A STUDY OF FLOOR HEAVE IN THE MINES OF THE SOUTHERN COALFIELD OF NEW SOUTH WALES BY TWO DIMENSIONAL FINITE ELEMENT MODELLING

By

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ABSTRACT

The excessive displacement of the seam floor in headings (i.e. roadways) called 'floor-heave' is often experienced in the underground mines of the Southern Coalfield of New South Wales. Apart from interfering with the mining operations, the phenomenon could be detrimental to the stability of the pillars left for support leading to an unpredictable increase in the subsidence of the overlying strata. The latter could pose a serious problem, particularly in the design of partial extraction layouts of mining for areas where subsidence is to be controlled.

The susceptibility of the floor of different rock materials and thicknesses in a given 'panel and pillar' partial extraction geometry was examined by two-dimensional Finite Element Modelling of the displacements, stresses and failure zones around the excavations. The modelling, assuming elastic behaviour of the materials, indicated that the maximum vertical displacements of the floor increased substantially as the Young's Modulus of the material decreased to less than 7GPa and the thickness of the layer increased.

The results also discount the possibility of a properly designed panel and pillar geometry in the Southern Coalfield of New South Wales being unable to adequately control surface subsidence through the pillar, or its core independently of the yielded ribs, penetrating the floor.

INTRODUCTION

The phenomenon of 'floor heave' (i.e. excessive uplift of the floor) in headings (i.e. roadways) in underground coal mines is often encountered in the Southern Coalfield of New South Wales and elsewhere. Such heave is usually associated with soft floor strata like shales and clayey sandstones (Ainge et al., 1958) and high horizontal stresses (Peng, 1978). It tends to impede the operational activities and may necessitate costly and inconvenient re-excavation of the floor.

The floor heave may be caused by the adjoining pillars under load either, punching into or, squeezing out the floor material. The squeezing out of the floor from underneath a pillar exerts an outward pull through friction at the base of the pillar, leading to increasing rib spall and sometimes even failure of the pillar. Morgan et al. (1965) observed that floor heave up to a certain degree may improve the stability of a heading, but beyond that can lead to roof failure or structural collapse. In addition to the localized effects, the unpredictable vertical lowering of a pillar through floor heave may have undesirable consequences e.g. prevent the reliable design of 'panel and pillar' layouts of partial extraction for restricting the subsidence effects on the undermined strata.

This paper presents an investigation, by two-dimensional Finite Element Modelling, of the circumstances which may give rise to floor heave in a given panel and pillar layout, which may otherwise be appropriate for controlling surface subsidence.

FINITE ELEMENT MODELLING PROGRAM

The two-dimensional Finite Element Modelling program of Zienkiewicz (1977) as modified by Yestes (1977) was used in the study. The two-dimensional mesh was composed of 1022 constant strain triangular elements linked by 533 nodes. The elements represented continuous, isotropic, elastic media. The elements signifying excavations were assigned zero strength values.

The modifications to the program carried out by Yestes facilitated the representation of the unfaulted nature of coal measure rocks, typical rectangular cross-sections of excavations, vertical stress relating to the depth of cover and presence of high horizontal stress. The program also included criteria for failure of rocks in shear, based on specified Coulomb-Navier envelopes and in tension, based on specified strength.

In the modelling, the loads assumed to act at the nodes on the perimeters of excavations in the mesh were determined assuming to the 'relief method' described by Kuliwany (1974). This method was considered appropriate by Yestes, because it was equivalent to the creation of the excavation within a stressed medium.

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The results obtained from the modelling were the patterns of stresses, displacements and zones of failure around the given excavations.

**BOUNDARY CONDITIONS**

Of the outer boundaries of the mesh (excluding the perimeter of the modelled panel), those orientated vertically were free to move in the vertical direction and those orientated horizontally were free to move in the horizontal direction.

**MODELLING GEOMETRY**

A transverse vertical cross-section showing a symmetrical half of a panel and pillar geometry shown in Figure 1, was modelled in this study.

![Figure 1 Dimensions of the half mesh used during modelling](image)

**HORIZONTAL DIMENSIONS**

The widths of the completely extracted panel and the adjacent pillar on one side were respectively 0.3H and 0.19H, H being the depth of the extracted geometry from the surface. The chosen widths were as suggested by Wilson (1982) for the design of 'panel and pillar' geometries to reduce the subsidence of overlying strata. Assuming the workings to be in the Southern Coal Field of New South Wales at a depth of 400m below the surface, the symmetrical half-widths of the panel and pillar were thus, 60m and 30m respectively.

**VERTICAL DIMENSIONS**

Again, according to Wilson and Ashwin (1972), the caving height above a panel is about 2-3 times the extracted height of the seam. Accordingly, assuming an extracted seam height of 2.6m, the height of roof strata represented in the modelling was taken as 13.6m. In the absence of any other relevant information, the depth of the floor strata represented in the modelling was also taken as 13.6m.

Thus, the two-dimensional mesh used in the modelling represented a cross-section for strata of height 29.2m (including the 2.4m coal seam) and width 90m.

**MODELLING STRATA**

The strata considered in the modelling were the coal seam and its immediate roof and floor. The pillar was assumed to be in the Bauli coal seam, alternatively with or without a peripheral yield zone. The depth of the yield zone was considered to be 6m, based on observations by Senoviratne (1986). The required values of the deformational parameters of the strata considered in the modelling were their respective Young's Modulus, Poisson's Ratio, tensile strength, cohesion and angle of friction.

The mechanical properties of the coal and the alternative rock types considered to form the roof or floor of the seam are given in Table 1. The respective sources for those properties are: intact and yielded coal (Jagger, 1974), shale 1 (Yeas, 1977), shale 2 (Jagger, 1974), mudstone (Richmond and Smith, 1976) and sandstone (Jagger, 1974). Shale 'X' is a hypothetical rock with properties in between those of shale 1 and shale 2.

<table>
<thead>
<tr>
<th>ROCK MATERIAL</th>
<th>MOONEY MODULUS</th>
<th>SHEAR MODULUS</th>
<th>TENSILE</th>
<th>COHESION</th>
<th>ANGLE OF FRICTION</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>COAL</strong></td>
<td>12.0</td>
<td>1.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>SHALE 1</strong></td>
<td>2.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
<td>0.5</td>
</tr>
<tr>
<td><strong>SHALE 2</strong></td>
<td>1.0</td>
<td>0.1</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>MUDSTONE</strong></td>
<td>0.5</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>SANDSTONE</strong></td>
<td>20.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
<td>2.0</td>
</tr>
</tbody>
</table>

**MODELLING THE BEHAVIOUR OF THE STRATA AROUND THE PANEL AND PILLAR GEOMETRY**

The basic aspects modelled were the maximum vertical displacements of the roof and floor, the maximum horizontal displacements of the rib (i.e. pillar) side and the cross-sectional areas of the zones of failed rock in the roof and floor. The following different conditions were considered in the modelling:

(i) The coal pillar without or with a peripheral yield zone to a depth of 6m, sandstone roof 13.6m thick and (the weakest material i.e.) shale 1 floor of alternative thicknesses 1.3m, 3.3m, 7m and 13.6m overlying the same type of sandstone.

The purpose of this part of the modelling was to determine the effect of peripheral yielding in the coal pillar on the modelled aspects.

(ii) The coal pillar without a peripheral yield zone, sandstone roof 13.6m thick and the immediate floor of 1.3m, 3.3m, 7m or 13.6m thickness of the alternative rock types shale 2, shale 'X' or mudstone, again overlying sandstone.

The purpose of this part of the modelling was to demonstrate the effect of the increase in thickness of a given floor stratum on its strength on the modelled aspects.

11th International Conference on Ground Control in Mining, The University of Wollongong, N.S.W., July 1982.
(iii) The coal pillar without a peripheral yield zone, shale 1 roof to depths of 1.3m, 3.3m, 7m and 13.6m with sandstone beyond and shale 1 floor to 13.6m depth.

The purpose of this part of the modelling was to determine the effect of a shale roof (instead of sandstone) of variable thickness on the modelled aspects.

ASSUMPTIONS IN THE MODELING

The modelling was based on the following assumptions:

i) The considered rock materials deformed elastically.

ii) The principal stresses in the modelled cross-section of stope were vertical and horizontal. The vertical stress at the assumed depth of 400m was taken as 10MPa. The horizontal stress, suggested by Richmond and Smith (1979) to be typically twice the magnitude of the vertical stress in the coalfields of New South Wales, was taken as 20MPa.

iii) After the mining of the panel, the possible caving of roof and the subsequent reconsolidation was ignored.

iv) The resistance from the supports in the roadways or at the face of the panel during extraction was ignored.

RESULTS

The results from the modelling are summarised in Tables 2 (A),(B),(C) and 3, as well as Figures 2 and 3.

Effects of the variation of the immediate floor rock type and its thickness

For any given rock type forming the immediate floor, the maximum vertical displacement of the later increased with the thickness of the stratum. The rate of such increase however, was much greater for shale 1 in the floor compared to the other rock types.

The variations in the floor rock type and its thickness did not cause any change in the vertical displacement of the 13.6m thick sandstone roof.

The maximum horizontal displacement of the coal rib increased only slightly with the decrease in strength of the immediate floor stratum.

Regarding zones of failed rock in the floor, significant (cross-sectional) area were indicated only in the instance of the shale 1 floor, increasing with the thickness of the stratum. The indicated maximum value for that zone is indicated in Table 3.

Effect of the variation of the immediate roof rock type and thickness

With the total thickness of the immediate floor being shale 1 and increasing thicknesses of the same rock forming the immediate roof, the maximum vertical displacements of the roof increased as indicated in Figure 3. The maximum vertical displacements of the floor however, remained constant. The maximum horizontal displacements of the coal rib also increased slightly.

Zones of rock failure in the shale 1 roof increased with the increase in thickness of the stratum.
Effect of the yielding of the coal rib

With the total thickness of the immediate roof being sandstone and variable thicknesses of the alternative rock types forming the immediate floor, the assumed yield condition of the coal rib did not affect the respective maximum vertical displacements of the roof and floor, as shown in Tables 2(A) and (B). With the yield of the coal rib and the immediate floor being composed of shale 1 however the maximum horizontal displacement of the rib increased considerably, as shown in Table 2(C).

Zones of indicated rock failure in the roof and floor were not affected by the yielding of the coal rib, as shown in Table 3.

CONCLUSIONS

The following conclusions were drawn from the modelling of the displacements and zones of rock failure in the immediate strata surrounding the panel and pillar geometry designed for restricting surface subsidence:

i) The maximum vertical displacement of the floor increased with the thickness of a weak floor stratum like shale 1, as indicated by Figure 2. The sharp increase in the maximum vertical displacement of floor constituted by a rock type with an Young’s Modulus less that 7 GPa indicated in Figure 3, suggests the possibility of floor heave adjacent to pillars of small dimensions.

ii) For the modelled geometry however, the maximum vertical displacements of the floor were not large enough to be considered as heave. Additionally, the possibility of the core of such a pillar penetrating the floor independently of its yielded rib seems to be ruled out by the lack of significant increase in the maximum vertical displacements in Table 2(B), when yielding of coal rib was considered compared to when it was not.

iii) Based on the preceding conclusions, the likelihood of a properly designed panel and pillar geometry being unable to adequately control the surface subsidence in the Southern Coalfield of New South Wales can be discounted.

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