GEOTECHNICAL CONSTRAINTS ON A 6 M SINGLE PASS LONGWALL

by

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ABSTRACT

The feasibility of 6 m high single pass longwalling has been studied using Newlands Mine as a case study. An intensive geological investigation identified a range of hazards but a mine layout was possible that minimised the risks with respect to joints, cleats, angular bedding, coal shear and horizontal stress. Geotechnical design input was required for support capacity, subsidence, gate to face transition, face spall, and roof support. It is concluded that longwall face equipment can be made available by modifying existing designs, gate to face transitions will require a number of steps, and a mid-face sprag should not be required for routine operations.

1. INTRODUCTION

Thick seam (greater than 4 m) coal represents about 36% of Queensland's total underground limit resource of black coal and 22% of its total limit black coal resource. Thick seam black coal also represents a significant proportion of NSW resources. Internationally, high production longwalling is limited to seams less than about 4.5 m. Recognising this, the Queensland Coal Association Thick Seam Mining Technology Committee (QCA) commenced research into thick seam extraction in 1977 and in 1985 successfully applied to the National Energy Research Development and Demonstration Council (NERDDC) for funds to investigate the feasibility of high lift single pass longwalling. A target of 6 m height was set with 10,000 tonnes/day production. The project was structured around a typical longwall tender enquiry based on Newlands Mine in the Bowen Basin (Fig. 1).

Fig. 1 - Location Plan

2. STRATEGY

Given that this longwall would be the first high production thick seam face in Australia, if not the world, the overall strategy for the study was to identify and minimise as many mining, geologic, and geotechnical risks. From a mining perspective, the thick seam workings greater than 5.0 m overseas, were associated with very low productivity (less than 1500 tonnes/day). Australia's high

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production figures (12,000 - 15,000 tonnes/day) are from 2 - 3 m seam sections and the thickest seam worked is about 3.5 m. Only one longwall operation in the same geologic formation as selected and this is about 100 km distant.

From the geotechnical perspective, there was obviously no data on in situ behaviour for the seams to be extracted. Furthermore, extrapolation was required from workings in the 2 - 3 m seam thickness range for which there are very few design approaches.

A comprehensive geological and geotechnical exploration program was conducted. A mine layout was selected that put priority on minimizing the risks from perceived geologic hazards. In only a few instances did this conflict with operational and scheduling factors. Simple, but innovative design techniques were developed for issues such as support load density, face spill, gate to face transition, and subsidence.

The geological and geotechnical information formed the basis of a preliminary mine design that was used in the preparation of a longwall tender. Submissions were received from Gillick Australia, Meco Australia, Matari Mike, and Klöckner Bocor/Westfalia as the prime tenderers. Anderson Roe and Eiffel Australia submitted as sub-contractors.

3. GEOLOGIC HAZARDS AND LAYOUT

GENERAL GEOLOGY

The immediate roof strata consists of 15 m to 20 m of laminated mudstones with occasional sandstone layers. At least three rider seams split from the Upper Newlands Seam and in the vicinity of the split lines channel-shaped sandstone bodies are present. A further 10 m - 15 m thick mudstone overlies the topmost rider seam followed by well bedded sandstones. Strengths of all the lithologies are typically 40 MPa - 50 MPa, significantly less than for other Australian longwalls.

Joint trends are north east to north with a minor set approximately at right angles. Cleat orientations are variable but the dominant direction is north east. The fault pattern for the lease is still being developed. In common with other Queensland coal mines, the principal horizontal stress was found to be approximately twice the vertical stress and aligned sub-parallel to the regional strike.

The general geology of the lease was judged to be suitable for longwalling, with good caving conditions anticipated. An appropriate layout for the mine could be readily adopted. There were some localized hazards that needed extra consideration.

Compaction dips is the term applied to the tendency of bedding in the immediate roof strata to dip at an angle to the seam roof (Fig. 2). A sedimentological model for their formation was developed which allowed prediction of their orientation by mapping of the split lines for the three rider seams. It was decided that the preferred retreat direction was in the direction of the dip of the bedding. This decision was based on the basis of literature suggesting better support conditions for the support. Top coal is also available to be left as an extra precaution.

Fig. 2 - Recommended mining direction with respect to compaction dips

Angle shears in the seam were identified during mapping of the adjacent open cut (Fig. 3). They strike north/south and dip at about 45° to the east. Westward retreating faces were ruled out.

Low strength floor (less than 3 MPa) was identified in some areas. Bearing capacity analyses were used to analyse the possibility of longwall supports punching into the floor. About 0.5 m of floor coal was recommended despite the superior quality of this basalt section.

Fig. 3 - Schematic diagram of cleats and angle shears on a westerly aligned face.
4. GEOTECHNICAL DESIGN ISSUES

LONGWALL SUPPORT CAPACITY

The Australian coal industry is credited with the development of highly rated supports as a response to the thickly bedded strata of the Illawarra Coal Measures. Support load densities of up to 114 tonnes/m² are used in the Newcastle Coalfield. The most recent Australian longwalls have been supplied to Queensland mines and are rated at about 100 tonnes/m² (all 800 tonne capacity, 4 legs).

Available techniques for specifying support capacity are mostly empirically based with no data on thick seams. The postulated connection between support capacity, bulking factor, and seam height was viewed with much suspicion. Consideration of the overburden strata, and the dependence of beam thickness on cantilevering, led to the conclusion that initial caving could extend up to the base of the first significant sandstone (30 - 40 m). A detached block analysis gave a minimum support load density of 100 tonnes/m² for such a caving height.

The detached block analysis was the only published method that could give a definite support capacity. Given its well known limitations, an alternative analysis was sought. This led to the adoption of ground reaction curve concepts (Fig. 4). Unlike earlier models for longwalls, the ground reaction concept allows consideration of both support capacity and face convergence. The concept relaxed by Fig. 4 is that reduced support load density is possible if some convergence is allowed. If too much convergence is permitted large scale rock mass failure develops leading to increased support requirements. The approach is not yet quantified but it is still valuable in checking the reliability of the support load density of 100 tonnes/m² determined for Newlands.

Consider the heavy conditions prevailing under massive sandstones. As a longwall begins retreating under massive sandstones the roof is self-supporting (Point A) and the supports do little work. As retreat continues the roof begins to converge and the supports begin to work (Point A to B). In order to be able to control the roof, supports need to have a high set capacity both through a high support load density and a high set yield ratio.

Now consider the case of a thinly bedded mudstone roof. Mudstone have a lower modulus and curve readily; they have less self-supporting characteristics and hence converge more before failure. Such roofs require lower support load density to control the failure case but may induce greater face spall as a result of convergence. Low set pressures and low set to yield ratios, implying larger leg closures, are compatible with such roofs. Higher set pressures would be appropriate if the goal is to reduce roof to floor convergence and face spall.

Recent work (Frith, this volume) suggests that equilibrium is never attained - all faces do converge and if stood long enough will go into yield. This does not detract from the simple model: Fig. 4 can be taken as a projection onto a convergence rate plane of say 5 mm/hr.

According to this model specifying a highly rated support (100 tonnes/m²) under the Newlands mudstone roof should be conservative as far as support load density is concerned. It is interesting to speculate if face spall will develop to a greater degree than that seen typically under sandstone roofs. Using a model that relates face spall to the amount of roof convergence, the set yield ratio was specified in terms of convergence - 6 mm is a typical value for lower seam sections so this was maintained for the 6 m case. Such a specification leads to set yield ratios of in excess of 90%.

A four leg support was specified, partly as a response to the demand for a clear walkway behind the legs to protect operators from face spall (see later).

SUBSIDENCE

The prediction of subsidence in a greenfields area cannot be reliable. Comparing the NCB Subsidence Engineers' handbook with Illawarra and Newcastle Coal Measure data suggests a trend of increasing subsidence with decreasing presence of thickly bedded units. For Newlands, conditions were judged to be midway between the NCB and Illawarra field. With some supporting data from Queensland longwalls it was decided that maximum subsidence could be 75% of extracted thickness (Fig. 5).

FACE TO GATE TRANSITION

To maximise development rates, gate roads are to be driven at 3.5 m heights requiring, therefore, a transition of mining height from the 6.0 m face to the gate. Transitions can be via single steps, multiple steps, or ramps. The main gate was always located in the bottom of the seam but options for the tailgate in both the top and bottom of the seam were examined.

The geotechnical aspects of this stepping were investigated using a simple wedge analysis (Fig. 6). Consideration of the cutting action of the shearer indicates that complete canopy contact at the step

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Fig. 4 - Ground reaction curve

Fig. 5 - Postulated maximum ground displacement.

Fig. 6 - Analysis of the stability of steps in the face to gate transition.

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will not be possible. A factor of safety of 1.2 - 1.5 was selected, giving a maximum step height of 0.7 - 0.8 m. Such steps were recommended for the 2.5 m step. A similar analysis for stabilising the 2.5 m step to the tailgate chock gives a requirement for a 360 tonne side canopy on the first chock on the face.

**SPALL ON THE FACE**

One major concern with high longwall faces has been the possible development of face spall and the consequent need for flippers, forspotes and face sprays. The ground reaction concept allows a relationship between low support load density, roof convergence, and resultant face spall. It was considered that the prime strategy in reducing face spall was to maximise support capacity and set/yield ratios. A 40 tonne capacity flipper on an extendible forspote was recommended for Flexibend in steering spall blocks onto the AFC. Numerical analyses indicated that prevention of top spall would require flippers of at least 200 tonne capacity (Fig. 7).

The provision of a mid-face spray was a major issue. If such a spray was required for operator safety, it would be a challenge to maintain high production given the need to withdraw it before each pass of the shearer. Numerical modelling using a finite element/blocky element code suggested that face spall would not extend over the complete face. Fig. 7 shows that for the same amount of roof convergence face spall extends the same distance from the top of the seam. Stone bands in the coal contribute little if any stabilising influence.

It was concluded that face sprays should not be required for face operation. However face sprays will be required for protection of men and materials during maintenance.

**ROOF AND RIB SUPPORT**

The longwall was planned for shallow depths (<200 m) with good alignment to horizontal stresses. Given a coal roof, the support was specified as 4 x 1.8 m long fully encapsulated mild steel bolts with W straps at 1.5 m spacing. This was based on experience as no design techniques are available for greenfield sites.

Rib support was difficult to specify and this was compounded by the economic sensitivity of the mine to the amount of rib support. The coal is highly creased and roadways are of significant height - 3.5 m. A tentative proposal of 1 bolt/m at least to 200 m depth was forwarded. This concern about rib support in thick seams was first identified by the QCA in 1976 and despite much research since, still needs further work.

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**CONCLUSIONS**

This NERDC study provided considerable encouragement for the future development of thick seam single pass longwall mining. Importantly, from a geotechnical perspective, few additional risks were identified and the longwall face equipment can be made available by modifying existing designs.

At this stage Newlands Coal Pty Ltd is not proceeding with plans for thick seam longwalling. Further investigations of Newlands will study the extraction of a thinner seam section whilst maintaining options for later thick seam extraction.

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