Development and Application of Strata Management Systems in Coal Mines

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Abstract: The continuing need to improve productivity and safety requires mine operators to both successfully manage the hazards associated with strata control whilst optimising mining practices.

Recent experience in Australian coal and metalliferous mines has seen the introduction of legislation to ensure that adequate consideration is given to geotechnical design and strata control.

This paper outlines a rational approach for the development of a Roadway Strata Management System that is based upon the systematic assessment of strata behaviour during all stages of a roadways use and describes its application by Strata Control Technology Pty. Ltd. at Ulan Coal Mines Limited.

Key Words: strata management system, routine monitoring, hazard maps, geotechnical investigation.

Introduction

The development of a Roadway Strata Management System is an extension of the well established investigation and design process used by SCT and well documented previously (Siddall and Gale, 1992 and Gale et al, 1992).

The intent of the Roadway Strata Management System is to ensure that appropriate levels of roadway stability are maintained during all stages of its use. The approach adopted has been to:

- define the expected range of conditions
- define the expected range of roadway behaviour
- design appropriate reinforcement and support for each environment
- implement routine monitoring of key design parameters about the roadway
- implement design changes based upon the routine monitoring and pre-determined guidelines

Figure 1 details the general outline of a Roadway Strata Management System.

It is emphasised that routine monitoring alone does not constitute a management system. In isolation, the monitoring information has no context. What is an acceptable amount of roof movement? What reinforcement design is appropriate for a given level of roof movement? How close to the edge is my design?

By defining the expected range of roadway behaviour, and designing reinforcement schemes appropriate for each environment, the monitoring triggers have a context in which to be interpreted. It is these triggers and action/response guidelines that are the ongoing control loop for ensuring roadway stability.

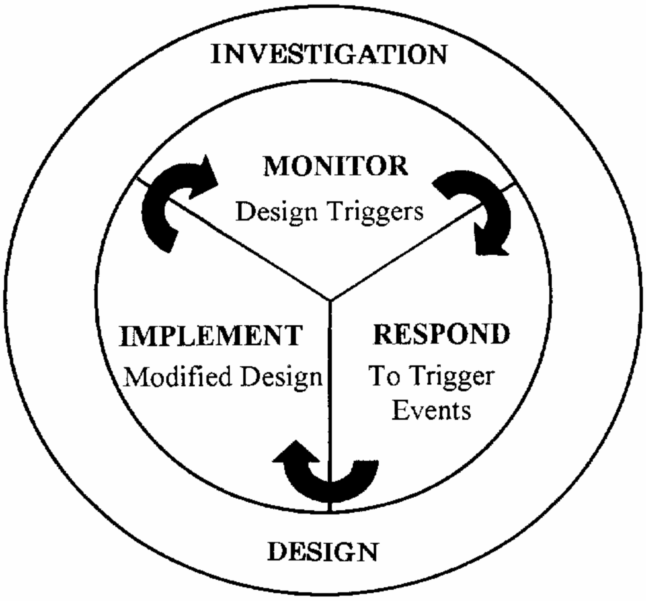


Fig. 1 – General model for a roadway support management system.

Basis for a Roadway Strata Management System

The basis of the plan is a clear understanding of the geotechnical environment. The approach includes the determination of (refer Figure 2):

- anticipated geological conditions, and their variation
- strength and material properties of strata about the roadway, and their variation
- in-situ and mining induced stress regimes
- roadway deformation and failure mechanisms including the position, magnitude and timing of failure of strata about the roadway
- quantification of the effect of confinement (reinforcement) on roadway behaviour

In practice, we are defining geotechnical environments that can be characterised by one or more triggers. Each environment will have a corresponding set of response guidelines that are implemented to alter reinforcement practices, mining practices or flag non-conformance of the design.

For example, Figure 3 details a roof displacement versus height of roof failure (softening) for a particular colliery. Each of the two curves represents a specific geotechnical environment (in this case a thick shale roof versus a sandstone roof section). The figure shows that for a given roof displacement, the height of roof failure can vary significantly and correspondingly the requirement for reinforcement.

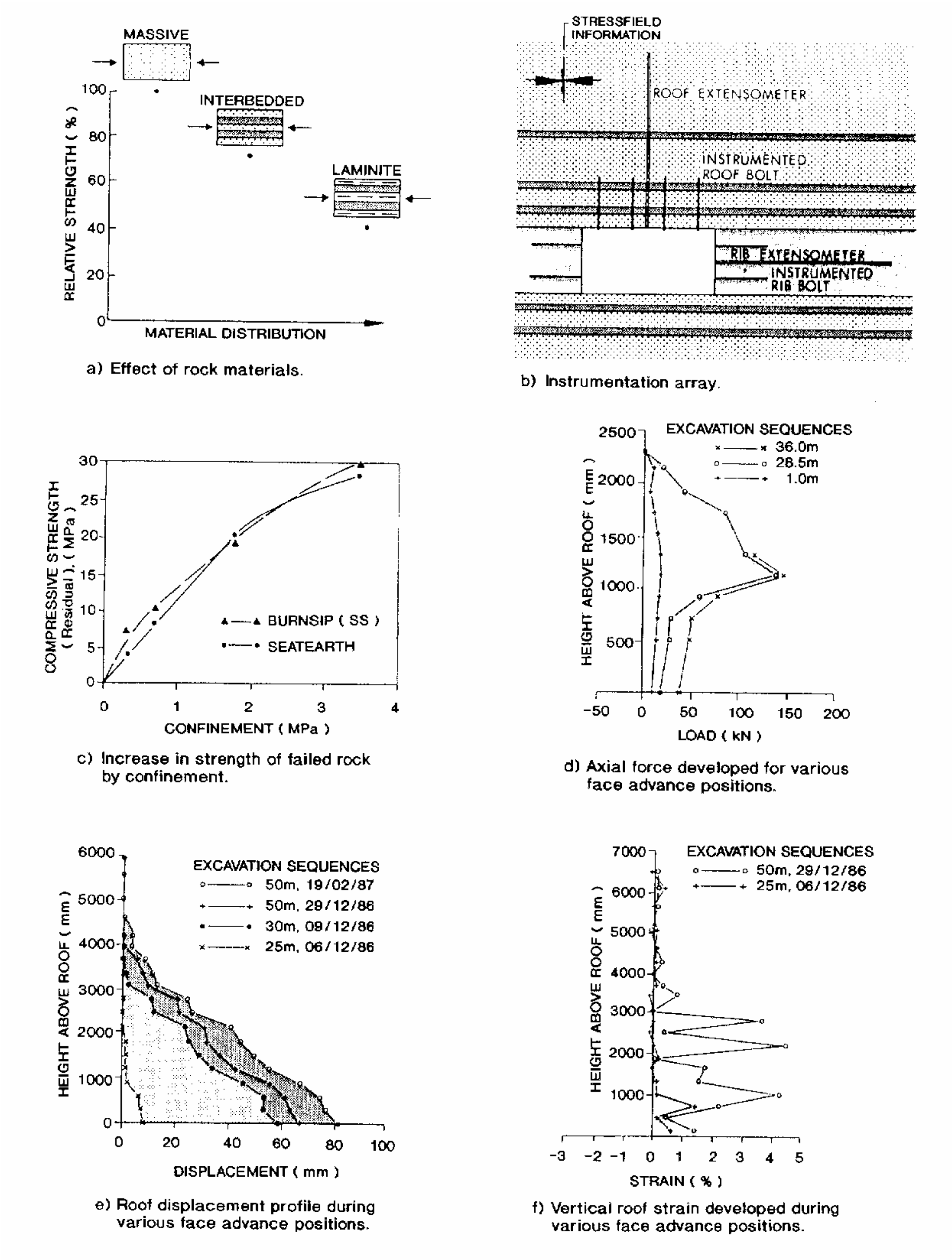


Fig. 2 – Summary of roadway reinforcement investigation monitoring methods.

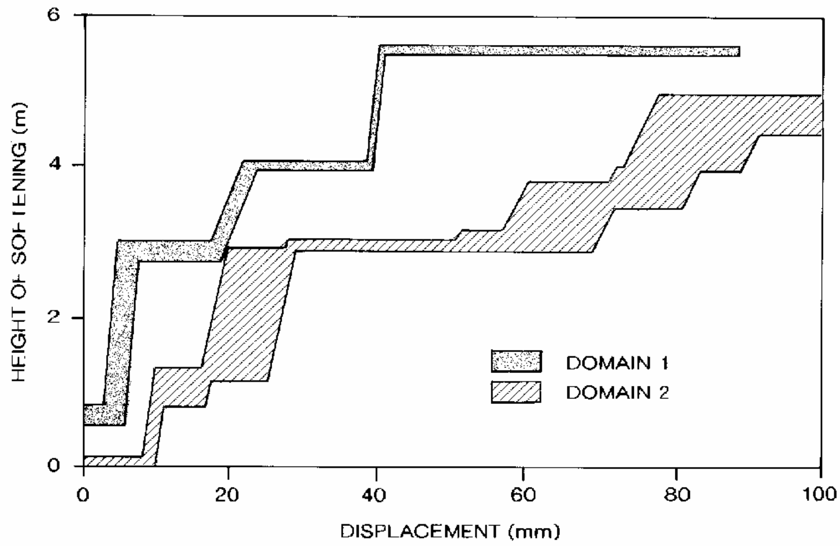


Fig. 3 – Summary of measured relationship between height of softening and roof displacement.

The establishment of the response guidelines is aided by the use of computer modelling to simulate roadway and reinforcement behaviour. This technique has been widely used by SCT in Australia and internationally to quantify trigger levels and provide a predictive tool to assess the behaviour of roadways to:

- changes in reinforcement design (bolt length, bolt density, bolt type)
- changes to mine design (entry width/height, roadway orientation, adjacent workings)
- changes in geotechnical environment

that may not be achieved through field based investigations or where no previous experience is available.

Key components of a Roadway Strata Management System

The framework for a roadway strata management system includes:

- the “document(s)”
- strata management team
- process of routine strata control assessment
- action and response guidelines
- process of review and authority
- strata control hazard plan
- database
- training

The Document

By default, the format of the plan will depend upon the document control procedures in place at the colliery. However, in essence there are two main areas of focus.

The routine assessment of roadway conditions, and the guidelines implemented in response to triggers, are the "engine" for the plan. They provide the dynamic assessment of conditions and enable appropriate responses to be made, such as changes to reinforcement design or mining practices (reduced/increased cut-out, mining horizon etc).

Supporting this process is the framework of authority and responsibility within the plan, mine and Coal Mines Regulation Act.

The Queensland Department of Mines and Energy approved standard for mine safety management plan outlines the following sections for inclusion in hazard management plans.

1. Introduction
2. Identified hazards
3. Control procedures
4. Roles and responsibilities
5. Resources required
6. Action response plans
7. Communications
8. Training
9. Corrective action
10. Review
11. Audit
12. Document Control

Strata Management Team

The development of a strata management team to facilitate the introduction and ongoing implementation of the plan ensures that regular reviews are conducted to ensure compliance with the plan, outstanding issues are addressed and forthcoming issues are highlighted.

Although difficult to quantify, the successful adoption of the plan requires ownership from all levels of the workforce. Experience from introducing strata management plans at various collieries suggests that representatives from all levels of the workforce form part of the strata management team.

Process of routine strata control assessment

To ensure that the appropriate methods, and areas, of assessment are being used to routinely monitor roadway stability requires the key design parameters to be clearly defined. As highlighted in Figure 1, detailed geotechnical investigations should be conducted prior to implementing the management system.

Routine assessment may include (but not be limited to):

- monitoring magnitude, and location, of roof displacement (selected horizons)
- monitoring the mining horizon
- monitoring roof lithology
- mapping of roadway conditions
- confirming the quality of installed reinforcement

To avoid subjectivity, and provide a rational basis for comparison, the use of visual indicators as triggers must be supplemented with measurement of the key design parameters.

Action and Response Guidelines

Directly linked to the routine assessment of roadway conditions are the action and response guidelines. Depending on the trigger levels, a series of responses will be implemented, typically by the production crew as directed by the deputy or undermanager.

Figure 4 details an example of how the action and response guidelines are implemented in practice, and highlights the levels of review that are conducted at all stages of a roadways use. Note that a similar structure would be used for gateroads during longwall retreat.

The action and response guidelines provide colliery management with the tool that can minimise the risks associated with identified hazards, but can also optimise mining practices.

For example, there are benefits to development productivity by maximising the cut-out distance, minimising the number of bolts or reducing bolt length. The only safe and rational way to introduce these measures is to identify which environments are appropriate for these measures.

Strata Control Hazard Plan

Systematic and ongoing evaluation of strata control hazards minimises their "unexpectedness". The Strata Control Hazard Plan should incorporate all known features that have the potential to effect roadway behaviour. The definition of these features forms part of the detailed geotechnical investigations conducted, initially, prior to the implementation of the management plan, but also on a regular basis as mining proceeds (as highlighted in Figure 1).

The plan should contain:

- identified geological features (faults, dykes, monoclines etc.)
- monitoring locations, type and information
- mapping of roadways to define roadway condition
- seam contours, overburden isopachs
- adjacent workings (in and out of seam)
- any features identified as a strata control hazard

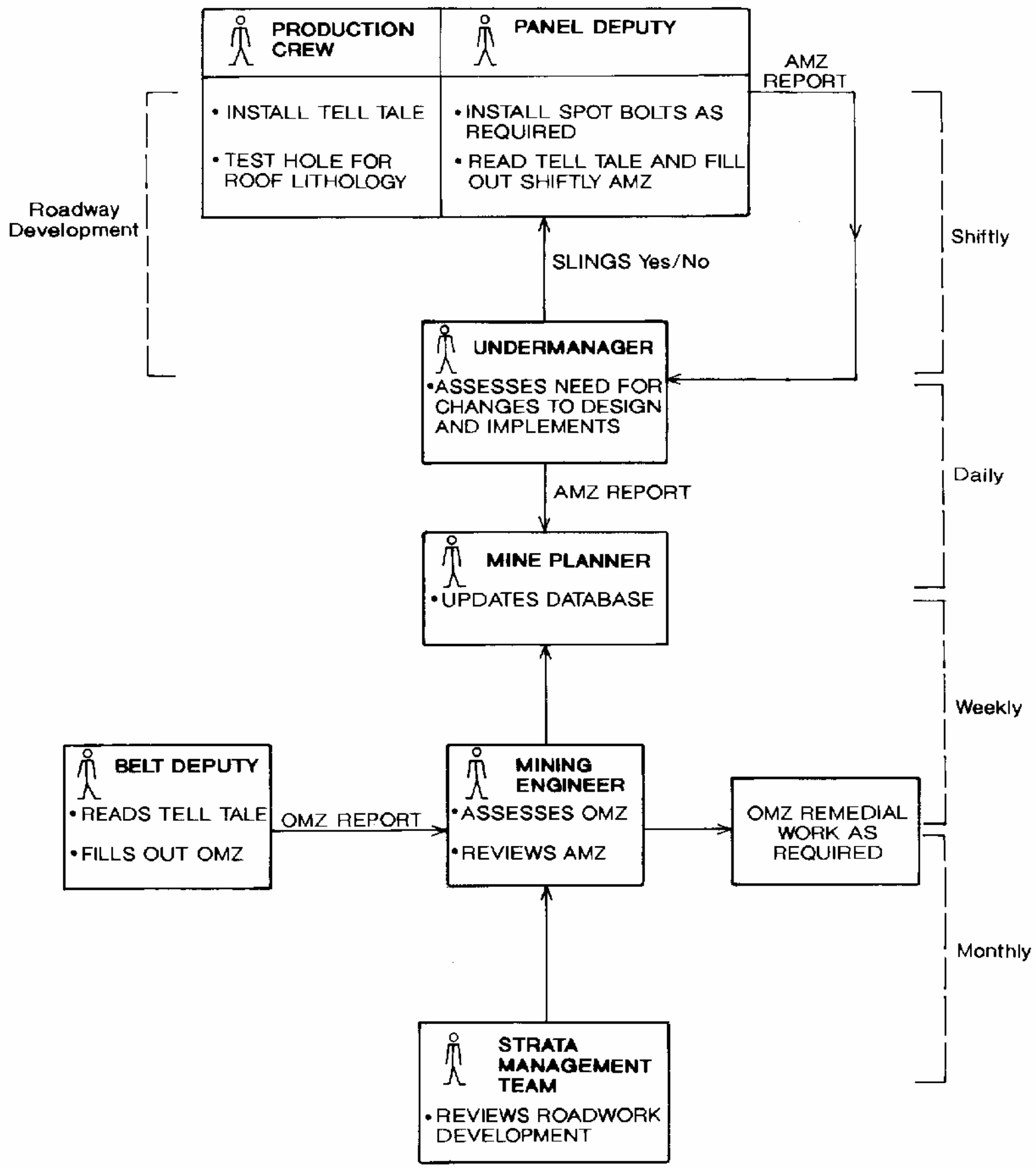


Fig. 4 – Example of responsibilities and reporting for a roadway strata management system.

The plan should form the basis for the periodic (typically monthly) strata management team meeting.

Database and Recording

SCT have developed an MS Access database that records all routine monitoring information including roof displacement, lithology and reinforcement practices. It enables ongoing assessment of the stability of roadways and can be used to flag deteriorating outbye roadways or longwall gateroads requiring secondary support prior to longwall retreat.

The system can be set up to enable production personnel direct access to monitoring information for their panel.

Training

The successful introduction of a Roadway Strata Management System requires that all sections of the workforce have ownership of the system. This is achieved by ensuring that all personnel are aware of their responsibilities and duties as outlined in the document, and are provided with the appropriate tools, training and infrastructure to carry out their duties.

Example of the use of a Roadway Strata Management System at Ulan Coal Mine

Ulan Coal Mines Limited operate surface and underground coal mining operations at Ulan, approximately fifty kilometres to the north-west of Mudgee in N.S.W. In 1997, the underground operation produced approximately 2.8 million raw tonnes from its one longwall and associated roadway development (JCB statistics).

Subsequent to a significant fall of ground in their main headings, Ulan Coal Mines Limited implemented a Roadway Strata Management Plan to routinely assess the stability of their roadways.

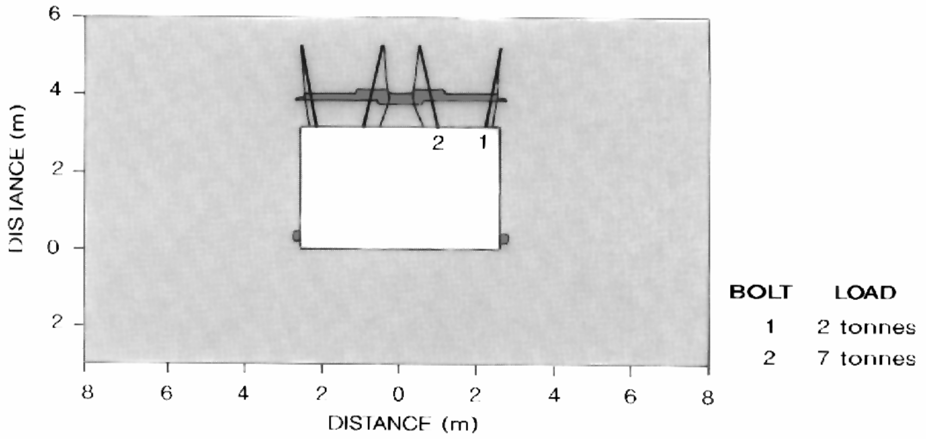
The trigger levels and response guidelines were established from detailed field investigations and numerical simulations conducted by SCT. It was found that:

- The magnitude of horizontal stress had increased by approximately 100% (based on measurement) in the area adjacent to the fall compared to the measured stress levels in outbye areas.

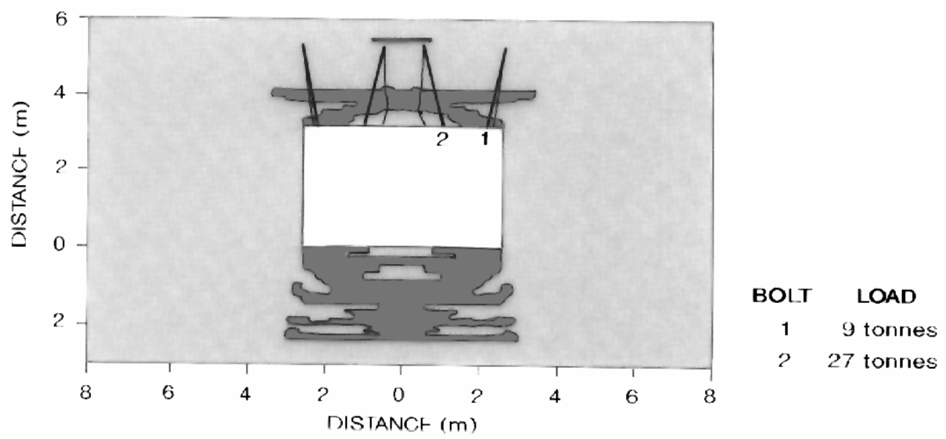
- The style, and extent, of roadway failure was a direct function of the magnitude of horizontal stress

- A failure pathway defined by the magnitude of roadway deformation and the height of failure into the roof was established based on the field work and numerical simulation

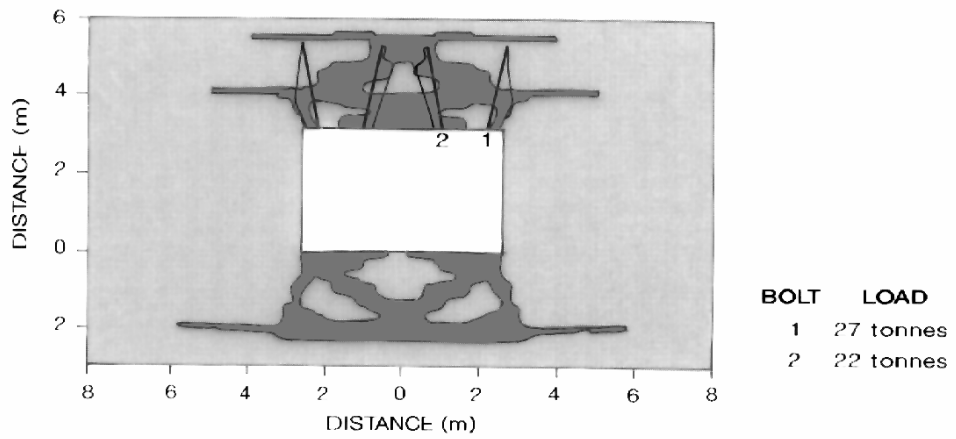
The use of numerical simulation of roadway and reinforcement behaviour provided an important tool to assess a matrix of modified bolting layouts, reinforcing products and geotechnical environments. An example of the use of numerical simulation at Ulan to quantify the style, location and pathway of strata failure and reinforcement performance is shown in Figure 5.



a) **Low horizontal stress (TSF = 0.7).**



b) **Moderate horizontal stress (TSF = 1.1).**



c) **High horizontal stress (TSF = 1.4).**

Fig. 5 – Softening expected about the roadway for various levels of horizontal stress using the modified 4 bolt pattern at Ulan Coal Mine.

A series of reinforcement designs were established for each environment, to be implemented depending upon roof displacement triggers. These were:

Roof Displacement Trigger	Reinforcement Design
< 15mm total movement	4 x 2.1m long bolts at nominal spacing
15mm-40mm total movement	6 x 2.1m long bolts at nominal spacing
> 40mm total roof movement	secondary reinforcement

In Practice

The intent of the Roadway Strata Management System is to provide ownership, and responsibility, to the production workforce. On a day to day basis, the monitoring, decision making process and implementation of changes is achieved by the underground workforce.

Production crews install Rock-IT dual height roadway monitors at the face that measure roof displacement in the bolted horizon and in the upper seam section (to 9m). The frequency and location of monitoring depends upon the panel layout, with up to one Rock-IT per intersection in the mains.

Each Rock-IT is given a unique identifier which is recorded adjacent to the monitor. The Panel Production Superintendent (PPS) records the readings on all Rock-IT's in their section on a dedicated sheet, which is handed to the undermanager at the end of shift.

An example of how the management system is utilised, highlighting the use of triggers to implement secondary reinforcement changes in a main heading intersection, is shown in Figure 6. The intersection was located two pillars inbye the significant fall of ground described previously.

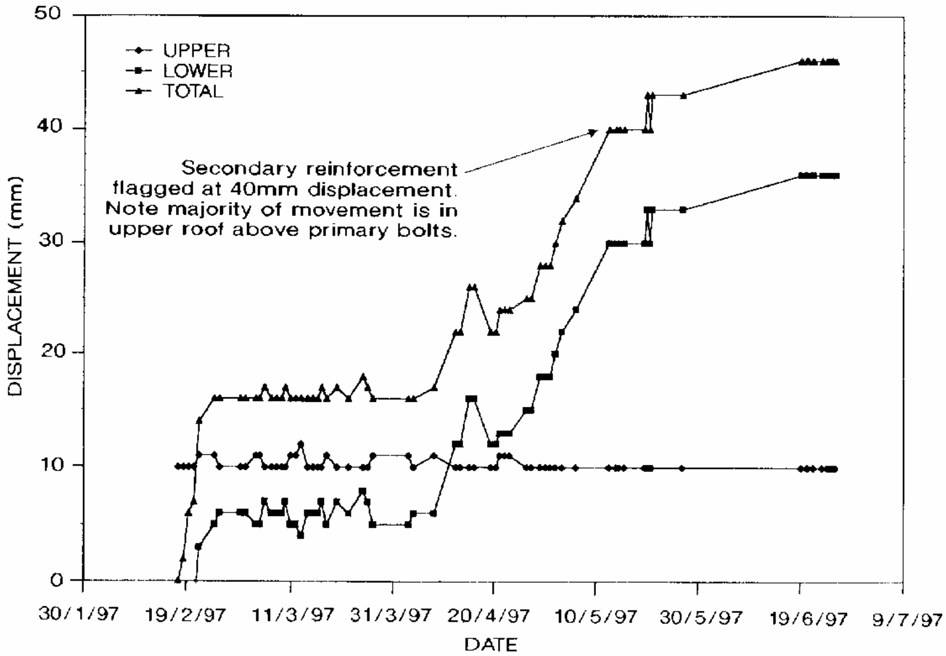


Fig. 6 – Rock-IT displacement versus time.

Conclusions

The systematic assessment of roadway stability by measurement of key design parameters is fundamental to ensuring appropriate levels of roadway stability are maintained.

Incorporating the assessment of roadway stability with predetermined response guidelines provides colliery management with the tool to rationally and safely optimise mining practices.

The use of a Roadway Strata Management System at Ulan Coal Mine has proven to successfully identify areas of roadway instability and provide rational guidelines for reinforcing the roadways.

Acknowledgments

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