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Case study and design of steel set support for aged belt entry rehabilitation

Kevin Jinrong Ma *, John Stankus

Keystone Mining Services, LLC, Pittsburgh 15106, USA

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ABSTRACT

In order to access remote reserve areas, some U.S. coal mines have to maintain aged underground entries for a great distance. However, high humidity, warm temperature, and time dependent deterioration can cause progressive roof deterioration and unexpected roof falls, and pose a great challenge to ground control engineers. With an active belt structure in place and limited space, re-bolting becomes very costly, less effective, and, sometimes, impractical and unfeasible. To gain long-term entry stability and serviceability, operators typically rehabilitate the aged belt entries by installing standing steel set supports. In the last several years, Keystone Mining Services, LLC, (KMS) has assisted many coal mines with their belt entry rehabilitation projects, evaluated the ground condition of various aged belt entries, and designed different standing steel set support systems. This paper presents a case study of a large-scale roof fall that occurred at an aged belt entry in a mine located in an eastern coalfield, analyzes root causes of excessive deformation of square sets that were installed in an adjacent entry, evaluates the adequacy of an existing rehabilitation square set, and develops remedial recommendations for future rehabilitation practice. Based on the case study, the paper outlines design guidelines for rehabilitation steel sets that include field evaluation, engineering considerations, design assumptions, steel structural analysis, and field installation quality control.

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1. Introduction

With gradual depletion of shallow coal reserves, some underground coal mines have to maintain long-term entries (belt, track, return airway, etc.) for a great distance in order to access remote coal reserve areas. However, due to high humidity, warm temperature, and aging in the belt entry, roof strata weathering and pillar degradation become more and more severe. Progressive roof deterioration poses a great challenge to ground control engineers. Pillar rib sloughs at certain locations, entry width increases in some areas, immediate roof sags, immediate roof rock falls out between bolts, existing bolts lose functionality due to corrosion, cutters develop deeper in corners, and strata separation develops deeper up into the main roof. As a result, unexpected roof falls occur in a random manner resulting in loss of production, damage of belt structure, and even injuries to underground personnel.

With an active belt structure in place and limited space on either side of the belt structure, re-bolting can be very costly, less effective, less reliable, and, sometimes, impractical and unfeasible. To gain long-term opening stability and serviceability, coal companies typically rehabilitate the aged belt entry by installing standing steel set supports. In the last several years, Keystone Mining Services, LLC, (KMS) has been involved in several belt entry rehabilitation projects. To help operators achieve additional service life and to minimize production downtime, KMS ground control engineers conduct field examinations, evaluate ground condition of various aged belt entries, and design different standing steel set systems.

This paper presents a case study of a large-scale roof fall that occurred within an aged belt entry of an underground coal mine in an eastern coal field, analyzes the root cause of excessive yielding of rehabilitation square sets that were installed in an adjacent belt entry area, evaluates the adequacy of an existing rehabilitation square set, and develops remedial recommendations for future rehabilitation. Based on the case study, the paper outlines a rehabilitation steel set design guideline that includes field evaluation, engineering considerations, design assumptions, steel structural analysis, and field installation quality control. The guideline serves as a useful tool for ground control engineers to develop economical, yet feasible, standing steel set supports for long-term underground belt entry rehabilitation.

2. Typical belt entry conditions

The following illustrates a few typical roof conditions in aged belt entries.

* Corresponding author.
E-mail address: kma@jennmar.com (K.J. Ma).

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2.1. Laminated immediate roof

Progressive collapse of laminated stack rock (laminated weak shale, black shale, clayey shale, sandy shale, and interbeds) commonly occurs in aged entries [1–3]. When effective surface control (wire mesh, etc.) is not in place, the separations and small scale roof falls occur progressively between roof channels or roof bolts and can propagate close to the anchorage zone of installed roof bolts.

Fig. 1 shows a deteriorated immediate roof condition in an aged belt entry. Such a condition is generally associated with thin, weak, laminated roof strata that is weathered and deteriorated due to long-term exposure to moisture and air, lack of adequate surface control, and insufficient roof support. In this case, the roof beam initially built by the primary support is completely compromised.

2.2. Pillar sloughage and increased roof span

In some cases, portions of coal ribs fracture, yield, and collapse over time due to concentrated stress on the pillars and a lack of proper rib support. In many cases, pillar sloughage occupies walkway space, and operators usually remove loose material off the rib and floor for an easier walkway for mine personnel. However, this action removes lateral confinement from the coal rib and results in additional rib sloughage. Consequently, effective pillar size reduces, and roof span at the area increases. Fig. 2 shows a belt entry that has severe pillar sloughage and increased roof span.

2.3. Corrosion of existing ground support

In aged belt entries, metallic roof support systems, such as bolts, cables, plates, roof channels, wire mesh, and roof pans, are likely to corrode and rust away due to exposure of moisture and air over time. Fig. 3 shows typical rusted roof support systems in a belt entry. The metallic roof support systems have corroded and degraded so that ground support no longer exists. Furthermore, broken roof channel and related hardware hang over the running belt structure, posing an immediate hazard to the conveyer belt and to personnel if they fall off the roof.

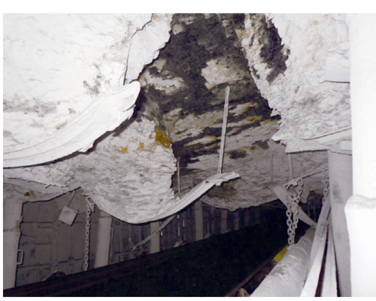

Fig. 1. Laminated roof.

Fig. 2. Pillar sloughage and extended roof span.

Fig. 3. Corroded mesh, channels, and roof bolts.

2.4. Deep gutter roof failure

In a laminated roof, the progressive roof failure sometimes initiates as a cutter (in stiffer laminated roof) or gutter (in weaker clayey laminated roof) roof failure at the roof-rib corner of a belt entry. With gradual pillar sloughage and progressive yielding and collapsing of roof strata, the gutter roof failure propagates upward into and above the pillar to a height above the bolting horizon. The failure process could be caused by either a regional or local horizontal stress field generated by geological features or by adjacent mined-out areas. Due to the horizontal stress, the laminated roof can shift horizontally towards the solid side of the entry instead of towards the entry center and pop out due to localized buckling failure.

Fig. 4 shows a typical gutter roof failure. In this case, the gutter roof failure was about 13.7 m long, 3.7 m upward from roof line, and 2.4 m into and above the pillar. From a ground control perspective, this condition is particularly dangerous and should be addressed in a timely manner.

3. A case study

This case study involves a belt entry roof fall evaluation for an underground coal mine in an eastern coal field that has been active for more than 30 years. In order to fully utilize the existing underground infrastructures and surface facilities, the operator acquired additional coal reserve areas and plans to continue coal production by extending and maintaining the existing long-term entries. However, the belt entries are fairly long (16.1+km) by linear distance and have been in service since the 1960s. Unexpected roof falls occurred frequently within the belt entries, which resulted in significant production downtime and monetary loss. The following

Fig. 4. Cutter roof failure.

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