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Unanticipated multiple seam stresses from pillar systems behaving as pseudo gob–case histories

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ABSTRACT

Underground coal mining in the U.S. is conducted in numerous regions where previous workings exist above and/or below an actively mined seam. Miners know that overlying or underlying fully extracted coal areas, also known as gob regions, can result in abutment stresses that affect the active mining. If there was no full extraction, and the past mining consists entirely of intact pillars, the stresses on the active seam are usually minimal. However, experience has shown that in some situations there has been sufficient yielding in overlying or underlying pillar systems to cause stress transfer to the adjoining larger pillars or barriers, which in turn, transfer significant stresses onto the workings of the active seam. In other words, the overlying or underlying pillar system behaves as a "pseudo gob." The presence of a pseudo gob is often unexpected, and the consequences can be severe. This paper presents several case histories, summarized briefly below, that illustrate pseudo gob phenomenon: (1) pillar rib degradation at a West Virginia mine at 335 m depth that contributed to a rib roll fatality, (2) pillar rib deterioration at a Western Kentucky mine at 175 m depth that required pillar size adjustment and installation of supplemental bolting, (3) roof deterioration at an eastern Kentucky mine at 400 m depth that stopped mine advance and required redirecting the section development, (4) coal burst on development at an eastern Kentucky mine at 520 m depth that had no nearby pillar recovery, and (5) coal burst on development at a West Virginia mine at the relatively shallow depth of 335 m that also had no nearby pillar recovery. The paper provides guidance so that when an operation encounters a potential pseudo gob stress interaction the hazard can be mitigated based on an understanding of the mechanism encountered.

1. Introduction

The U.S. underground coal mining industry has conducted mining in multiple seam environments, where the active mining has underlying or overlying old workings at varying interburden distances, throughout its history. Often no serious consequences arise from the multiple seam mining. However, sometime mines have been confronted with hazards from underlying or overlying workings that include localized roof and rib failure, pillar system failures through propagating roof falls and floor heave, and also pillar bursts.

The major underground coal mining basins in the U.S. are shown in Fig. 1. Historically, the Central Appalachian region, consisting of southern West Virginia, eastern Kentucky, and southwestern Virginia has encountered the most significant multiple seam mining issues. This is attributable to the more than 100 years of underground mining, existence of numerous mineable seams in the respective stratigraphic sequences, and the predominant use of pillar recovery that concentrates mining stresses. While less frequent, multiple seam interactions occur in all the other coal mining regions as well [1].

2. Evaluation of multiple seam interaction

For decades the stresses that arise from multiple seam mining scenarios and the impact on the seam being mined has been the subject of much research. In 2007 the National Institute for Occupational Safety and Health (NIOSH) developed the analysis of multiple seam stability (AMSS) program to help reduce the risk of ground failures from potential interactions. The NIOSH study reviewed previous multiple seam mining research, established an extensive database of multiple seam mining case histories, applied LaModel 2D to establish multiple seam stress levels, and incorporated these stress levels to analysis of retreat mining pillar stability (ARMPS) and analysis of longwall pillar stability (ALPS) computations. The computations and statistical analyses of the database

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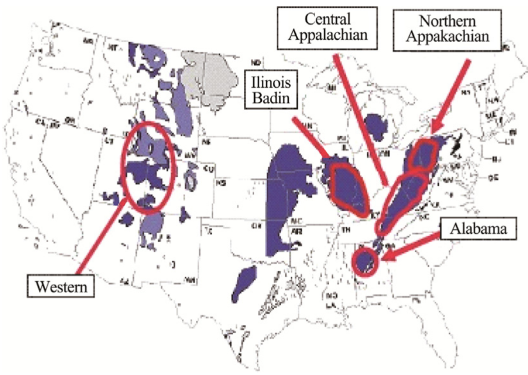

Fig. 1. The U.S. major underground coal mining regions [1].

helped determine the significant parameters that need to be accounted for in a multiple seam mining environment. The AMSS program offers criteria for an appropriate pillar design and guidance for the installation of supplemental roof and rib support [1]. A significant finding from the AMSS research is that when there is no full extraction, and the past mining in an overlying or underlying seam consists entirely of intact pillars, interactions with the active seam are usually minimal unless the interburden is less than 10–15 m.

AMSS has been used extensively in the U.S., underground coal mining industry. After the Crandall Canyon Mine disaster in 2007, the Mine Safety and Health Administration (MSHA) has instituted technical review procedures to ensure that appropriate pillar designs are used in underground coal mines [2]. The most numerous category of MSHA technical review are multiple seam mining scenarios evaluated with AMSS by the operator and/or MSHA [3].

2.1. Multiple seam interaction factors

The NIOSH study found that the most important factors affecting the intensity of a multiple seam interaction were the depth of cover, whether the past mining was conducted above or below the active seam, the immediate roof geology of the active seam, the interburden thickness between the active seam and the previously mined seam (or seams), and type of remnant structure in the overlying and/or underlying seam. Remnant structures in the previously mined seam(s) are typically created when coal is left in place adjacent to areas of full extraction, also known as gob areas. Isolated remnants, with worked out areas on two or more sides, have the most hazardous stress concentration, while less severe stress concentrations occur along gob-solid boundaries [1,4].

By definition, remnant structures exist in conjunction with gob areas which are de-stressed and have transferred load to the remnants. Regions in which all the pillars are intact are usually presumed to have minimal stress concentrations. However, a number of situations have been encountered where severe stress concentrations have occurred without the presence of full extraction mining in the overlying and/or overlying seam. In these cases, smaller developed pillars in old works have apparently yielded and transferred much of their load onto larger nearby pillars or barriers. In other words, the documented pattern of roof, rib, and floor degradation observed in these situations suggests that the small pillars are behaving as a "pseudo gob."

3. Multiple seam pseudo gob case studies

The case studies presented below all involve pseudo gob situations. They illustrate the range of unanticipated multiple seam mining hazards that can be encountered.

3.1. Pillar rib deterioration-West Virginia

The mining operation is located in Boone County, West Virginia in the Central Appalachian coal mining region. In 2006, a 46-year old roof bolting machine operator was fatally injured when a large portion of the rib fell [5]. The accident was investigated by the Mine Safety and Health Administration, Technical Support (MSHA-TS).

The mining unit investigated consisted of a five entry configuration being developed to establish a pillar recovery panel. The mine portals were in the No. 2 gas seam with the mining area accessed via an in-mine slope from the No. 2 gas seam down to the Powellton Seam. The pillars on the mining unit were established on 24 m × 34 m to 46 m centers with approximately 3 m × 5.5 m mining dimensions. Depth of cover was approximately 335 m.

The section was overlain by development mining in the No. 2 gas seam with 20 m of interburden (Fig. 2). U.S. multiple seam mining research has shown that when overlying seams have no pillar recovery and consist of development mining, this interburden distance normally will have minimal stress interaction. The investigation revealed that pillars located under the No. 2 gas seam chain pillars showed no or minimal evidence of rib spall (Fig. 3). In contrast, ribs located beneath the edge of the overlying barrier pillar exhibited intense rib sloughing (Fig. 4). The accident occurred in the Powellton Seam #5 entry face area after it had advanced beneath the overlying barrier. The accident site was subjected to an elevated intensity of rib sloughing and the rib side had a thick shale parting that had a tendency to roll out as large blocks.

As shown in Fig. 4, this photo illustrates thick shale parting that tends to roll out as large blocks.

The ARMPS SF calculated for the chain pillars in the overlying No. 2 gas seam was 2.3, a value that would normally indicate a stable pillar configuration [6]. Nonetheless, it is apparent that some factor allowed the No. 2 gas seam pillar system to yield and transfer loads onto the surrounding barrier. An AMSS evaluation, not yet developed at the time of the investigation, of the Powellton Seam mining shows that if the No. 2 gas seam chain pillars are treated as gob, pillar SF = 2; however, a "condition yellow" cautionary warning is generated indicating the likelihood of rib instability.

Rib control measures were subsequently instituted in the high stress region. In-cycle rib bolting was instituted to protect the personnel. Also, the mine operator purchased "inside control" dual boom bolting machines, with drill station controls located between

Fig. 2. Powellton Seam mining completed (black) with overlying development mining in the No. 2 gas seam (red).