drillholes and highwall exposures. Downhole geophysical logs, notably the sonic velocity log, were used to obtain a distribution of the major lithological units over the mine area. A representative type section of the strata and geomechanical properties was compiled to form the basis for numerical modelling.

Two-dimensional finite element methods were used to predict strata movements and chock loads under cantilevered roof conditions. The model incorporated a 6.3 m thick roof beam either bonded or detached, with either a 2 m or 5 m overhang. The solid rib, immediate roof, chock support and goaf were modelled as distinct parts, in addition a jointed stress profile, derived from three-dimensional displacement-discontinuity analysis, was superimposed on the model.

INTRODUCTION

The German Creek Project in Central Queensland encompasses open cut dragline pits and two underground mines, both of which operate 200 m wide, longwall retreat faces with two heading gatecrad development. Central Colliery commenced longwall extraction in 1986 and the seventh panel is presently being mined. Face support comprises 800 tonne, 4 leg chocks. Southern Colliery, which is located nine kilometres south of Central Colliery, commenced development in 1986, much stronger and more massive roof conditions. Prior to ordering new face equipment, investigations were made to check if the changed roof conditions warranted any increase in support capacity.

Investigation included the collection and interpretation of geological and geotechnical information, followed by numerical modelling using a novel combination of three-dimensional displacement discontinuity and two-dimensional finite element models. It was concluded that 800 tonne, 4 leg chocks would be suitable for the heavier conditions at Southern Colliery. Leg pressures and convergence were monitored during the extraction of the first two panels to ensure the chocks were performing satisfactorily.

This paper summarises the geotechnical investigations leading to the establishment of a geomechanical type section, and describes how the numerical model was developed and used to predict...
ground displacement and shock loading. The results of shock monitoring during extraction are compared to the predicted values.

GEOLOGY

The German Creek seam belongs to the late Late Permian German Creek Formation, which is of deltaic origin with fluvial and marine phases. The overburden typically comprises moderately strong to strong, thickly bedded, fine to medium grained lithic sandstones, with interbedded siltstones and occasional mudstones. The immediate roof includes a series of massive, fine to medium grained quartzitic sandstones. The coal seam is moderately weak with near vertical cleat, very closely spaced at 30 mm to 50 mm.

 Seam thickness varies from 2.4 m to 3.2 m, and averages 2.8 m thick over the mining area. Seam dip is to the east at an average gradient of four degrees. Depth of cover varies from 60 m to about 220 m in the current mining district.

Geotechnical type sections for Southern and Central Collieries were compiled using a combination of detailed highwall mapping, about 100 drillhole lithology logs and downhole geophysical logs. Interpretation of geophysical logs provided the bulk of the data for most boreholes.

Table 1
Correlations between geologically logged lithologies and geophysical responses.

<table>
<thead>
<tr>
<th>Strata unit</th>
<th>Geophysical log response limits</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sonic (μsec/ft)</td>
</tr>
<tr>
<td>Sandstone</td>
<td>&lt;75</td>
</tr>
<tr>
<td>Claystone</td>
<td>&gt;85</td>
</tr>
<tr>
<td>Siltstone</td>
<td>75 - 85</td>
</tr>
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</table>

Initially a group of cored holes was selected for which both logs of drill core and a full suite of geophysical logs were available. Correlations between the geophysical responses displayed on the logs and geologically logged lithologies were made. From these correlations, geophysical log response limits were established for each rock type (Table 1).

In general the sonic logs provided the most reliable correlations, closely followed by neutron logs with gamma logs being of limited value on their own. The full suite of logs were utilised wherever possible.

Laboratory testing, which included determinations of bulk density, uniaxial compressive strength (UCS), tensile strength, Young's modulus and Poisson's ratio, was completed on 95 samples (Ward and Klenowski, 1987).

Calculation of equivalent UCS from sonic velocity was made using the following formula, which was derived specifically for Southern Colliery (McNally, 1987).

\[ UCS = 1277t^{-0.076} \]

where \( t \) = sonic transit time (μsec/ft) and UCS is in MPa.

A comparison of immediate roof conditions at Southern and Central Collieries is shown in Figure 1. The immediate roof strata at Southern Colliery comprise massive sandstone beds with UCS values of 80 to 100 MPa, containing one or two weaker mudstone bands with an average strength of 50 MPa. By contrast, the immediate roof strata at Central Colliery consist of laminite with a UCS range of 60 to 70 MPa. Formation of cantilever beams was expected in massive sandstone strata, especially as the main joint set was almost perpendicular to the face line. Floor rock at both collieries is siltstone with an average strength of 80 MPa. The German Creek seam is weak throughout the lease with an average strength of 9.6 MPa and a bulk modulus of 1.24 GPa.

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NUMERICAL MODEL

It was decided to model chock loading by numerical analysis using the finite element method on a two dimensional section. The model is shown in Figure 2 and comprises four distinct parts, namely the solid coal rib, chock, immediate roof and the goaf. The coal, immediate roof and goaf were allocated stiffness values of 1.24 GPa, 20 GPa and 20 MPa respectively. Chock support density at yield is 112 tonnes/m².

Figure 2
Diagram of two dimensional model

In addition, the roof was permitted to cantilever off the back of the chocks by 2 m and 5 m, which corresponds to the range of joint spacing measured in highwall massive sandstone, adjacent to Southern Colliery. The roof was analysed both as a continuous system with no delamination of strata, and as a detached cantilever beam (Figure 2). The heights of the detached beams were 3.4 m and 6.3 m, which coincide with the mudstone partings in the roof.

The finite element method is commonly used to model stresses and displacements around underground excavations and requires discretization of a specified region into a number of elements. The elements form a mesh and are assigned material properties which match modelled stratigraphic layers and joints. The finite element mesh is shown in Figure 3 and consists of 1100 elements and 1200 nodes. The variation of material properties is described by nine bulk material types and one joint material layer.

In order to provide a more realistic representation of loading conditions, the front abutment pressure was superimposed on the system as indicated in Figure 2. The abutment loading was estimated from the three-dimensional displacement-discontinuity program MINLAY. This program models underground excavations by treating the relative movement between the roof and floor as a displacement discontinuity or dislocation (Wardle, 1984). The predicted pillar and abutment loads have been confirmed by stress monitoring during extraction of the first two longwall panels at Central Colliery (Wardle and Klesowski, 1988).

Figure 3
Finite element mesh

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RESULTS OF ANALYSIS

Chock convergences were calculated for a support at yield load of 800 tonnes with the canopy tip located at 0.3 m and 1.3 m (one web back) from the face (Figure 2). Results for a 5 m overhanging, cantilever beam are summarised in Table 2.

Table 2
Predicted chock convergences

<table>
<thead>
<tr>
<th>Cantilever Beam</th>
<th>Beam Thickness (m)</th>
<th>Distance between canopy tip and face (m)</th>
<th>Max Convergence (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attached</td>
<td>3.4</td>
<td>1.3</td>
<td>15.0</td>
</tr>
<tr>
<td>Attached</td>
<td>6.3</td>
<td>0.3</td>
<td>0.0</td>
</tr>
<tr>
<td>Attached</td>
<td>6.3</td>
<td>1.3</td>
<td>15.6</td>
</tr>
<tr>
<td>Detached</td>
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<td>1.3</td>
<td>20.2</td>
</tr>
<tr>
<td>Detached</td>
<td>6.3</td>
<td>0.3</td>
<td>15.2</td>
</tr>
<tr>
<td>Detached</td>
<td>6.3</td>
<td>1.3</td>
<td>26.4</td>
</tr>
</tbody>
</table>

Monitoring at Central Colliery indicated that fracturing of the roof between chock canopy tips and the face commonly commenced when chock convergence exceeded 30 mm. Roof fracturing only occurred when chocks were set a pressures below 50% of yield pressure due to hydraulic problems or when chocks were left one web back for mechanical repairs. Monitored chock loads were generally less than 700 tonnes.

Predicted convergences in Table 2 and results of chock monitoring at Central Colliery indicated that 800 tonne chocks would be satisfactory for Southern Colliery. Because of the significant effect of detachment of the roof cantilever beam in Table 2, chocks with a guaranteed minimum set pressure of 80% of yield pressure were recommended for Southern Colliery.

RESULTS OF MONITORING

Chock monitoring methods included manual monitoring of chock convergences and remote monitoring of all chock leg pressures using the Meco Invise Chock Monitoring System linked to a surface computer and 24-hour trend display system.

During extraction of the first two panels the maximum recorded chock convergences were 15 mm during normal production cycles when chocks were set at 80% of yield pressure and 130 mm during chock salvage. Measured convergences compare favourably with predicted values in Table 2.

Serious, rapid convergences to 400 mm, gatering and face spall leading to deterioration of the roof condition in front of the longwall, occurred on several occasions when chocks were operated off guaranteed minimum set, in undulating roof conditions, at set pressures of less than 60% of yield pressure.

Figure 4(a) shows a pressure trend for chock 55 over 24 hours. Set pressure is 345 bar with the chocks yielding at 434 bar. Each peak represents the end of a shear cycle for that chock as abutment load due to advance of the adjacent chock causes a sharp increase in load. The trend shows 3 to 4 shears with chock load peaking to yield followed by 8 to 9 shears with chock load peaking below yield resulting in an approximate cyclic loading of 12 shears or metres.

Figure 4(b) shows a face pressure profile for heavy loading.
CONCLUSIONS

Numerical modelling of Southern Colliery geological conditions, using a combination of three-dimensional displacement-discontinuity and two-dimensional finite element methods, was able to realistically predict roof convergence and chock loading.

The 800 tonne capacity chocks selected for Southern Colliery proved capable of controlling the strong sandstone roof provided that the recommended high positive set pressure was maintained.

Although the final choice of the 800 tonne capacity chocks was made with the benefit of previous experience in a nearby colliery, albeit under much more benign conditions, the success of the numerical modelling predictions in this instance suggests that an approach using compilation of a representative geotechnical model and integrated numerical analysis could have more widespread application in new or less well known geological environments.

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REFERENCES


