Estimation of \textit{in situ} viscoelastic parameters of weak floor strata by plate-loading tests

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Summary

This paper explores an approach to estimation of the viscoelastic parameters of weak floor strata using plate-loading tests. Mathematical equations are derived to describe deformation-time history for the standard Burgers model under three-dimensional stress-strain conditions, which are verified with a finite element model. A number of time-dependent in-mine plate-loading tests were conducted and the values of the viscoelastic parameters were estimated based on the derived equation. It is shown that large discrepancies between the parameter values estimated from the plate-loading tests and those acquired from the in-mine convergence data are the results of neglecting adjacent pillar interaction. Finite element modelling was conducted to investigate the effects of adjacent pillar interactions upon the pillar settlement. Based on the finite element analyses, a correction curve was developed to adjust the viscoelastic parameter values to take into account the interaction between adjacent pillars. With the correction, the parameter values estimated from the plate-loading tests compared favourably with those acquired from the in-mine convergence results.

\textit{Keywords:} Plate-load test, viscoelastic, modelling, weak rock, mine floor

Introduction

In underground coal mines associated with weak floor strata, the characteristics of the floor strata play predominant roles in determining the stability of mine openings. Studies conducted in the Illinois coal basin, where coal seams are typically underlain by 0.5–2 m of weak strata, indicate that the pillar design in room-and-pillar mines at depths less than 120 m is governed by the strength of weak floor strata rather than that of coal (Chugh and Hao, 1990). The mining-induced deformation of weak floor strata frequently manifests itself in the form of floor heave, pillar settlement and surface subsidence. These types of deformation are generally time-dependent (Chugh \textit{et al.}, 1987; Chugh and Hao, 1990). Therefore, estimating the time-dependent properties of the weak floor strata is extremely

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important for determining long-term pillar settlements, surface subsidence, and stability of longwall supports operating on top of weak floor strata.

Few data are available on the time-dependent properties of weak floor strata. Those from in situ time-dependent plate-loading tests are even more limited. An attempt is made in this study to estimate viscoelastic parameters of weak floor strata from in-mine tests. Mathematical equations were derived to describe deformation-time history for the standard Burgers model under three-dimensional stress-strain conditions. The equation was verified using a three-dimensional finite element model developed with ABAQUS on a CRAY supercomputer. A number of time-dependent in-mine plate loading tests were conducted and the values of the viscoelastic parameters were estimated based on the equation derived. The estimated parameter values were compared with those acquired from the in-mine convergence data. The discrepancies were discussed and analysed. Additional finite element modelling was conducted to investigate the effects of adjacent pillar interactions upon the pillar settlement. Based on the finite element analyses, a correction curve was developed to adjust the viscoelastic parameter values to take into account the interaction among adjacent pillars.

Mathematical modelling of the viscoelastic behaviour of the weak floor strata subjected to a three-dimensional stress field

Rheological models have been effectively utilized to describe time-dependent behaviour of geological materials (Hardy et al., 1969; Sheorey and Dunham, 1978; Chugh et al., 1987). Among the four basic models, namely, Maxwell, Kelvin, Ross and Burger's models, the last one is considered to represent most realistically the creep behaviour of mine rocks (Lu and Wright, 1968; Sheorey and Dunham, 1978; Chugh et al., 1987). In this study, the Burgers model with one Kelvin unit, as shown in Fig. 1, was selected to simulate the time-dependent behaviour of the immediate weak floor strata.

The differential equation of the standard Burgers model in one-dimensional form is:

\[ \frac{\partial \varepsilon}{\partial t} = \frac{1}{\eta_1} \varepsilon + \frac{\varepsilon_0}{\eta_2} \frac{\partial \sigma}{\partial t} \]

Fig. 1. The standard Burger's model.