2010

Managing the geotechnical aspects of longwall face recovery

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MANAGING THE GEOTECHNICAL ASPECTS OF LONGWALL FACE RECOVERY

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ABSTRACT: Longwall face recovery is almost certainly the most involved recurring geotechnical problem faced by operators, with major loss potential should problems occur. The outcomes of an industry sponsored (ACARP) research project on the geotechnical issues associated with conventional longwall recoveries is presented with updates the experiences gained.

A number of critical features of the geotechnical environment, support design and mining geometry have a pronounced impact on ground control during take-off. A model of roof behaviour at the take-off point has been developed and validated. Key geotechnical issues include low roof competency (ie weak roof), an adverse weighting environment, geological structure and horizontal stress concentrations at the gate ends (generally the maingate). All of these are identifiable either at the support design stage or, at worst, prior to the start of powered support removal, which is the critical stage of the take-off process.

Key aspects of the geometry and process are the ability to maintain powered support resistance during bolt-up and take-off, the direction in which the powered supports are removed, the impact of take-off chutes and the speed of the powered support removal process.

The author presents case studies that illustrate these issues and the associated ground behaviour.

THE ACARP PROJECT

Longwall face recovery is almost certainly the most involved recurring geotechnical problem faced by operators, with major loss potential should problems occur. However, unlike most geotechnical aspects of coal mining, very little research has historically been undertaken on the issue of conventional longwall recoveries. In 2006, Strata Engineering completed an ACARP-sponsored research project aimed at defining and minimising the geotechnical threats during take-off (Strata Engineering, 2006). The project had the overall objective of developing guidelines for the specification of ground control strategies, so as to minimise the likely geotechnical threats relating to the safety, operational costs and production delays associated with the recovery and relocation of a longwall face.

The project commenced with an industry survey of longwall relocation practice. The resulting database covered issues such as the geotechnical environment, support practices and ground control experiences, including any difficulties encountered. Fieldwork aimed at geotechnical characterisation covered a range of environments in NSW and Queensland, drawing also on existing data from a number of mines. Longwall take-off monitoring data was obtained from 24 face recoveries across all the major coalfields. The fieldwork identified a number of critical features of the geotechnical environment, support design and mining geometry that have a pronounced impact on ground control during take-off. A cantilever model of roof behaviour at the take-off point was developed and validated by the data collected. The roof cantilever acts to transfer load to the solid abutment, the primary support element.

Four parameters were identified as the main geotechnical hazards, namely:

i. low roof competency (ie weak roof),
ii. an adverse weighting environment,
iii. geological structure and
iv. horizontal stress concentrations at the gate ends in deeper mines (generally the maingate).

All of these are identifiable either at the support design stage or, at worst, prior to the start of powered support removal, which is the critical stage of the take-off process.

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Four aspects of the geometry and process were seen to be particularly significant, in terms of their impact on roof stability and the success of the overall operation, namely:

i. the ability to maintain powered support resistance during bolt-up and take-off,

ii. the direction in which the powered supports are removed,

iii. the impact of take-off chutes and

iv. the speed of the powered support removal process.

The general rule with regard to the geometry of the take-off face and overall process is that the preparation done prior to the start of powered support removal should result in a high degree of reliability in terms of roof control, minimising the likelihood of subsequent difficulty and delay during the shield removal phase. The benefits of a relatively modest amount of preparation (eg in terms of floor repairs or concreting, roof cabling, cavity remediation and shield canopy contact) greatly outweigh the time and costs involved and moreover are dwarfed by the costs related to any remedial support action that inadequate preparation might subsequently necessitate (never mind the associated delays).

Several distinct ground control difficulties were identified by the project, namely goaf tightening / ingress, roof sag and cavity formation in the tip-to-face area. Although often related, the means of addressing these issues can vary (eg regarding the chock removal sequence). In recent years, the application of cables has become common in reactively managing areas of deterioration, as well as pro-actively reinforcing zones of identified potential difficulty.

A number of visual and quantitative triggers can be used to guide strata management. Again, the focus must be on maximising the likelihood of success prior to chock removal, rather than modifying the support and/or process in response to subsequent difficulties. Visual indicators include face breaks, cavities, guttering, rib spall, powered support loading, tendon loading (bolts and cables), as well as difficulties with tendon installation or tensioning. Quantified triggers relate primarily to creep rates and evidence of beam breakdown; guidelines were developed by the project with regard to the likely impact of various creep rates, in the critical period prior to the start of powered support removal.

The project formulated a support design process that provides a framework for managing the geotechnical threats in a pro-active manner, including a mechanism for quantifying support (bolt and cable) requirements. Software developed as part of the ACARP project aids this process, enabling alternative options to be identified and rationalised.

THE DESIGN PROCESS

The following summarises the design process applied by Strata Engineering for initial roof support design on the longwall take-off face:

i. Characterise roof competency in the take-off area, specifically in terms of Coal Mine Roof Rating (ie CMRR).

ii. Utilising CMRR and the key geometrical parameters of longwall face width and depth, apply the design equations provided in the ACARP project report to derive an indicative appropriate roof support density (Reinforcement Density Index or "RDI"). Unless quantified local experience suggests otherwise, a minimum probability of success of 0.99 is set (implying a high degree of support system reliability in the tip-to-face area). The software developed during the ACARP project assists in the derivation of RDI.

iii. Using the RDI as input, derive a practical bolting pattern, taking into consideration operational requirements. Typically:

   a. The final tip-to-face distance should be limited to a maximum of 3m (even allowing for the practice of staggering chock positions).

   b. The zone of bolted roof should extend from the final face to within 1m of the rear of the canopies, which typically implies a minimum of seven rows of bolts.

   c. The roof bolts in the tip-to-face area (at least) should be X grade steel.

   d. The bolt density in the tip-to-face area should be ≥ 1 bolt / m^2.

iv. If the roof is weak (ie a CMRR of <45), the support design should almost certainly incorporate systematic cabling in the final tip-to-face area. The overall design RDI should again be used to derive the appropriate cable density. Cables should generally be:

- at least 6m long,
- configured to anchor outside of the likely roof failure zone and
- post-grouted at least 24 hours prior to the start of powered support removal using a high strength thixotropic grout.

v. Specific cable designs should be developed for intersections, including chutes, taking into consideration actual gate road roof behaviour under conditions of longwall extraction, the strategic importance of the excavations involved and the required machine movements (eg setting up of buttress chocks at the tailgate intersection).

vi. Specific secondary roof support designs should also be provisionally developed for expected or known areas of geological structure.

vii. Polyester roof mesh (or "geogrid") should be employed, with a heavy grade (ie ≥ 60t capacity) suggested from the rear of the canopies to the face (ie for the control of both goaf flushing and the tip-to-face area).

viii. The buttress or walker chock configuration should be determined with due regard to the geometry of the powered supports and the take-off area as a whole (eg support length and final tip-to-face distance), taking into consideration local experience. Configurations involving three walker chocks are particularly susceptible to goaf side sag and require specific consideration of the support design above the canopies of the line chocks; often this involves additional cabling.

ix. The design of standing support for goaf edge takes into consideration local experiences and operational preferences, captured and formalised in some form of trigger-response plan ("TARP").

During the actual take-off, this preliminary design should be ratified or refined with the aid of the following:

i. A review of powered support leg pressure monitoring on the approach to take-off, to identify any cyclic loading and to define zones of distinct loading along the face (eg heavier conditions towards mid-face).

ii. Mapping to identify and / or confirm geological structures, areas of adverse roof behaviour (eg cavities or face breaks) and geometrical issues (eg horizon errors, floor steps and poor canopy contact).

iii. Roof monitoring to determine the ongoing rate of displacement (ie creep) and any signs of cantilever breakdown.

iv. A review of anticipated versus actual conditions prior to the commencement of powered support removal and the implementation of tertiary support if necessary (eg at geological structures and cavity areas).

v. A formalised trigger-response plan.

Finally, the documented LW recovery outcomes, both from an operational and geotechnical perspective, should be reviewed and used to refine future practice.

RECENT EXPERIENCES

Since the ACARP project was completed at the end of 2006, Strata Engineering has extended the original database to over 30 mines in Australia and overseas, including over 100 monitored case studies. The expanded database is currently being analysed, with the primary aim of re-assessing the impact of face height and width, as well as the significance of powered support capacity / design and the role of standing support. Future longwall recovery practice must take cognisance of the trend towards wider faces with larger powered supports, as well as increasing depth at some mines.

Of the outstanding issues flagged by the ACARP project report, the appropriateness and use of buttress / walker chocks remains topical. The most common operational difficulty related to ground control on a take-off face is the inability to advance the buttress chocks, due to roof deformation (ie sag, particularly on the goaf side). Goaf side tightening and sag are only issues in the context of the need to be able to continually advance the buttress chocks; without the buttress chocks, the practical impacts of the ground movement would be materially reduced, if not insignificant. This is particularly the case given trends with regard to improved support products (eg stronger mesh and higher roof support densities, including more routine use of cables). In this regard, the few mines which continue to employ systems based on standing support only tend to have a significant advantage, in that in heavy conditions it is usually a simple matter to increase the quantity of support at the goaf edge and continue with chock removal.

This problem can be exacerbated by the use of three as opposed to two buttress chocks. The use of three buttress chocks requires particular attention to roof and goaf edge control in the vicinity of the goaf side buttress chocks; this often involves cabling towards the rear of the canopies. It is sometimes possible to achieve adequate roof control in difficult ground conditions in the tip-to-face area, but still have ongoing problems with goaf side sag. The potential for deterioration on the goaf side during powered support removal is increased in the event of adverse weighting or presence of geological structure, noting that the slow rate of retreat during bolt-up tends to exacerbate the associated impacts.

A second issue flagged by the ACARP project was an increasing interest in the use of pre-driven recovery roads. Since that time, a number of pre-driven recovery roads have been successfully utilised in relatively aggressive ground conditions and difficult circumstances, demonstrating that a reliable methodology does exist (Thomas, 2008). Some of the issues often flagged as specific hazards with regard to pre-driven roadways are also factors influencing the success of conventional recoveries; examples include an adverse weighting environment and weak roof. The relativities of the risks associated with the two methodologies should be appraised on a mine specific basis, with equivalent levels of scrutiny. Along with the increased use of full pre-driven recovery roads in recent years has come a greater interest in the use of partial face-parallel stubs. Relatively short (ie 20m to 60m long) stubs driven along the stop line at either the maingate or tailgate end of the face exploit the protected ends of the face (with locally reduced weighting potential) and offer a number of operational advantages, primarily the removal of a significant portion of the bolt-up task from the critical path of the recovery process. The time required for bolt-up is becoming an increasingly significant issue with the trend to wider longwall faces.

CONCLUSIONS

Future recovery practice must take cognisance of the trend towards wider longwall faces and larger powered supports, as well as increasing depth at some mines. The result will tend to be increased densities of tendon support and a need to review the overall longwall recovery process. The ACARP project provided a rationale for addressing the related geotechnical issues and support design; this foundation is now being updated as a wider range of experiences becomes available.

The challenges presented by the abovementioned operational trends increase the emphasis on finding effective solutions, with a focus on the more efficient use of support elements, as well as strategies to limit the time associated with bolt-up and subsequent shield removal.

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