Floor Design in Underground Coal Mines

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Summary

Floor failure and excessive heave in underground coal mines can jeopardize the stability of the whole structure, including the roof and pillars, due to differential settlements and redistribution of stress concentrations. Besides, floor failure is detrimental to haulageway operation and can lead to unacceptable conditions of high deformation. Thus, the design of any underground opening must consider roof/pillar and floor as one structural system.

This paper presents guidelines for the design of mine floors, including the necessary field and laboratory investigations and the determination of the bearing capacity of floor strata. The design methodology is based essentially on a modified Hoek-Brown rock mass strength criterion. The main modifications are the introduction of the concept of the point of critical energy release to account for the long term strength, the inclusion of tensile strength and the adoption of a lithostatic state of stress in the rock mass. The determination of the dimensionless parameters $m$ and $s$ result from correlations with the RMR ("rock mass rating") of the Geomechanics Classification. Nine case histories, both in longwall and room and pillar coal mining, were analyzed with the proposed methodology.

1. Introduction

Floor stability plays an important role in the safety and operation of underground coal mines, both in maintaining the access for equipment transportation and in providing a foundation for the roof/pillar/floor system. An excessive floor heave, and ultimately floor failure, may subject the pillars and the roof strata to excessive displacements and stress concentrations leading to pillar failure and roof falls. There is an analogy between the interaction of the roof and pillars with the floor and the interaction of a building with its foundations. Therefore, an underground mining project must feature an integrated design considering the roof/pillar/floor system as a whole.

Coal seams are generally underlaid by clayey sediments (often called "underclay") displaying a geostructural attitude of the bedding parallel to
the seam itself. The “underclay” in turn usually comprises multiple strata of clay material, each with different geotechnical properties. Underlying these materials one frequently finds sandstone, which in the vast majority of cases is also in concordance with the upper strata.

Although such argillaceous layers constitute, from the geological point of view, a distinctive sedimentary rock, sometimes they have such poor mechanical characteristics and granular nature that are more appropriately treated using soil mechanics concepts, rather than the typical discontinuous jointed rock mass. Rock floors are nevertheless also found, predominantly in deeper mines, where the coal seam is situated above hard layers of either shale, claystone or mudstone, or sometimes even siltstone or a clayey sandstone.

Literature reviews on the subject have been done by Bieniawski (1987) and Faria Santos (1988). Most reports of floor instability in underground coal mines relate the problem to three principal mechanisms: pillar punching into the floor strata due to a foundation collapse; buckling of the upper floor layers provoked by high horizontal stresses and swelling of the floor rock when exposed to moisture or water.

2. Rock Mass Strength Criterion

In order to assess the stability of floor strata in underground mines, particularly in terms of bearing capacity (considering that the mine floor acts as a foundation to the system formed by pillar and roof), it is necessary to adopt a strength criterion for rock masses that can be used to establish the maximum allowable stress on the floor layers. There have been several failure criteria reported in the technical literature, from the first one presented by Coulomb (1773) to that proposed by Murrell (1965), and finally to the current method developed by Hoek and Brown (1980).

Since an analytical solution to the problem of determining the strength of rock masses is difficult in view of the complex nature of geologic materials, all criteria proposed so far are essentially empirical. For foundation analyses, which is the case of floor stability in underground coal mines, a failure criterion will lead to the definition of the bearing capacity of the floor strata.

The failure criterion selected for this research work was that proposed by Hoek and Brown (1980), since it is the only rock mass strength criterion available, as opposed to rock material criteria. A rock mass strength criterion for floors in underground mines was thus based on the original concept presented by Hoek and Brown but incorporated subsequent modifications by Hoek (1983, 1986 and 1988), as well as the additional interpretations made by Bray (in Hoek, 1983), Ucar (1986) and Londe (1988). The methodology proposed here for mine floors also entails the influence of the time-dependent behavior of the rock, which is ignored in the original criterion. Specifically the long term strength of rock