Coal Operators' Conference

Faculty of Engineering and Information Sciences

1998

Experience with stress control methods as a planning tool - Elouera Colliery

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ABSTRACT

Continued extraction of the No. 3 Seam at Elouera Colliery required the driveage of a sequence of roadways within an area of significantly elevated horizontal stress. Initial roof conditions varied from excellent to very severe as the panel entered the high stress area. The variation was attributed to the extraction sequence, with different roadways "leading" the panel into the high horizontal stressfield.

This paper summarises field and analytical work designed to evaluate the use of stress control methods as an effective planning tool. The "leading" roadway of the panel would be required to remain stable whilst experiencing moderate to severe deformation whilst the neighbouring roadways (stress relieved) could be driven at more acceptable advance rates using less reinforcement.

The planning implications of developing the panel with stress control methods are discussed.

INTRODUCTION

The use of stress control methods to optimise extraction and reinforcement systems was evaluated for a panel to be driven through a high horizontal stress area at Elouera Colliery.

The investigation program included a routine monitoring program using tell-tales, supplemented with extensometry at key locations. The analytical work included the use of a numerical model developed to simulate roadway and reinforcement behaviour over a range of conditions.

This paper outlines the approach adopted and incorporates the practical implications of using stress control provided by colliery personnel.

BACKGROUND GEOTECHNICAL INFORMATION

Panel layout

The panel layout shown in Fig 1 illustrates the extent of deformation within Thompson and Hume Panels prior to the investigation, the area over which field and analytical work was conducted and future roadway driveage.

Geological setting

The Colliery mines the No. 3 Seam under a depth of cover of approximately 350 m over Thompson Panel. A roof core obtained from the investigation area is shown in Fig 2. The roof up to 6 m is composed of a sequence of coal and carbonaceous mudstone with various sandstone and clay (tuff) units present.

A sandstone unit approximately 1 m thick is located between 2.4 m and 3.4 m into the roof. This unit overlies a weak claystone material, locally known as the "puggy band". A further weak claystone unit is also present at the top of the seam. The weak claystone interfaces play an important role in the mechanism of stress redistribution about the roadways.

A major fault forms the western boundary of the panel as shown in Fig

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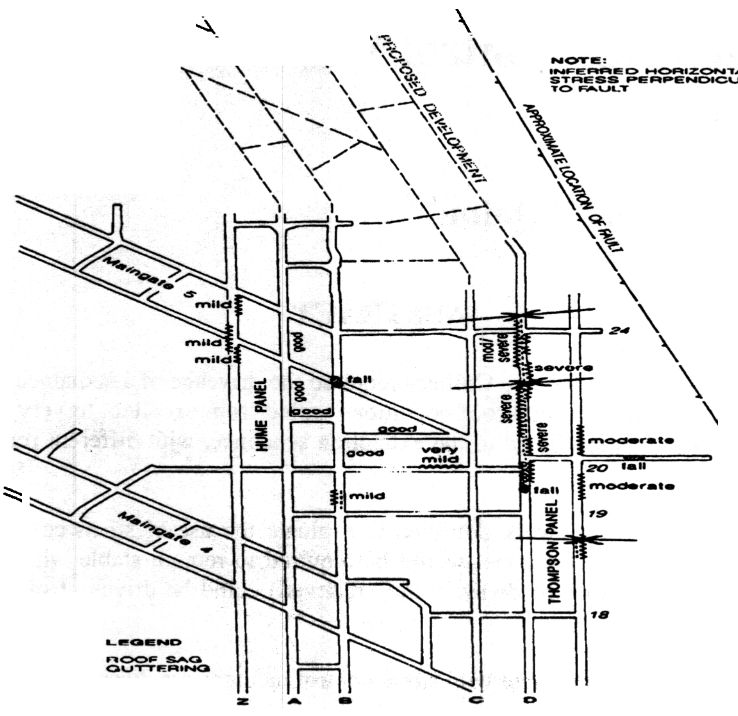


Fig. 1 - Elouera Colliery panel layout roadway deformation, layout and inferred stress direction

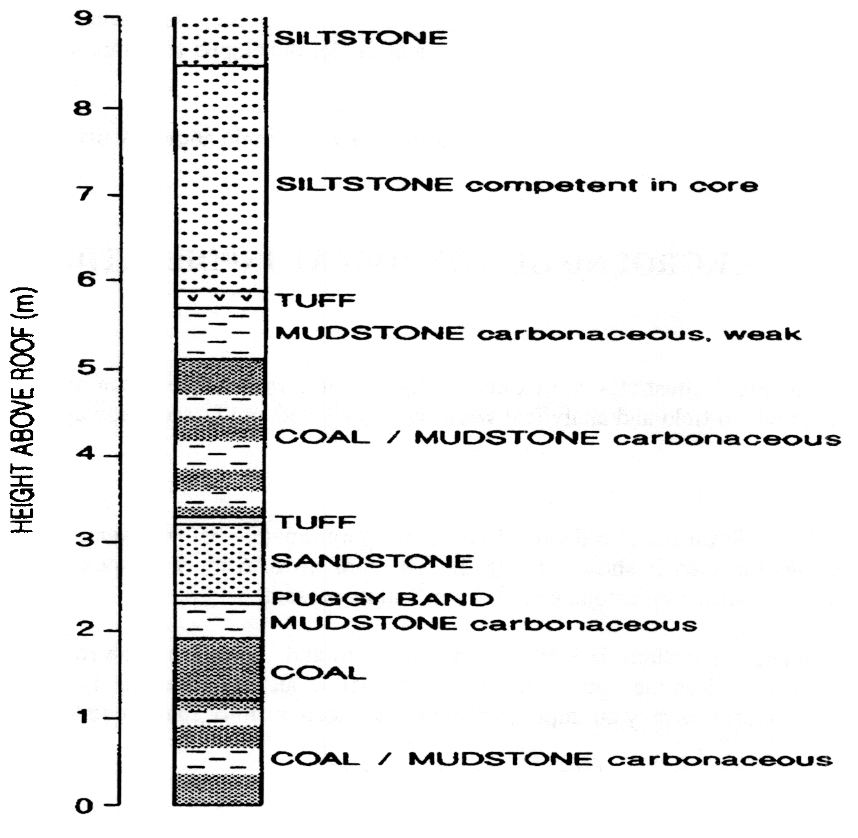


Fig. 2 – Elouera Colliery Gelogical profile – Thompson Panel

Stressfield

Initial driveage of Thompson and Hume Panels were inspected to determine the orientation of the major horizontal stress on the basis of the deformation mechanisms observed. The relative magnitude of the horizontal stress could also be gauged by the level of deformation evident.

The results of the mapping are shown in Fig 1, which illustrates a strong correlation between the increased horizontal stress levels with proximity to the major fault. The major horizontal stress direction inferred from mapping was west northwest - east southwest, approximately perpendicular to the fault.

The future panel geometry would require a panel to be driven in more unfavourable circumstances than that already experienced (headings aligned almost perpendicular to the major horizontal stress direction).

General concept of stress control

The general concept of stress control methods is well understood and has been previously outlined by Gale et al (1990). In summary, the extraction sequence for a panel of roadways comprises a leading roadway with respect to the horizontal stressfield. This roadway is subjected to the pre-mining horizontal stress and experiences the most deformation. An area of reduced horizontal stress is formed about the leading roadway, providing more favourable driveage conditions. The general concept is illustrated in Fig 3. Stress control is most appropriate where roadways are aligned perpendicular to the major horizontal stress.

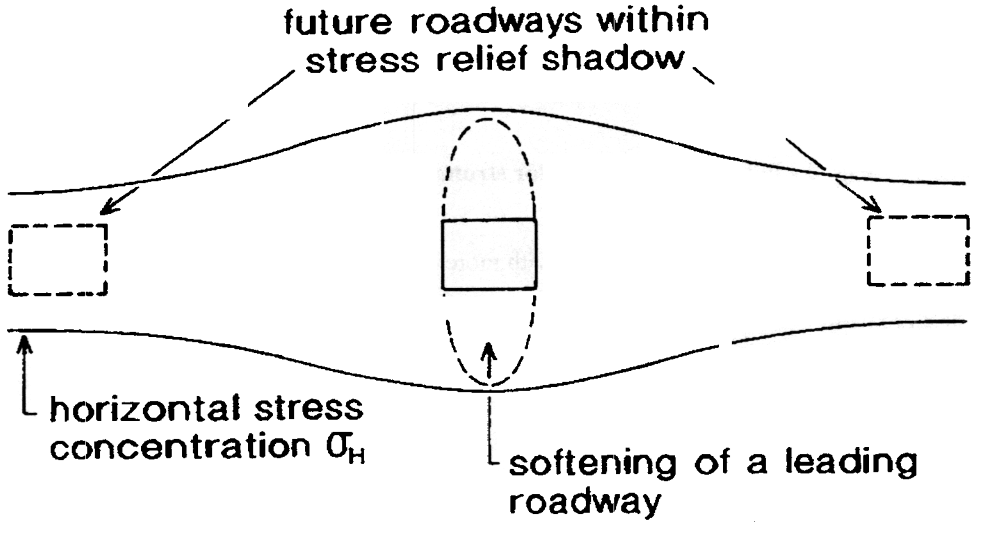


Fig. 3 - Slow build up of vertical stress in the pillar where slip occurs and confinement is reduced

MONITORING PROGRAM

The layout of instrumentation is shown in Fig 4.

Tell-tales are used on a routine basis by Elouera Colliery to ensure that the roadway deformation levels are within acceptable design limits. In areas where the roof movement exceeds a predetermined level, further action, usually in the form of long tendon secondary reinforcement is used.

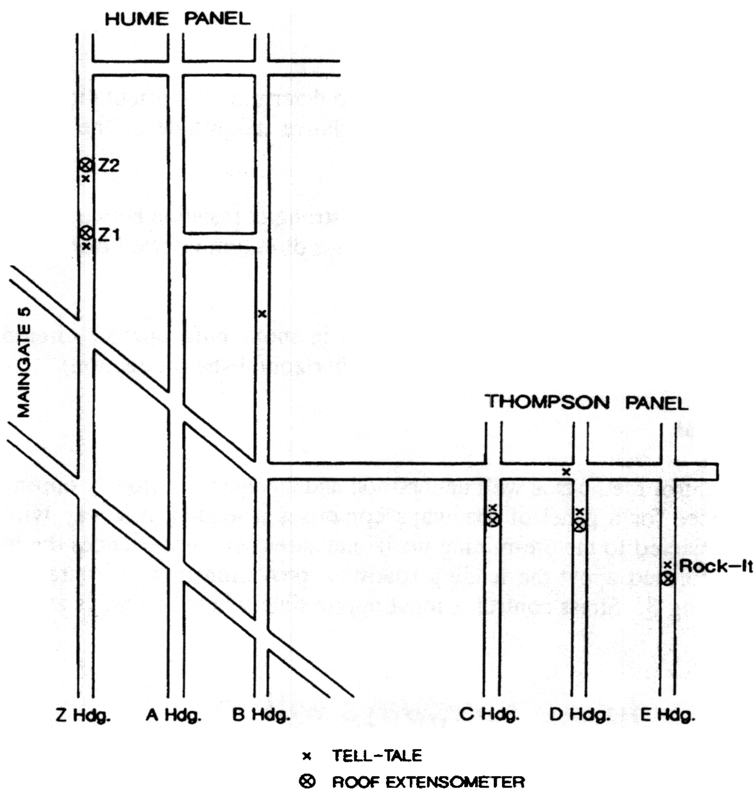


Fig. 4 - Pillar strength cases for strong and weak geologies

The monitoring program supplemented the routine tell-tales with more detailed extensometry at key locations.

General style of roof deformation

Fig 5 is an extensometer which shows the typical style of deformation at Elouera Colliery. Initial movement is restricted to the immediate roof below the competent sandstone unit at 2.4 m to 3.4 m into the roof. Deformation occurs as both slip along weak interfaces, particularly the "puggy band" and shear failure of the intact material itself through overstressing.

The propagation of deformation is characterised by softening of material above the sandstone, followed by shear failure of the sandstone itself. At this stage in the deformation pathway, softening has occurred up to 6 m into the roof and secondary reinforcement is typically required to maintain roadway stability.

Roof monitoring results

'D' Heading was the first driven roadway in this sequence. It was driven with an ABM20 and supported with mesh modules and 6 x 2.7 m bolts at 1 m centres. Whilst the miner achieved good driveage rates of 11 m per shift with good (visible) initial roof conditions, the roadway eventually deformed over 300 mm and required cable bolts along its entire length.

Flanking roadways, 'C' and 'E' Headings were driven without problems, experiencing less than 40 mm of roof movement. 'C' Heading has experienced approximately 13 mm of movement to date.

A summary of the total roof movement for each heading within the sequence for Thompson and Hume Panels is shown in Fig 6. The comparative roof conditions between 'D' Heading and 'C' Heading is also shown in the photograph taken outbye 24 Cut-through (Fig 7). Note the extensive use of cable bolting in the leading roadway.

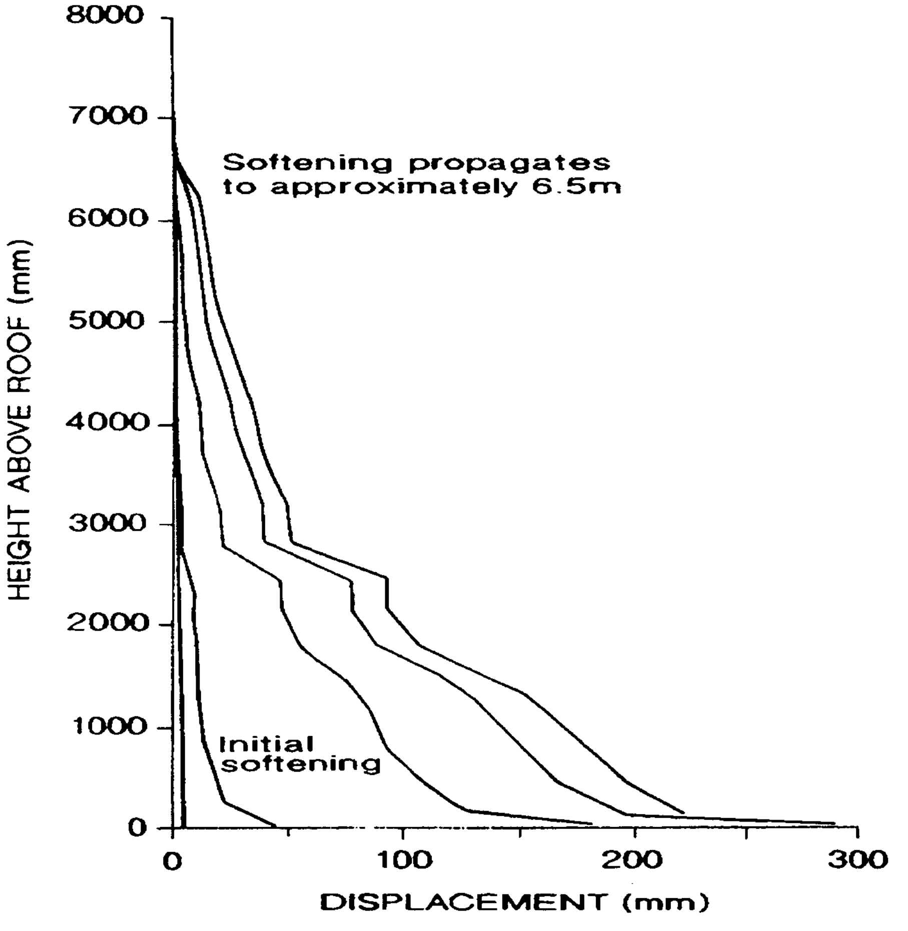


Fig. 5 - Range of potential pillar strengths relative to width / height based on confinement variation

Driveage was continued inbye 24 line with a heliminer with 'E' Heading the leading roadway. After reaching 45 m the miner was taken out and the heading was chocked due to the severe roof deformation. 'D' Heading was then driven approximately 25 m in advance of 'E' Heading at which point the miner was again taken out due to severe roof conditions.

Extent of stress relief

A contour diagram of inferred stress relief is presented in Fig 8. The stress relief zone can be visualised as a bow wave about a boat. The leading roadway itself is always pushing into an area of increased horizontal stress, leaving a wake of reduced stress.

One of the major contributing factors to the mechanism of stress relief is considered to be the slip along the weak interfaces such as the "puggy band". The weak interface can be visualised as a surface on which a series of ball bearings rest. Removal of confinement (mining the roadway) allows the material below the "puggy band" to mobilise towards the opening, effectively moving along the ball bearing surface. In a frictionless world, the movement would propagate forever. At Elouera, the movement propagates at least 50 m.

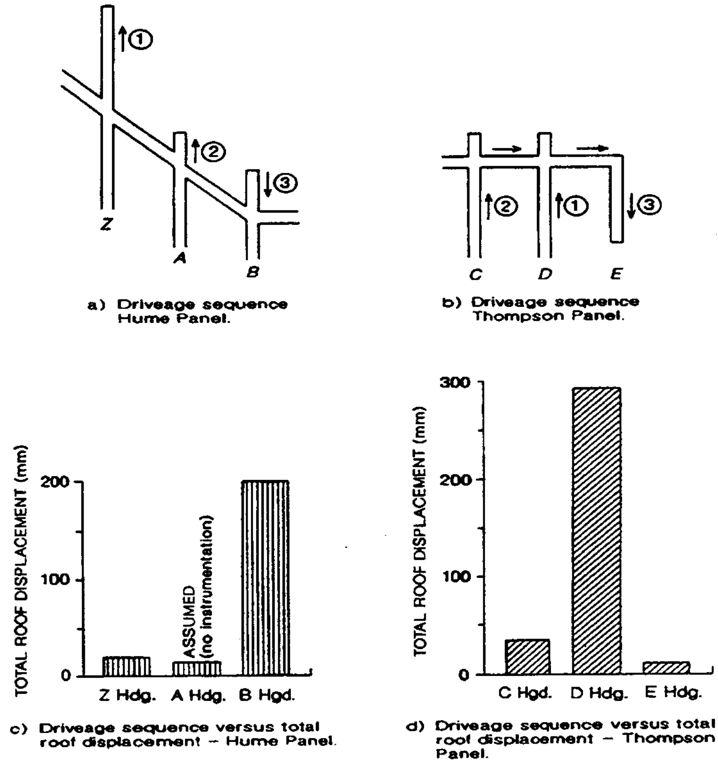


Fig. 6 – Elouera Colliery summary of roof displacement Thompson and Hume panels

PLANNING IMPLICATIONS

It was decided to review the future layout and support design for the area as it was considered too unsafe to mine the planned layout. The roadways were essential to the viability of the mine, being the main development leading to the last remaining longwall blocks. Concerns about longwall continuity meant that they had to be driven quickly.

The main planning implications included:

Driveage sequence;

Reinforcement system required to manage the deformation of the leading roadway; and

Implementation of new support systems.

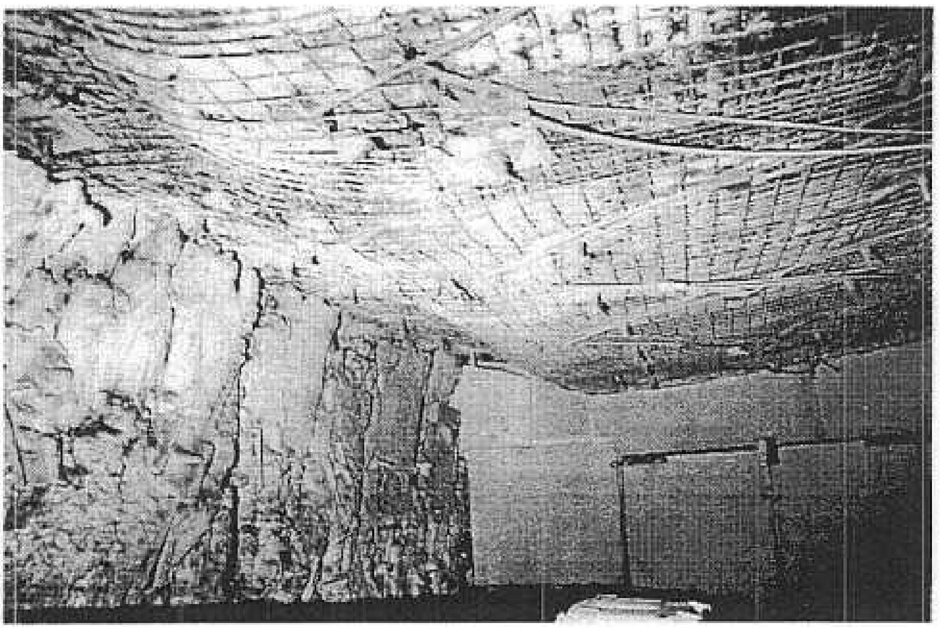
Driveage sequence

In determining the new panel layout, the purpose of the leading roadway had to be considered. Allowing total collapse of the leading roadway (sacrificial heading) was considered but would have altered the layout too much and would have been difficult to drive safely.

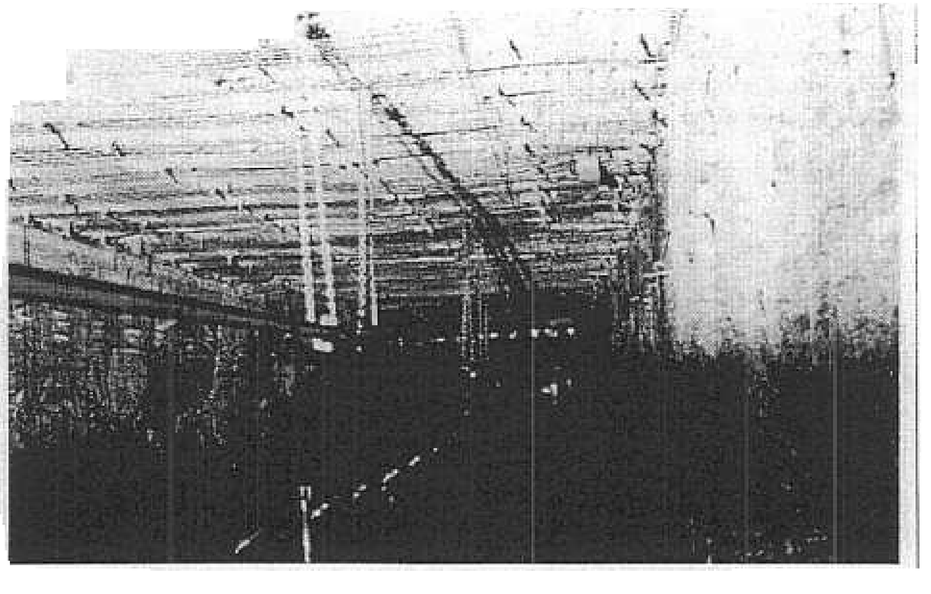
A four heading layout with flanking returns was decided. Since 'D' Heading was a return and the belt road ('C' Heading) required the most protection, it was decided to drive 'D' Heading 20 m to 30 m in advance of 'C' Heading.

If the new support system failed in 'D' Heading, then timber support could be used and the heading still serve as a return, although less efficiently if timbered. It was expected that 'C' Heading would then be driven under much more favourable conditions with only primary reinforcement.

The sequence of driveage required to maintain 'D' Heading as the leading roadway was not the optimum driveage sequence for the panel. Driveage of the belt road first would have allowed more time to construct the necessary infrastructure for the next longwall.



7(a) Leading roadway D heading, outbye 24 line, Thompson Panel



7(b) Stress relieved roadway C heading outbye 24 line, Thompson Panel

Fig. 7 - Elouera Colliery comparaive rook conditions between leading roadway (D) heading and flanking roadway (C heading)

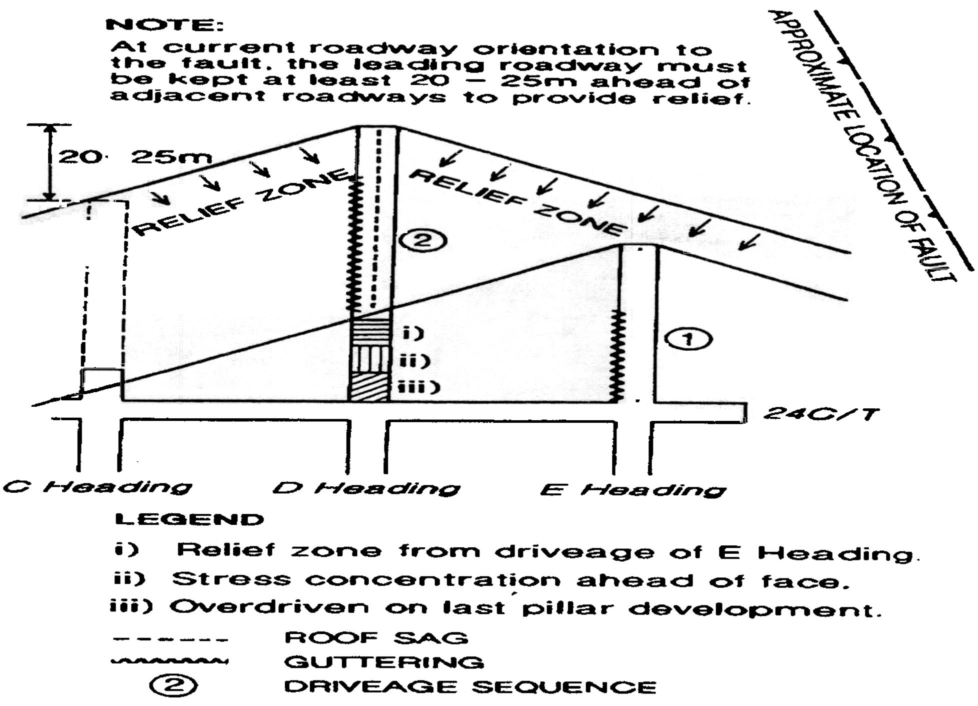


Fig. 8 – Elouera Colliery stress relief zone formed about a leading roadway – Thompson Panel

Leading roadway stability

Analytical study

To determine the reinforcement required to maintain stability of the leading roadway, the numerical model developed to simulate roadway behaviour and reinforcement performance was used. The model is regularly used to evaluate various reinforcement options over a range of geological and loading environments.

The panel driveage coincided with the development of two new products, the "Megabolt" and "High Performance Capacity" (HPC) bolt.

The Megabolt is a 65 tonne "caged" wire product which is marketed as an alternative to cable bolting. Its main advantage is seen to be the ability to be installed at the face. The HPC bolt is a 50 tonne solid bar product marketed as an alternative to the 30 tonne "X" grade rebar.

Whilst a complete description of the modelling work is beyond the scope of this paper, in summary, an interim design of three megabolts per linear meter was presented to the colliery, to be installed at the face in addition to the existing primary bolting pattern. The roof would still be expected to soften to the top of the seam (6 m) and between 100 and 150 mm of roof displacement was anticipated. Whilst this level of deformation is high, it represented a significant improvement in roadway conditions, providing a high level of confidence in the safe driveage of the leading roadway whilst still allowing stress relief to adjacent roadways.

Field experience

Mining was carried out with a heliminer and all support work, including megabolting was carried out with hand held machines. The face was advanced on a 1 m cut/support cycle, including installation of the megabolts at the face.

The reinforcement system comprised the standard 6 x 2.7 m bolts per row plus three megabolts per meter. The megabolts were 8 m long with the top 2 m encapsulated. Initial pull tests indicated that the 2 m chemical anchorage was sufficient to hold their rated 65 tonnes.

The initial megabolts were difficult to install as the roof was fairly broken. Post grouting of the megabolts was required to arrest roof movement. This was conducted on a weekly basis.

At 30 m inbye the dogleg (see Fig 1) 2.7 m long HPC bolts with cups and saucers were used instead of 'X' grade bolts. Megabolting with weekly grouting was continued.

A specific cycle of cutting the right hand side (the guttered side) was maintained to contain the guttering on that side. If the left side was cut first, guttering would have occurred on the right hand side of the initial cut which would become the centre of the roadway on widening.

The conditions in the leading roadway at the time of writing were characterised by a level, intact roof. Elevated stresses were still evident from the monitoring (roof displacement approaching 100 mm) and high bolt loads evident, however the roadway conditions are considered to be manageable.

Whilst time dependent movement is still occurring in the leading roadway at the time of writing, the level of roof deformation has decreased from over 300 mm outbye 24 line, to 130 mm where megabolts were installed at the face and post grouted to less than 100 mm where HPC bolts have replaced AX bolts.

The improved roadway conditions is considered to be a combination of:

- Cutting sequence-cutting the stressed side first and minimising opening width
- Installation of secondary support (megabolts) on first pass
- Post grouting (weekly) of the megabolts
- The introduction of the higher capacity HPC bolts with cup and saucer plates
- Close monitoring of roof movement and quick adjustments made to improve support
- The persistence and dedication of the crews whom have had to cope with fairly difficult conditions and have had to learn new support techniques very quickly.

CONCLUSIONS

Stress control methods were successfully used at Elouera Colliery to manage potentially problematic roadway conditions within a high horizontal stress environment.

Routine monitoring of roof displacement provided an effective means to establish the extent of stress relief achievable and to ensure that the magnitude of roadway deformation was within design expectations.

The successful implementation of stress control methods has allowed driveage in an area which may previously have been considered unmineable. Use of new support products (megabolts and HPC bolts) has allowed more manageable driveage conditions of the leading roadway whilst still allowing enough roof softening to provide stress relief to adjacent roadways.

The cost of additional resources required to drive the panel in a specific sequence is expected to be recouped with improved driveage rates in the flanking roadways and in increased recoverable reserves.

REFERENCES

Gale, W J, Fabjanczyk, M W and Matthews, S M, 1990. Stress Control in Underground Coal Mines. AMIRA Annual Tech. Meeting. Pokolbin, NSW 5th September 1990.