Subsidence prediction in shallow room and pillar mines

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Received 31 May 1985

Summary

A mathematical model has been developed utilizing the relative flexural strength of the strata overlying a coal seam to predict the vulnerability of shallow room and pillar mined areas to subsidence. The model assumes the failure of the immediate roof as the precursor of a subsidence event in shallow room and pillar mines. After the roof fails, either a sink hole subsidence event develops if the unconsolidated material is thin and dry; or a subsidence trough forms if the unconsolidated material is thick and wet. The model relates the Missavage number ($M_n$), which is dependent only on the stratigraphy and rock strength, to the extraction number, which is dependent only on the extraction ratio and maximum span of the opening. A high correlation coefficient ($r=0.78$) between $M_n$ and the extraction number for 27 subsidence events in a southern Illinois mine showed potential for using this model to delineate areas more vulnerable to subsidence. The developed and validated model was then subjected to a blind test on a 12.9 square kilometer area of an Illinois Coal Basin mine. The model successfully predicted 10 out of 12 subsidence events in the blind half of the study area and two of three additional subsidence events in the known half of the study area.

Keywords: Coal mining; subsidence; room and pillar mines.

Introduction

Concern over mining-related subsidence is inhibiting the development of surface land uses in previously mined areas and is constraining the recovery of coal resources in areas with established land uses that might be impacted by subsequent subsidence. The determination of subsidence vulnerability of mined out areas (especially abandoned mine areas) can be a useful tool in the design and location of surface structures. Most of the previous subsidence prediction work has concentrated on the determination of the subsidence profile over longwall and high extraction retreat mined areas. Missavage and Chugh (1983) have developed a model for assessing subsidence vulnerability in shallow room and pillar mines based on the flexural rigidity and strength characteristics of the overlying strata. The model does not predict the subsidence profile or when the subsidence will occur. It only predicts those areas that are likely to subside.
Since subsidence in shallow room and pillar mines typically only affects a small portion of the mined out area, subsidence prediction models should discriminate between those areas likely to subside and those that are not. A knowledge of this can aid in premining planning (location of mains, submains, panels, etc).

Related studies

Subsidence vulnerability prediction models are relatively sparse in the literature. One comprehensive technique in this area was developed for the Northern Field of the Anthracite Region of Pennsylvania. The study, sponsored by the Corps of Engineers (1963), was conducted by the Bureau of Mines during the period 1961–1963. The study developed a four step methodology to define susceptibility of an area to subsidence: (a) preparation of mine maps for different mined seams in small rectangular areas (1280 m $\times$ 915 m); (b) classification of mine workings in each seam into three categories based on depth, per cent extraction, type, and extent of second mining; (c) projection of subsidence vulnerable areas of different seams on the surface using suitable angles of draw; and (d) modification and reclassification of subsidence vulnerability of each area based on consideration of additional factors such as geology, mine water pool elevations, etc. The Pennsylvania Department of Environmental Resources (1972) has used a similar methodology with consideration of additional factors such as elapsed time since mining, pillar extraction, proximity to existing surface subsidence, and severity of last subsidence events.

More common are the models (Kohli et al., 1982; Karmis et al., 1981; Kiusalaas et al., 1983) that predict the extent/maximum subsidence given the mine geometry and local geology. These models primarily rely on the influence function approach to predict the subsidence profile on the surface. The models contain site specific constants that are determined by measuring the subsidence profile and fitting the data to the theoretical profile. While they work well for longwall and high extraction retreat mined areas, their success is limited in partial extraction shallow room and pillar mines. The models do not distinguish between areas more likely to subside and those that are not.

Model development

The model developed by Missavage and Chugh (1983) assumes the mechanism for subsidence in shallow room and pillar mines is a progressive failure of the overlying roof until the failure zone intercepts the unconsolidated/weak overburden. The floor failure is not considered a major factor since at shallow depth stresses acting on the floor are not very large. The surface subsidence profile will depend on the strength characteristics of the unconsolidated overburden. If the unconsolidated overburden is dry and thin a pit or sink hole will form with a discontinuous surface profile as the failed zone migrates to the surface with a small angle of draw. If the unconsolidated overburden is thick and wet a trough will form with a continuous surface profile as the unconsolidated overburden flows into the failed mine opening with a large angle of draw.