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Barrier and Chain Pillar Design Research Outcomes: Angus Place Colliery

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Summary A case study is presented which applies the results of pillar design research initiatives at The University of New South Wales. Angus Place Colliery in NSW operates a longwall mining system within a relatively hostile geotechnical environment of high lateral stresses and stratified weak strata surrounding the coal seam. Two major issues presented themselves as the mine commenced development into a new area of the lease. These were:

1. The design of a barrier pillar between the main development panel and flooded old mine workings.
2. The design of the future chain pillars between each successive longwall block.

The design study has been undertaken using a combination of two and three-dimensional numerical modelling, plus an empirically-based analytical procedure for pillar design. The paper presents the design approach, the pillar performance criteria determined in consultation with the mine, the methodology and outcomes with respect to the anticipated mining conditions.

1. INTRODUCTION

1.1 Pillar Design Research

The School of Mining Engineering at the University of New South Wales (UNSW) has undertaken a major program of applied research into underground coal mine pillar design since 1993.

This work has led to the adoption of sound, statistically based analytical design techniques for determining coal pillar strength (Galvin et al, 1996, Salamon et al, 1998) resulting in significant mine safety and design benefits acknowledged by the coal mining industry in Australia.

More recent research work has focussed on the application of these outcomes and subsequent investigations to the design of barrier and chain pillars in underground coal mines (Galvin & Hebblewhite, 1996). In this application, the pillars fulfill dual roles of:

- (a) requiring stability to support overlying strata load
- (b) providing sufficient width to protect adjacent mine workings from abutment stress effects, water inflow, etc.

This paper presents the design procedures developed through this ongoing research program by way of a case study based on actual design requirements for a new mining area at Angus Place Colliery.

1.2 Angus Place Colliery

Angus Place Colliery is owned and operated by Powercoal Pty. Limited in the Western Coalfields of NSW, near Lithgow, approximately 150km west of Sydney. It mines the Lithgow Seam to provide thermal coal to two nearby domestic power stations.

The Lithgow Seam is mined at varying heights from 2.7m to 3.0m. Coal, containing interbedded coal, mudstone and claystone bands forms the immediate roof. The floor is a carbonaceous mudstone, underlain by a weak sandstone.

Figure 1 shows a typical Angus Place geological section. Angus Place Colliery was developed in the early 1980's as an extension to the old Newcom Colliery (also referred to as the old Kerosene Vale Workings, which are now sealed and flooded). Mining depths vary considerable due to the surface topography, which includes vertical cliff lines and escarpments, plateaux and river valleys.

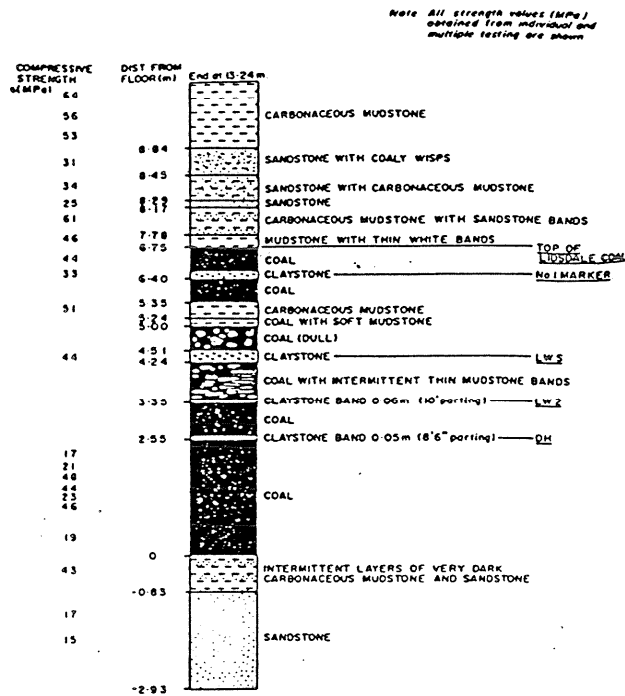


Figure 1. Generalised Angus Place log (after Shepherd & Temby, 1997).

Initial workings were under less than 100m depth of cover, whereas current and proposed mining areas are under 240m to 380m depth of cover.

The pre-mining virgin stress field at Angus Place varies considerably in magnitude and direction and is particularly influenced by geological structure, which dominates the lease and impacts severely on mining conditions.

For design purposes, a horizontal to vertical stress ratio of 2:1 has been used for the major principal horizontal stress, with values (depending on location) of:

Major Horizontal Stress	-	14.2-19.2MPa
Minor Horizontal Stress	-	7.1-9.6MPa
Vertical Stress	-	7.1-9.6MPa

Exploration borecore geomechanical test results were used to provide the rock property data required for numerical modelling.

2. SCOPE AND METHODOLOGY

The scope of work for the design study was to:

1. Develop a geotechnical design for a barrier pillar to be located between the Southern Area development beyond 303 Panel (South Mains) and old Kerosene Vale workings (Newcom Colliery).

2. To provide geotechnical advice with respect to chain pillar widths in the new Southern Development Area longwalls.

Figure 2 is an extract from a mine plan of Angus Place Colliery.

The extract shows the Old Kerosene Vale workings on the western side, the current workings including 303 Panel and a possible future mine layout for the proposed new development area.

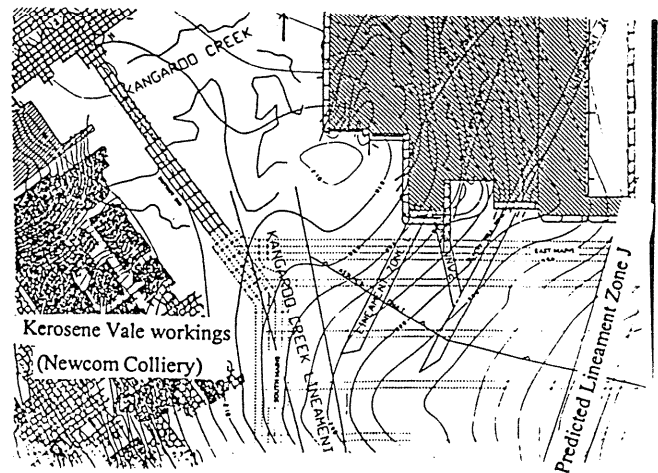


Figure 2. Future longwall plan.

The following methodology was established for the above scope of work:

- Underground inspection of mining conditions in the closest current point of access to the proposal pillars and panels (303 Panel)
- Development of pillar performance criteria in conjunction with Angus Place staff (this should include clear statements of required pillar functions, life expectancy, limiting acceptable levels of critical design parameters such as abutment stress levels, stability Factor of Safety (FOS) levels, minimum and maximum widths for other non-geotechnical purposes)
- Collation of available geotechnical data including stress levels, stratigraphic and rock property data for surrounding strata
- Two and three dimensional numerical stress analysis of the two pillar geometries under investigation, including parametric studies of a range of differing pillar widths, as appropriate
- Analysis and interpretation of outcomes for all above steps, together with appropriate analytical methodologies, in order to formulate recommended barrier and chain pillar dimensions.

3. PILLAR PERFORMANCE CRITERIA

In discussions with colliery staff, the following pillar performance criteria were specified. (Tables 1 and 2).

Table 1. South Mains – Old Kerosene Vale Workings Barrier.

Lifecycle Requirement of Pillar	Life of mine, ie. approximately 20 years
Pillar Function:	1. To prevent water, gas and air connection (or even pressure leakage) across barrier
	2. To provide stable, load-bearing regional support for overburden
	3. To prevent excessive abutment stress interaction on South Mains headings
Performance Criteria:	1. Catastrophic collapse or interconnection, pillar yield or other strata breakdown across width of barrier must be prevented
	2. Pillar must have stable core
	3. Quantity and rate of water seepage into headings on development should not exceed current face levels in 303 Panel
	4. Minimal abutment stresses can be tolerated in flank roads of South Mains, with the use of secondary support in close proximity region to old workings, however stability must not be compromised, even in a single heading. Cannot afford to lose this return airway.

Table 2. Future longwall chain pillars.

Lifecycle Requirement of Pillar	Duration of development and extraction of both adjacent panels. This could be up to 5 years due to block lengths of 3.4km
Pillar Function	1. To provide stable pillars until at least second longwall face has passed
	2. To provide adequate pillar width to separate gateroads so that travelling road and tailgate are outside influence of excessive side abutment pressures from adjacent goaf
Performance Criteria	1. Pillars must retain stable, confined core without interaction of opposite yield zones, at least until second longwall face has passed
	2. Excessive abutment stress on travelling road (future tailgate) must be avoided

4. NUMERICAL MODELLING

The design approach taken in this investigation was to investigate the planned dimensions for each pillar system and then evaluate sensitivity to variation in pillar dimensions as appropriate.

The methodology was to use a three-dimensional stress analysis package, MAP3D Version 38 (Mine Modelling, 1998). It was important to look at the overall layout of each pillar system in three dimensions, given the irregularity of some aspects of the mining geometry and the consequent variations in loading regime applied to the pillars. Sensitivity studies on width variation were then conducted using a two-dimensional program, FLAC Version 3.3 (2D), (Itasca, 1995).

Analysis of the results was undertaken, taking into account the outputs from the numerical stress analysis, the known conditions underground and other empirical pillar design approaches, specifically the UNSW Pillar Design Procedure (Galvin & Hebblewhite, 1995). (Note that the number of separate analyses undertaken in this design study was far too extensive to report individually in this paper, however the outcomes have been descriptively presented with sample graphic output, as appropriate).

The design study was focussed on regional stability and stress distribution across large areas rather than localised strata behaviour. For this reason, and, in view of the complexity of the geometries modelled, the three-dimensional MAP3D analyses were conducted using uniform roof and floor strata properties and an elastic solution only. Whilst this simplification may impact on localised stress distribution and potential failure around excavation boundaries, the regional stress distribution across pillars would not be compromised significantly by this approach.

The two-dimensional FLAC analyses allowed for geological variation to be represented with non-linearity of material behaviour modelled using an elastic - perfectly plastic constitutive model and Mohr-Coulomb failure criterion (ie. yielding and potential failure of mesh elements). This was particularly relevant for investigating excavation (gateroad) stability.

5. BARRIER PILLAR RESULTS

The critical geotechnical design issue for this barrier clearly relates to the small region of the old workings where a goaf of approximately 50m x 60m dimensions extends much closer to the proposed South Mains development. This minimum barrier width is approximately 55m on current plans.

7. CONCLUSIONS

The UNSW Pillar Design Procedure provides a sound, empirically based means of determining in-situ coal pillar strengths and a set of design procedures based on risk and probability of pillar failure.

In complex mining geometries, such as barrier and chain pillars, the determination of pillar load requires the use of numerical analysis.

Furthermore, pillar stability is only one component of the pillar design process. Other considerations, such as pillar width to provide separation and protection from abutment stresses can become dominant.

The Angus Place case study presented in this paper demonstrates the outcomes of the ongoing UNSW pillar design research, highlighting the combined use of numerical and analytical techniques.

8. REFERENCES

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