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Analysis of monitored ground support and rock mass response in a longwall tailgate entry

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ABSTRACT

A comprehensive monitoring program was conducted to measure the rock mass displacements, support response, and stress changes at a longwall tailgate entry in West Virginia. Monitoring was initiated a few days after development of the gateroad entries and continued during passage of the longwall panels on both sides of the entry. Monitoring included overcore stress measurements of the initial stress within the rock mass, changes in cable bolt loading, standing support pressure, roof deformation, rib deformation, stress changes in the coal pillar, and changes in the full three-dimensional stress tensor within the rock mass at six locations around the monitoring site. During the passage of the first longwall, stress measurements in the rock and coal detected minor changes in loading while minor changes were detected in roof deformation. As a result of the relatively favorable stress and geological conditions, the support systems did not experience severe loading or rock deformation until the second panel approached within 10–15 m of the instrumented locations. After reaching the peak loading at about 50–75 mm of roof sag, the cable bolts started to unload, and load was transferred to the standing supports. The standing support system was able to maintain an adequate opening inby the shields to provide ventilation to the first crosscut inby the face, as designed. The results were used to calibrate modeled cable bolt response to field data, and to validate numerical modeling procedures that have been developed to evaluate entry support systems. It is concluded that the support system was more than adequate to control the roof of the tailgate up to the longwall face location. The monitoring results have provided valuable data for the development and validation of support design strategies for longwall tailgate entries.

1. Introduction

Longwall gateroads are subject to significant changes in stress as the adjacent longwall panels are being retreat mined. The stress changes may include variation of the magnitude of the vertical and horizontal stress components as well as rotation of the major principal stress directions. These stress changes can cause damage to the coal ribs and the rock mass surrounding a gateroad entry. Support systems to control the rock deformations have been developed over many years, and currently gateroad supports may consist of rock reinforcement using roof bolts and cable bolts, surface control using support channels and screen, and standing supports to control excessive roof and floor deformation [1,2]. Most support systems used today are developed through an empirical approach in which support systems are optimized to match the local geologic and stress conditions. The study presented in this paper is part of a research project being conducted by the Pittsburgh Mining Research Division of the National Institute for Occupational Safety and Health (NIOSH) to develop engineering-based design procedures for gateroad support design.

The study was conducted at a longwall mine in West Virginia operating in the lower Kittanning coalbed at a depth of cover of 150–200 m. The coalbed thickness is about 1.5 m in the study area, but may be up to 2.4 m thick. In narrower seam conditions the mine will extract up to 1 m of shale roof rock during longwall extraction. The longwall district where the study was conducted consists of three longwall panels that are 365 m wide and are between 1500 and 2100 m long. The study site was located in the tailgate of the third panel to be mined in the district, shown in Fig. 1. For the purpose of discussing mining adjacent to the monitoring site, Panel 2B is the first panel to pass the site, and Panel 2C is the second panel.

Monitoring was initiated a few days after development of the gateroad entries and continued during passage of the longwall panels 2B and 2C on both sides of the entry. Measurements were

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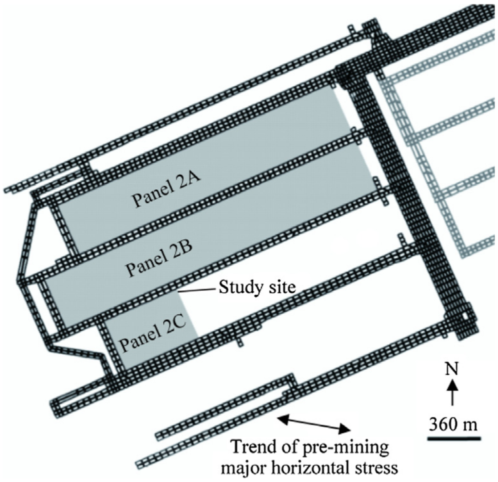

Fig. 1. Layout of longwall panels and location of study site.

conducted at a mid-pillar location of the entry as well as at an intersection location. Rock properties were obtained through uniaxial and triaxial strength tests conducted on rock cores collected from the monitoring site. Monitoring included overcore stress measurements of the initial stress within the rock mass, changes in cable bolt loading, standing support pressure, roof deformation, rib deformation, stress changes in the coal pillar, and changes in the full three-dimensional stress tensor within the rock mass at six locations around the monitoring site. The mid-pillar instruments were monitored up to 24 m inby the face, while the instruments at the intersection were terminated when the face reached the intersection. Fig. 2 is a sketch map showing the location of the instrumentation sites on the last day of monitoring. Visual records were kept of changes in rock and support conditions during the 13-month monitoring exercise. A detailed description of the monitoring system and a summary of results that were obtained from the study are provided in Gearhart et al. [3].

2. Geotechnical information

The immediate roof rocks of the lower Kittanning coalbed consist of dark gray to carbonaceous clay shale. The clay shale grades upward to gray sandy shale, dark-gray sandy shale, or gray sandstone. The gray sandy silt shale and dark-gray sandy silt shale beds vary in grain size and sand content, based on their proximity to the laterally correlative gray sandstone beds. Grain size and sand content decrease as the distance from the correlative sandstone beds increases. Stratigraphically located above this sandy zone is the Johnstown limestone, a lacustrine limestone of varying purity,

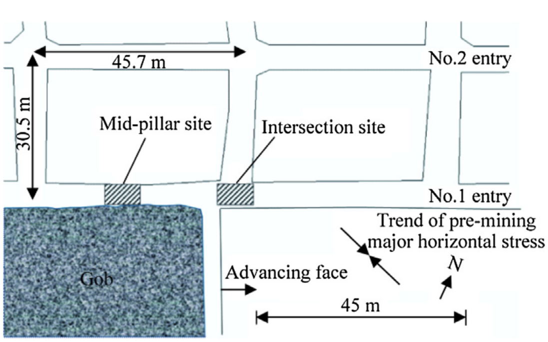

Fig. 2. Detail view of location of monitoring sites in the No. 1 (tailgate) entry of the longwall, showing longwall face position at the end of the monitoring period.

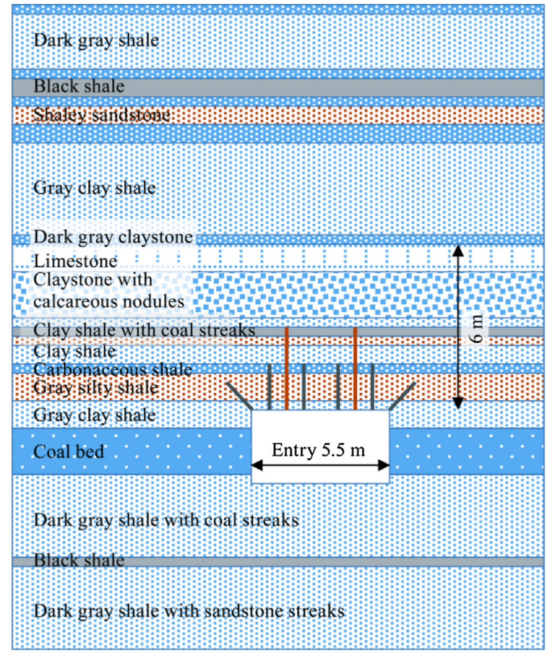

Fig. 3. Section showing geologic layering and location of entry and support system.

which locally grades laterally to a claystone with calcareous nodules or flint clay. The Johnstown limestone is a regionally recognized marker bed in the Allegheny Formation. The general overburden consists of alternating sandstone and shale beds with sandstone layers of between 10 and 20 m thick. The local geologic composition of the roof and floor, determined by core-drilling at the study site, is shown in Fig. 3. Inby the mid-pillar site the floor rolls downwards, and a slickensided joint extending across the entry was observed on the inby side of the mid-pillar site. These features indicate that the test site may be located on the margin of a paleochannel in the roof.

Laboratory testing of rock core was conducted to obtain geotechnical characteristics at the study site. Testing was conducted on core from the vertical holes in the roof and floor of the entry. In addition, core was tested from a 30° inclined hole drilled over the pillar adjacent to the study site. Laboratory tests consisted of uniaxial compressive strength testing, triaxial tests, and multistage triaxial tests. The compressive strength, elastic modulus, Poisson's ratio, and frictional and cohesive strength were obtained during this testing. The core from the inclined hole was used to determine shear strength along the bedding planes within the rock. Where rock samples were inadequate for compression testing, point load tests were conducted to supplement the results. Both axial and diametral point load tests were conducted. These tests were attempted to obtain a continuous strength record along the full length of the core, but this was not possible owing to the bedding breaks that occurred during core drilling and subsequent sample preparation. Only 30% of the recovered core was successfully cut, polished, and tested, indicating that most likely only the strongest sections of the core was tested. Table 1 summarizes the strength and mechanical properties of the rocks as tested.

Overcore stress measurements using hollow inclusion cells (HI-cells) were conducted to determine the initial stress conditions prior to the approach of the first longwall. Two measurements were made at depths of 8.0 and 8.5 m in a 30° inclined hole drilled into the roof strata over the solid coal on the panel side of the site. The results of the overcore measurements are presented in Table 2. The results confirmed the general east-west trend of the major horizontal stress observed in the eastern United States [4]. The