ROOF FALLS IN AUSTRALIAN LONGWALLS

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SUMMARY

This report outlines the experience of Australian mining operators in dealing with large falls of roof in advance of longwall supports. Previous and present techniques used for face stabilisation have been described, together with an analysis of factors which contributed to the roof falls, in each case.

Attention has been focused on the stabilisation technique used at Angus Place Colliery, where the face coal was successfully reinforced by injecting chemical foam into the fractured areas. Although considered to be one of the worst roof falls in the history of Australian longwalls (60 m in length and up to 20 m in height), it was subsequently possible to resume cutting in Longwall 9 two weeks after the foam injection.

A preliminary schedule of work involving the 'strata replacement' method, is also discussed. It has been based substantially on experience gained with cementitious supports, principally by ACIRL and Monier Resources.

INTRODUCTION

There have been several occurrences of major falls in Australian longwalls. In this study, emphasis has been given to the causes of these costly and unproductive phenomena. In addition, an evaluation of the various techniques used on the local scene was made, covering the following aspects:

1. Meshing, strapping and roof bolting of the break line.
2. Steel girders used as forepoles to reach the face.
3. Breasting (and reinforcing roof) on advance.
4. Installation of protective canopies and reinforcement of broken-down face coal, using polyurethane foams.
5. Strata stress redistribution techniques, employed for drivages of initial longwall lines.
6. 'Strata replacement' method, in the proposal stage.

The individual methods listed above were successfully used at various collieries. In the case of major roof falls, the faces were unproductive for periods of up to two months. Relevant case histories are presented in the following sections, as well as a discussion of conditions leading to the development of roof falls.

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Due to zones of weakness and the presence of ground water, the mudstone roof was recently exposed locally to a 2.5 m roof height. Subsequently, bolting, strapping and meshing were applied successfully in Longwalls 203 and 206. Fully grouted bolts of 2.5 m length were used, making it possible to secure a 15 m long roof section in one shift.

When a major roof fall occurred in Longwall 204 (May 1984), the face was standing idle for 6 weeks. This fall extended from chock Nos. 20 to 45 and reached a height of 5 m.

A method of forepoling was undertaken (Figure 1), consisting of 6 m long, high tensile hollow steel rods (50 mm in diameter, ASAB). These were installed in 62 mm diameter boreholes. Since the holes were drilled with great difficulty (sub-horizontally to the roof), the method was soon abandoned. Instead, the fall was progressively and slowly mined through.

After a total 4 m face advance, a more reliable tip at the roof fall was attained and mining continued with some improvement in face stability.

Excessive Strata Loads, Longwall 204

Longwalls 203 and 204, both 182 m in length, were separated by a row of 24 m (rib to rib) coal pillars. The initial position of Longwall 204 was 150 m behind the initial line of Longwall 203 (Figure 2).

After Longwall 203 was extracted and Longwall 204 face line (unfortunately slowly progressing) reached the initial goaf line of Longwall 203, a 'double' abutment load situation was created. The chock-shields (600 t capacity) started to yield. Under 'super-stressed' conditions, the 24 m pillar had apparently approached its load bearing capacity.

Super-stressing occurred when the overburden strata were near to collapse over the (merging) goafs of these two longwalls, each being of a sub-critical width.

For comparison, critical extraction widths of as much as 1.2 h (h = 400 m, depth of cover) have been experienced at mines in the Illawarra District.

Fig. 1 - Forepoling in L/W 205

Fig. 2 - Critical position for Longwall 204

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WEST CLIFF COLLERY

At West Cliff Colliery, 900 t yield-capacity chock-shields operate in the longwalls. With extraction of the first longwalls (Nos. 1 to 3, during 1960-1964), the immediate sandstone roof was always standing intact along the face line and power forepoles were not used. In contrast, under mudstone roof, at a thickness of up to 1.1 m, the forward cantilevering units were incapable of securing the continuity of this brittle type of rock. An unusual situation that occurred in Longwall 2, is shown in Figure 3. Between 10 to 15 of the power supports had fully extended hydraulic legs, which did not reach the major (overbridging) sandstone roof.

![Diagram of roof structure and support systems]

Fig. 3 - Collapse of immediate roof in L/W 2 -West Cliff Colliery-

When the shearer drum's width was subsequently reduced by 20% (from 1 m to 0.8 m), there was an improvement in stability of both the brittle mudstone and face coal. The narrower web cut had little effect on production rates, which for Longwall 4, averaged 7,800 t/day.

APPIN COLLERY

With the first three to five longwalls (1968-1970), the mudstone roof was very sensitive to bending and frequently sheared along the face lines. From underground monitoring, it was established that the actual Mean Load Density of supports was less than 45% of their designed load bearing capacity.

In Longwall 3, a steep break line developed above the face coal, as shown in Figure 4. Attempts to cut the face coal were accompanied by excessive face spalling. Consequently, it was decided to drive a heading around the roof fall area. The AFC was disconnected and a temporary return roller used to fill coal out from the 'breast' heading (Figure 4). Two months of coal production were lost. Since the introduction of modern support types (lemmicate systems and high loading/loading capacities), problems with roof instability have been significantly reduced.

![Diagram of roof structure and support systems]

Fig. 4 - Breasting in Longwall 3 at Appin Colliery

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ROOF FALL IN INITIAL LONGWALL POSITION

At Appin Colliery, roadways driven normal to the prevailing direction of minimum horizontal stresses, experience the least degree of stability problems. Maximum horizontal stresses were observed in the direction parallel to longwall face lines (Figure 5). Consequently, initial longwall lines were driven after the sacrificial headings, in order to relieve high horizontal stresses.

A 13 m wide pillar was usually left between two headings (Figure 5). Since the sacrificial heading was driven first, it experienced 'full scale' field stresses. To increase the stress-relieving effects during drivage of the second heading (which became the initial longwall line, driven at 6.5 m = 7.0 m width), roof collapse in the sacrificial heading was deliberately induced by shotfiring. Recently, a heading driven at 6.2 m width for Longwall 11 experienced a major roof fall (Figure 5), delaying the commencement of longwall operations by 3-4 weeks.

YIELD PILLAR TRIAL

In relation to modern experience with yieldable pillar sizes, the current 13 m wide pillar would be considered too strong. For comparison, chain pillars at 11.0 m to 12.5 m rib-to-rib widths have been found best suitable for redistribution of strata loads between longwalls 5 to 12, at Appin Colliery. Although the gateoads and chain pillars have been subjected to very high abutment loads at this mine, the stability of maingates has significantly improved since yield pillars were introduced.

When driving roadways in a virgin field, strata loads acting on coal pillars (between headings) are undoubtedly of lower magnitude.

Fig. 5 - Longwall No. 11 face heading - Appin Colliery - (new section of face to be driven)
Not to Scale

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Consequently, under such conditions, the width of yieldable pillars cannot be in the order of 11.0 m or 12.5 m. More appropriate dimensions would be, for example, between 6 m and 11 m. An accurate yield pillar width can be determined by experiment, using the Converging Heading Technique (an intervening tapering coal pillar between two roadways). Details of this method were given by Carr.

ANGUS PLACE COLLIERY

Attention has been focused on the recent event (September, 1985) in Longwall 9 at Angus Place Colliery. A roof fall, 60 m in length, stopped coal production for a period of 3.5 weeks. Firstly, the case history of Longwall 9 is presented, to enable a greater understanding of circumstances leading to the development of such a roof fall.

CASE HISTORY OF LONGWALL 9

During the first two months of operation, coal production in the order of 2500 t/shift, was maintained in Longwall 9. Major features of this operation were as follows:

1. Mining the Lithgow seam at a working height of 3.45 m - 3.50 m, under approximately 200 m depth of cover.
2. A uni-directional system of cutting was used, with a snaking-in operation in the middle of the longwall (further details are given in Section 6.4). Width of the web was 1.0 m. Setting pressures applied were 45% of the designed yield pressure.
3. Uniaxial compressive strength (UCS) of the coal was measured as generally between 10 to 20 MPa. At the top of the seam, UCS reduced to 4-7 MPa. In addition, soft claystones became more pronounced, as well as faulting and joints.
4. Since several roof falls had occurred in the gateroads of Longwall 8 (chain pillars at 35 m centres), pillars at 40 m centres were developed for the present Longwall. Roadway widths were reduced to 5.4 m.
5. Angle of draw, measured in the roof strata, changed progressively from 12° to 22° (from the vertical), as depth of cover increased from 130 m to 210 m, respectively.

ROOF-FALL IN LONGWALL 9

The 60 m long roof fall occurred in Longwall 9, after a weekend’s interruption to production. Consequently, bolting and strapping operations were initiated, at the locations shown in Figure 6.

![Fig. 6 - Initial longwall 9 face recovery](image-url)
During roof and face-coal reinforcement operations, the roof-fall height increased to 20 m, between chocks 73 and 83. Roof material, which was falling from the higher strata, posed a serious threat to bolting operators. At this stage, it was imperative to adopt appropriate remedial measures. For the most critical section (chocks 73 to 83), the following methods of passing through the large roof-fall area were considered.

1. Set an 'artificial' roof, consisting of protective canopies.
2. Bolt and dowel the roof and face coal.
3. Drill holes into displaced strata, for injection of the polyurethane resin (PUR).

Most critical roof-fall section, between chocks 73 and 83.

At the end of the first week, during which the roof-bolting and face-dowelling operations progressed towards the most difficult area of Longwall 9, a trial with PUR was initiated.

Between chocks 73 and 83, two to three rails were bolted to each forepole (Figure 7). The rails and wooden bars (laid across on them) appeared to be a safe enough system for the drilling operations to continue.

Preparation of the technical details and time schedule continued for an eventual emplacement of grout mixes behind the formwork along the coal face line (See Appendix).

Since the stability of face coal reinforced by the injection of PUR proved more than satisfactory, the mine management was encouraged to use this technology for the rest of the longwall. It consisted of the following two stages.

Fig. 7 - Steel rail canopy

1. Drilling 2 m long holes (28 to 30 mm diameter) into the face, under the protection of steel rails and steel ropes.
2. Inserting PVC conduits (20 mm in diameter), for the delivery of PUR to the end of boreholes.

A total volume of 1300 litres was consumed. The average was 12 litres per hole, with the maximum being 30 litres. On resumption of cutting operations, the face coal was standing as a brick wall.

CAUSES OF LONGWALL 9 ROOF-FALL

Major factors contributing to the roof fall in Longwall 9, were assessed and given the following order of priority:

Variation in overburden depth and changes in seam thickness

In general, adequate attention has not been always given to topography of the surface terrain, in relation to the location of longwalls below. For example, Carman\(^2\) reported that extreme variations were experienced in the West Virginia's coal fields.
In the above case, a longwall block encountered 300 to 400 ft (100 to 130 m) of overburden difference. In Cavan's opinion, overburden pressure caused the immediate roof to move or flow ever so slightly toward the goaf. A slight increase in pressures produced on the longwall, with cleavage planes parallel to the face line, appeared to have produced adverse stability effects. At Angus Place Colliery, from Longwalls 8 to 10, the depth of cover varies significantly. A longitudinal section is given in Figure 8.

The original Lithgow seam was as high as 6.6 m. The Lithgow seam thickness reduces to 5.0 m and ultimately to 2.5 m. In the Easterly direction, soft claystones (in the seam roof) become more pronounced with the decrease in seam height. This may be observed in Figure 9, which details the data obtained from boreholes D.B.H. 60 and D.B.H. 9.

Mode of cutting and supporting

A half-way system, involving unearthing of the AFC, was typical for Longwalls 1 to 9. Consequently, in the mid-longwall area, chocks were standing approximately 1 m off the face. The remaining supports were in a 'close-up' position. As the roof was exposed and unsupported in this mid-section, conditions for a roof fall were created.

Since the commencement of longwall operations at the colliery, a conventional mode of cutting has been used (Figure 10a). Chocks move forward after the AFC is fully advanced (being the last operation of the cycle).

Fig. 8 - Longitudinal section through boreholes

Vertical scale 1:3000
Tip load density and width of the web

Under a linear distribution of roof loads on the roof canopies, high break-off loads are generated. These are approximately 500 t, at 650 t yield load. During extraction of longwall 9, the break-line developed in extremely friable claystone roof, approximately above the centre of the rear legs. Consequently, the power-tip resistance was reduced.

Furthermore, width of the web is of particular importance when mining under incompetent roof. When the claystone roof was exposed and not adequately supported by the roof canopies, or power forepoles in longwall 9, propagation of cracks and bed separation ultimately resulted from high roof loads. In the Illawarra District, web widths of 0.75 m to 0.85 m have been adopted in the Bulli Seam. At Angus Place Colliery, the web was 1.0 m wide.

RECOMMENDATIONS

For the improvement of stability conditions in present and future longwalls at Angus Place Colliery, the following operational criteria are suggested.

1. Introduce a bi-directional mode of cutting, as shown in Figure 10b. Maintain forepoles in the extended position at all times.

2. Reduce web width from 1.0 m to 0.8 m, at a working height of 3.5 m. In order to reduce the web width by 0.2 m, apply external stroke limiters (collars slipped over and bolted) to piston rods of the pushing rams.

3. Increase setting pressures gradually from 45% to 80%, whilst monitoring support and roof behaviour.

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face coal is best achieved with chemical foams (PUR).

In the presence of a high stress field, sacrificial headings driven parallel to longwall initial lines, are recommended. Between such two heading systems, the coal pillar width should be designed at a practical minimum (yieldable).

REFERENCES


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APPENDICES

A. OVERSEAS EXPERIENCE WITH LONGWALL FACE STABILISATION

The following three references detail operations considered best applicable to Australian conditions, for longwall face stabilisation.

Fig. 10 - Mode of cutting - simplified

CONCLUSIONS

In terms of face downtime, none of the techniques used previously for face stabilisation in Australia, could be classed as a success.

Development of a break line above the face line can be controlled only if the face coal is stabilised. If protective canopies can be installed to secure drilling operations, stabilisation of the broken-down face coal.
1. POTHINI, B.R.
Polyurethane aids roof control in longwall mining at Island Creek Coal Company.
Chapter 20, 22pp. 155-166,

2. DALzell, R.S. et al
Remedial and strata replacement techniques on longwall faces.

3. DUTTON, B.
A successful example of the strata replacement technique.
Midland Institute of Min. Eng., IM in K. Wakefield, Paper No. 4811,
25th September, 1980.

These references provide a review of the known techniques and equipment, including resin injection, monolithic packwalls, timber-rib cavity filling, strain-absorbent modules and wire meshing. The second reference considers resin injection of strata as being most successful for improving the strength of deteriorated roof and coal, based on a number of case studies provided.

The following Section (b) gives a detailed account of the face recovery technique, which would be applicable for roof falls similar to the recent occurrence at Angus Place Colliery.

8. CEMENTITIOUS SUPPORT FOR FACE STABILISATION
This option could be used for Longwall 9 at Angus Place Colliery, if both the installation of protective canopies (Figure 1) and stabilisation of the facc coal by FUR, were not successful. The basic concept of this 'strata replacement' method is virtually the same as that detailed in references 1 to 3 (Appendix A).

Fig. 1 - Installation of protective canopy

STAGE 1: Preparation of site, materials and equipment

* All stone spall would have to be removed from the face, ahead of the AFG, for the forwork to be erected. Formwork could possibly be made of chipboard, collapsible steel stoppings, or specially a sewn type of reinforced cloth material, supported by a standing structure.
* Cement/lymph mix is readily available in Australia, exhibiting properties which include:-
  (a) self-supporting after 6 hours,
  (b) a compressive strength of 1 MPa in 24 hours, and

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(c) an ultimate strength of 2-4 MPa, after two days.

It was estimated that 200 tonnes of material would be required for a 50 m long face section.

* A cut-through, near the longwall maingate, would be selected as the bulk or bag delivery location, including pumps. The 'Sandpipe' pumps (e.g., by Manier) are capable of pump distances up to 150 m.

STAGE 2 - Formwork erection and pumping to a height of 3.3 m above floor level

* The forepoles must be left extruded and should have formwork angled towards the face (Figure 2).

Fig. 2 - Set up at start of pumping

* Raising of the cement pack to a height of 2 m, would commence immediately after the initial 1 m of emplacement.

* Once the pack has reached a height of 2.5 m, fibreglass rods or light steel girders would be laid across the top (Figure 3).

Fig. 3 - Set up on completion of pumping

STAGE 3 - Emplacement of pack up to 4.0 m above floor level

* In the NCB case (Reference 3), it was possible to install a packwall of 4.5 m height. It is not certain how this was achieved, as the formwork must first be placed above the roof support height.

* A possible solution is to use sliding formwork, which is supported by the underlying canopy frame and formwork.

STAGE 4 - Injecting PUR past the grout structure into the strata

* Drill 3 m to 5 m long holes, 28 mm in diameter (compared to standard inflatable packers, at 41 mm diameter), through the packwall.

* Inject PUR immediately after the emplacement of grout mixes. Cut coal immediately, since PUR chemicals are capable of setting in moistened structures and develop strength after 20 minutes (Figure 4).
Fig. 4 - Cutting through backwall