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Deep cover bleeder entry performance and support loading: A case study

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ABSTRACT

Several questions have emerged in relation to deep cover bleeder entry performance and support loading: how well do current modeling procedures calculate the rear abutment extent and loading? Does an improved understanding of the rear abutment extent warrant a change in standing support in bleeder entries? To help answer these questions and to determine the current utilization of standing support in bleeder entries, four bleeder entries at varying distances from the startup room were instrumented, observed, and numerically modeled. This paper details observations made by NIOSH researchers in the bleeder entries of a deep cover longwall panel—specifically data collected from instrumented pumpable cribs, observations of the conditions of the entries, and numerical modeling of the bleeder entries during longwall extraction. The primary focus was on the extent and magnitude of the abutment loading experienced by the standing support. As expected, the instrumentation of the standing supports showed very little loading relative to the capacity of the standing supports—less than 23 Mg load and 2.54 cm convergence. The Flac3D program was used to evaluate these four bleeder entries using previously defined modeling and input parameter estimation procedures. The results indicated only a minor increase in load during the extraction of the longwall panel. The model showed a much greater increase in stress due to the development of the gateroad and bleeder entries, with about 80% of the increase associated with development and 20% with longwall extraction. The Flac3D model showed very good correlation between expected gateroad loading during panel extraction and that expected based on previous studies. The results of this study showed that the rear abutment stress experienced by this bleeder entry design was minimal. The farther away from the startup room, the lower the applied load and smaller the convergence in the entry if all else is held constant. Finally, the numerical modeling method used in this study was capable of replicating the expected and measured results near seam.

1. Introduction

The National Institute for Occupational Safety and Health (NIOSH) recently began a research project aimed at improving understanding of stress redistribution due to full extraction mining and the methodologies to assess those stresses in underground coal mining. Two methods of mining coal are of primary interest to this project: longwall and room-and-pillar retreat. This paper focuses on the stress redistribution due to longwall mining.

Fig. 1 shows a longwall mine layout containing two gateroads, the longwall panel, startup room, and the bleeder entries. The longwall face and shields are initially located in the startup room and they progress towards the recovery room at the opposite end of the longwall panel. Once the shields begin moving towards the recovery room, the area mined out behind the shields becomes the gob—the broken overburden that fills the void created by the longwall mining process. The overburden stress after longwall mining is redistributed among the longwall panel outby the face, the shields in the face, the gob behind the shields, the gateroads on either side of the panel, and the bleeder pillars behind the gob. Fig. 1 shows a barrier pillar between the startup room and the bleeder entries that can also accept the load previously carried by the pre-mining longwall panel.

The bleeder pillars, entries, and standing support were studied in this research effort because they provide support to the bleeder entries that need to be accessible, and they provide ventilation support to the current and future longwall panels. In the past, load redistribution has been studied with a focus on the gateroads, longwall face, and, occasionally, the recovery rooms. Recovery rooms are the area at the end of the longwall panel where the face equipment is recovered for use in the subsequent longwall panel. Most of the recovery rooms studied in the past were pre-driven recovery rooms where the enlarged opening, around 7.6 m, was

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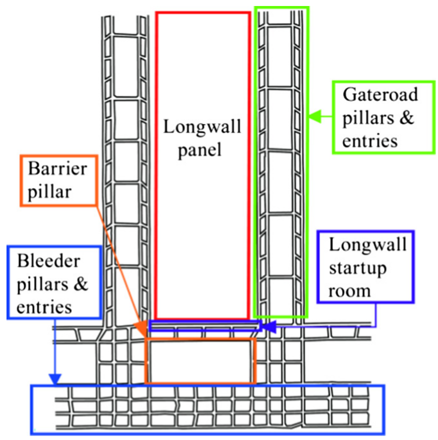

Fig. 1. A generalized layout of a longwall mine.

mined and supported prior to the longwall face reaching the recovery area. The redistributed load is referred to as the abutment—specifically, the front abutment, side abutment, and rear abutment (gob loading). The results of these previous studies show that the abutment extents and magnitudes are variable and associated with depth of cover, overburden lithology and mechanical properties, and mining sequence [1,2]. Hill, Stone, Suchowerska, and Trueman provide case studies that show abutment extent and magnitude are impacted by the specific mine, as well as the location of the abutment loading [2]. Peng links the maximum front abutment load to geologic conditions, face position relative to entry setup and periodic roof weighting, and adjacent mined-out areas [1]. A more streamlined approach to determining pillar stability, load redistribution, and abutment extent and magnitude uses a constant abutment angle of 21° and can be found in ALPS and ARMPS [3,4].

Bleeder support evaluations and designs primarily rely on experience at specific locations. Two recent studies address the bleeder support issue through numerical modeling simulations [5,6]. Although limited study has been given to bleeder supports, the same types of supports have been used elsewhere in mining and have been evaluated in those settings (for example, tailgate entry support, headgate entry support, and pre-driven recovery rooms). The tailgate study conducted by Zhang et al. in 2012 shows the importance of fairly high yield strengths while maintaining a reasonable residual strength through extended convergence [6]. In the case presented by Zhang et al. in their 2012 publication, the mine was relatively shallow, and the measured convergence that the standing support must endure ranged from a minimum of 3.8 cm to a maximum of 20.4 cm [6]. In addition, a pre-driven longwall recovery room was studied where pumpable cribs were instrumented in the same manner as used in this study and compared to their laboratory performance and capacity [7]. This study showed that 5–10 cm of convergence indicated that standing support is necessary, although the study monitored front abutment loading rather than rear bleeder loading [7].

Campoli studied pumpable crib supports for use in longwall gateroads and bleeder entries [8]. Again, the focus was on gateroads more than on bleeders, and this study emphasized field experience and laboratory testing. The field experience demonstrates the success of a double row of 61- or 76-cm-diameter pumpable cribs in bleeder entries around the country [8]. Different size pumpable cribs are used, depending on the support capacity needs, width-to-height ratio, and entry width. Laboratory testing of pumpable cribs has been ongoing for the past 20-plus years. A study conducted by Batchler focused on the design characteristics of pumpable supports' effect on their performance [9]. Batchler's database includes over 160 tests during the preceding seven years and promotes the importance of the stiffness, peak load capacity, load shedding events, and residual load characteristics [9]. NIOSH developed a software program called support technology optimization program (STOP) to allow mine planners and designers to evaluate different support types under varying conditions [10,11].

All of these previous research efforts helped us to develop and design this research project and allowed us to focus on areas not studied in-depth previously. Some of the questions developed from the results of these previous studies are as follows: how well do current modeling procedures calculate the rear abutment extent and loading? does an improved understanding of the rear abutment extent warrant a change in standing support in bleeder entries? what is the optimal standing support for bleeder entries separated from the startup room by a barrier pillar?

To help answer these questions and to determine the current utilization of standing support in bleeder entries, four bleeder entries at varying distances from the startup room were instrumented, observed, and numerically modeled. This evaluation was intended to determine the rear abutment extent and magnitude at various locations to optimize standing support in these entries and in those under similar conditions.

2. Field investigation

2.1. Mine conditions

Fig. 2 shows the geometry of the study sites. The depth of cover throughout the mine ranges from 365 to 701 m. The longwall panels in the newer districts are 213 m wide and 3048–3505 m long. The gateroad comprises a yield-abutment-yield system with entry centers of 15, 52, and 15 m, respectively. The crosscut centers for the abutment pillars are 137 and are 45 m for the yield pillars. The mining height averages 2.3 m with a range from 1.5 to 3.7 m. There are mined-out seams above the current seam, although no multiple seam interactions are anticipated. The mine generally mines in "districts," consisting of 4–6 longwall panels separated by a barrier pillar. The panels within a district use a common set of bleeder entries behind the startup rooms of the longwall panels. The bleeder entries consist of an entry 30.5 m directly behind the startup room, followed by a 91.5-m-wide barrier pillar. Then there is an additional set of four bleeder entries on 30.5-m centers with crosscut spacing varying from 38 to 52 m, as seen in Fig. 2.

Throughout the gateroads and bleeders, fully grouted torque-tension bolts on a 1.2-by-1.2-m pattern are installed with 3.7-m cable bolts installed in all intersections and as needed in the entries based on geological conditions. The standing support installed in the gateroads consists of a double row in the #2 and #1 entries. The bleeders have standing support installed in all four entries behind the barrier pillar, as well as the entry behind the startup room. The first two pillars have double rows of standing support on 1.8 and 2.4 m centers. The second two entries have six and four pumpable supports per intersection.

The geology of the 26-right panel consists of strata defined by cyclothems, an alternating repetitive sequence of sediments derived from marine and non-marine sources with coal beds in between the transitions from marine to non-marine sediment sequences (Fig. 3). The longwall mine operates within the Pocahontas Number 3 seam, known for its low sulfur and ash metallurgical grade coal. The Pocahontas Number 3 seam was deposited in an upper delta environment that resulted in thickly to massively bedded sandstones with a small series of shales lenses occurring occasionally. The geology in the floor of the seam consists of a fireclay that is approximately 15–61 cm thick, which acts as a