Back-analysis of roof conditions in the Great Northern Seam, Newcastle Coal Measures, Australia, using voussoir beam theory

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Summary

A typical roof profile for mine openings in the Great Northern Seam consists of a thin coal layer and several metres of claystone. From field evidence and shear flow analysis, the anchorage of fully grouted roof bolts in the claystone may fail. If so, the claystone may act as an extra load on the coal beam. Using voussoir beam theory, the relation between the minimum thickness of the coal beam, the thickness of the failed claystone and the width of the entry has been determined. The analysis is satisfactory for field performance observed in a number of case studies. Proposals are made on possible improvements to mining techniques.

Keywords: Coal; underground mining; roof stability; claystone; voussoir beams.

Introduction

Voussoir beam theory assumes that a roof beam consists of a no-tension material and that it can carry its own weight by arching. Its use for the design of mine roofs was advocated by Evans (1941). Beer and Meek (1982) improved and extended this early work and presented design curves suitable for metalliferous mining applications. Brady and Brown (1985) devised a simple iterative procedure which allows a wider use of voussoir beam theory. This paper discusses the use of this procedure to develop design curves for coal mining applications and uses published data to back-analyse roof instability in the Great Northern Seam of the Newcastle Coal Measures, Australia.

Voussoir beam theory and development of design curves

The techniques used to produce the design curves are based on the iterative procedure of Brady and Brown (1985) to which the reader is referred for a detailed discussion on the formulation of...
the voussoir deformation of a roof bed is made possible by the application of a relaxation method. Span, thickness, density and deformation modulus are entered into a simple program, an initial load distribution is assumed and iterations are continued until a minimum value for ‘maximum longitudinal stress’ is obtained. A listing of the program (in BASIC language) is given in Appendix 1.

A voussoir beam may fail in three ways. For a beam of low span: thickness ratio failure will tend to occur by shear at the abutments; for high span: thickness ratios buckling of the beam may occur. For rocks of low strength, compressive failure of the central or abutment voussoirs may occur at intermediate span: thickness ratios. The possibility of shear and compressive failure can be readily assessed by comparing the equilibrium distribution of stresses in the beam with the shear and compressive strength of the material in question. This is done within the program (Appendix 1). Buckling is indicated when the thickness of the arch exceeds the beam thickness or the arch height drops to zero.

To generate the curves, a series of beam thicknesses were examined for spans of 3.0, 5.5, 7.5, 10.0, 15.0, and 20.0 m until the required factors of safety (i.e. 1.0 and 1.2) against shear and compression were obtained. The onset of buckling was allocated a factor of safety of 1.0 and to obtain points for a factor of safety against buckling of 1.2, the ‘maximum longitudinal stress’ developed in the beam at the onset of buckling was divided by 1.2 and a search for the beam thickness with this longitudinal stress conducted. Lines of best fit were drawn through the data points. For the parameters used the factors of safety against compressive failure were all high. The analysis assumed plane strain conditions and no high lateral stresses.

**Roof conditions in the Great Northern Seam**

The presence of a thick claystone horizon in the immediate roof has severely limited the economic development of large portions of the Great Northern Seam in Monmorah, Newvale, Newvale No. 2, Wyee, Chain Valley, and Wallarah Collieries. When the claystone is less than about 0.5 m thick it can be cut down with the coal and a stable roof formed at the base of an overlying conglomerate. With greater thicknesses of claystone, the practice has been to leave a thin coal beam in the roof to support the claystone and isolate it from humid mine air. Roof support/reinforcement typically consists of five chemically anchored bolts and ‘W’ straps. The need to install this support close to the face has resulted in uneconomic production rates.

Lithologically, the roof of the Great Northern Seam varies from conglomerate (Terelba Conglomerate) to claystone. The conglomerate is believed to represent an infilled channel that eroded down into the claystone and in some areas into the coal-forming peat. The conglomerate itself forms a good roof but as mining progresses away from the margin of the conglomerate roof stability decreases as the claystone thickens. One cause of this instability may be the presence of unstable blocks of claystone formed by intersecting joint surfaces and slickensides that are often developed beneath and adjacent to channel margins (Moebs and Curth, 1976).

A typical roof profile in the presence of claystone consists of about 0.5 m of coal overlain by several metres of claystone and a very thick (10–30 m) conglomerate (Fig. 1). The coal and the claystone have similar deformation moduli (Table 1) but because of its lesser thickness the coal would tend to sag to a greater degree (Fig. 1b). Roof bolting should hold the claystone and the