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Influence of varying bedding thickness of underclay on floor stability

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ABSTRACT

The variation in bedding thickness of the weak immediate floor has long been a challenge in the Illinois basin coal mines when it comes to floor stability. The vertical thickness of the immediate floor is not constant throughout the mines and can vary over short horizontal distances. The biggest misconception from a design standpoint is to use the maximum or average thickness found from core logs taken from various locations on the mine property. The result of this practice is oversized pillars in the areas where the weak immediate floor has thinned vertically. This over-design leaves coal in situ which could have otherwise been extracted. This paper presents a plane strain numerical model to illustrate the effect of a change in bedding thickness of a weak immediate floor across one or two coal pillars. The floor bearing capacity of the variable floor below each pillar where then compared to the consistent floor. The results show that the varying bedding thickness of weak underclay has an impact on the bearing capacity of the floor. Geometrically with the decrease in bedding thickness for constant pillar width, the B/H ratio increases exponentially. The influence of varying bedding thickness on the floor bearing capacity is apparent at higher B/H ratios. The floor bearing capacity under a single pillar is in variable floor model if the average thickness remains constant. For single pillar, the average of the bedding thickness can be considered and for pillars in a panel, and a safety factor has been proposed to take into account this change in bedding thickness.

1. Introduction

In Illinois basin coal mines, the coal seam is often underlined by an immediate floor bed composed of weak underclay (fireclay), which can cause operational and stability issues due to the low strength characteristics of the weak floor. This is amplified in the presence of water. In the short term, the weak floor can undergo bearing capacity failure and develop floor heave which may cause complete abandonment of the panel or the part of the panel [1]. Further, if the bedding thickness varies over short horizontal distances (i.e. between the adjacent pillars) the differential settlement of the pillars can cause roof stability issues.

Geologically, underclay is classified as a gray, argillaceous rock and often, occurs beneath the beds of coal in the Illinois Basin [1]. The origin of the underclay has been speculated, but has been thought to be the decayed root system of the lush vegetation which now comprises the overlying coal bed. Depending on the composition of the clay (i.e. percentage of illite, kaolinite, montmorillonite, etc.) the clay has a tendency to swell in the presence of water.

The bedding thickness of the underclay can vary from less than 0.5 m, to 6 m at different locations in the Illinois Basin. The contact between the underclay and the older underlying bed is gradational whereas it is sharp with the contacts of the coal pillar [2]. The case studies across the Illinois Basin coal mines indicate that the weak floor thickness can vary about 0.3–1.0 m over a distance of two pillars and 2.0–2.5 m in the mine area [1]. In addition to the case studies, the core logs in Fig. 1, indicate that the thickness of the underclay can change dramatically at different locations. The punching failure in the West Kentucky coal mine in the No. 11 seam was observed due to the increase in floor thickness from 0.6 to 1.5 m [3].

2. Problem illustration

One of the problems the mine engineer faces when conducting the floor stability analysis is determining the thickness of the weak floor which can be representative of the mine as a whole. This would not be a significant issue if the thickness was constant

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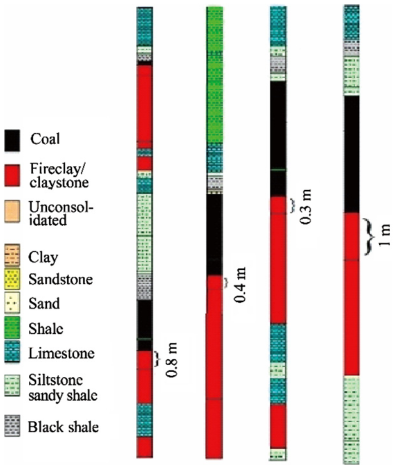


Fig. 1. Drill core logs representing varying weak floor thickness at different locations [2].

throughout the entire mine; but this is often not the case. The issue using the maximum floor thickness is that the pillars will be oversized. The issue using the average floor thickness is that the floor failure can initiate when a higher thickness is encountered as the pillars will be undersized. Often the more conservative approach is taken (average thickness of the underclay bed). In the author's opinion, the most practical method to account for the varying thickness is to estimate the floor bearing capacity by numerical modelling. This is because empirical equations cannot account for this variability.

The problem is illustrated in Fig. 2 which represents a coal pillar of width *B*, entry width *S* and the immediate weak floor with thickness *H*. The terms "consistent floor", which is represented by a constant (unchanging) floor thickness under each pillar, as well as the term "graded floor", which is characterized by the vertical thinning or thickening of the immediate floor by thickness *t*, will be used throughout this paper.

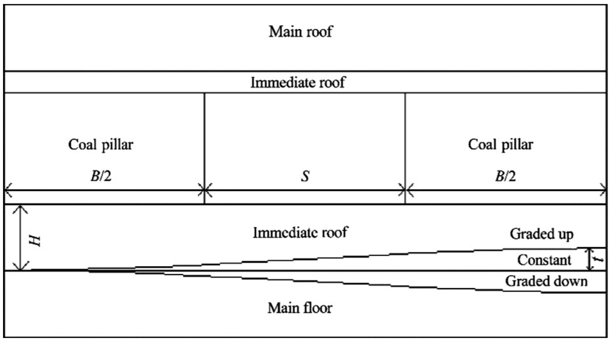


Fig. 2. Illustration of the problem.

A decrease in thickness of the underclay bed is represented by $H - t$ and will be characterized as "graded up" and an increase will be represented by $H + t$ and is characterized as "graded down". So that reference to the pillars is not confused, the term "base floor" will be used in reference to the left pillar and the term "graded floor" will be used for the right pillar unless otherwise noted.

The bearing capacity of immediate floor at varying thicknesses will be compared. Bearing capacities of the floor graded up, graded down at the left pillar and the base floor thickness at the right pillar will be compared to the bearing capacity of the consistent floor. The results will be presented in the form of increase or decrease in the percentage of the floor bearing capacity. For example, if a decrease in bearing capacity of 20% is observed under the graded down thickness, this means the bearing capacity is 20% lower under the right pillar relative to the bearing capacity of the consistent floor.

3. Model characteristics and properties

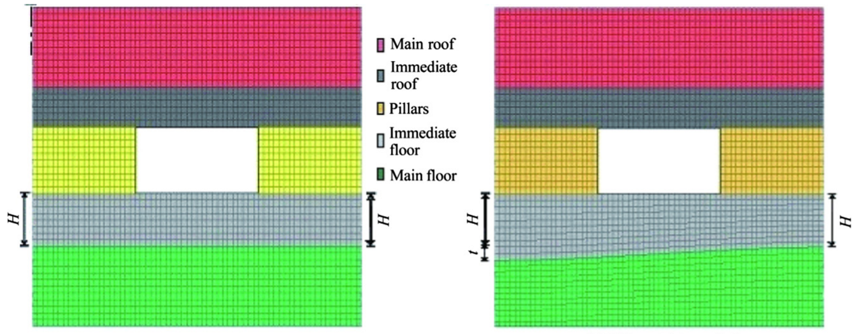
Numerical modelling was conducted using the finite difference method with FLAC3D, which has the ability to simulate the geotechnical problems associated with soil and rock. The problem was modelled in plane strain. Fig. 3 illustrates the two-dimensional numerical model consisting of a roof, a room, and two half-width coal pillars, with a consistent immediate floor (Fig. 3a) and a graded up immediate floor (Fig. 3b).

Plane strain can be modelling in FLAC3D when the element size in the out-of-plane direction is small compared to the elements of the in-plane direction (i.e. large aspect ratio of the in-plane element size relative to the out-of-plane element size).

Displacements and velocities were restricted normal to the plane *X* by creating the roller boundaries around the entire model grid. The farthest coordinate direction in the *Z* plane (bottom of the model) was pinned so that the displacements and the velocities are restricted both in normal and parallel direction. At the base of the model, zero displacements were set and at the top of the model, a constant compressive velocity was applied in the negative *Z* direction to compress the model grid.

The Mohr-Coulomb failure criteria were selected for all the materials. The material properties of the main roof, immediate roof, pillars, immediate weak floor, and the main floor are shown in Table 1.

This model was calibrated to an equation for bearing capacity design. This was the only avenue to calibrate to a known solution since field data on this type of problem is not readily available. The



(a) With consistent weak floor

(b) With variable weak floor

Fig. 3. Two-dimensional model.