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Control of floor heaves with steel pile in gob-side entry retaining

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ABSTRACT

A new approach named as steel pile method is innovatively proposed in this study to control severe floor heaves in gob-side entry retaining. It is required that the steel piles be installed in the floor corners with a certain interval before the influence of the dynamic pressure induced by current panel extraction. Using numerical simulation and theoretical analysis, this study investigated the interaction between the steel piles and the floor rocks during the service life of the steel piles, and revealed the mechanism of the steel piles in controlling floor heaves. The effect of the steel pile parameters on the control of floor heaves was presented and elaborated. It is found that the effectiveness of the steel piles in controlling floor heaves can be enhanced with greater installed dip angle, longer length and smaller interval of the steel piles. Compared with traditional methods, e.g., using floor anchor bolts and floor restoration, the advantages using steel pile were successfully defined in terms of controlling effect and economic benefits. It is hoped that the proposed method can contribute to the development of gob-side entry retaining technique.

1. Introduction

Gob-side entry retaining technique (GERT) is widely used in China for the last several decades, aiming to perform pillarless mining, improve coal recovery ratio, extend mine service life, reduce excavation work and mitigate tense relation between mining and excavation. Using this technique, it is possible to implement Y-shaped ventilation system which is very effective in mitigating or reducing gas accumulation in the upper corner of the panel. Besides, GERT can also eliminate the adverse effect of the remnant pillars on the extraction of adjacent coal seam [1–3]. All the above advantages make GERT hold a tremendous prospect for popularization and application.

However, field practices have demonstrated that GERT still confronts some undesirable problems, among which, severe roadway deformation is the most striking one. The roadway has to suffer strong dynamic pressure resulting from roadway excavation, former panel extraction and current panel extraction, which poses a serious challenge to the stability of the roadway, especially the roadway floor [4–11]. Severe floor heaves can result in the contraction of the roadway profile, which hampers transportation and ventilation, and even worse, requires the restoration of the roadway. In fact, these problems have gravely restricted the popularization and application of GERT. In controlling floor heaves in gob-side entry retaining, floor restoration is widely implemented, while reinforcement and stress-relief methods are seldom employed in actual practice. However, floor restoration is a passive method which is not only ineffective but also time-consuming. Against this backdrop, a new approach named as steel pile method is proposed in this study to control severe floor heaves in gob-side entry retaining. It is required that steel piles be installed in roadway floor corners with a certain interval before the influence of the dynamic pressure induced by current panel extraction. The proposed steel pile method is similar to the anti-sliding pile method adopted in the slope engineering [12,13]. However, they are fundamentally different in terms of the mechanical performances and movement characteristics of their control objects. Though systematic and in-depth studies have been performed to investigate the key contents concerning the anti-sliding pile, such as its interval design and control mechanism, these research results cannot be indiscriminately applied to the steel pile. Therefore, it is of great necessity to study the role of the steel pile in controlling floor heaves in gob-side entry retaining from aspects like its control effect, control mechanism and influencing factors, etc., which can lay a theoretical groundwork for its popularization and application.

2. Analysis of the advantages of steel piles in controlling floor heaves

2.1. Engineering background

The experimental site locates in the track roadway at 1204 panel in Zhongxing Coal Mine. The geometry of the roadway is

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illustrated in Fig. 1. And its support pattern is combined support using anchor bolt, wire mesh, W-shaped steel strap, anchor cable and U-shaped steel frame. Mining activities are performed in 2# coal seam, whose dip angle is 2–10° with an average value of 6°. The thickness of the seam ranges from 1.75 to 2.25 m with 2.0 m on average. The ground and underground elevation is +1201 to +1354 and +740 to +800 m, respectively.

GERT is implemented in the roadway. The filling wall is built of high-moisture filling material, which is 2.5 m wide and 2.0 m high. Water cement ratio of the filling material is 1.5:1. The support pattern of the roof above the filling wall is combined support using anchor bolt, wire mesh and anchor cable. The retained roadway is used as the track roadway of the adjacent 1206 panel. In addition, in order to reduce the impact of dynamic pressure resulting from 1204 panel extraction and 1206 panel extraction, hydraulic props and articulated roof beams were used to strength roof support of the roadway within the distance between 20 m ahead of the 1204 advancing panel and 100 m behind the 1204 advancing panel and the distance between 20 m ahead of the 1206 advancing panel and the 1206 advancing panel. Both the row space and the column space of the hydraulic props were 1000 mm.

Field monitoring results demonstrate that floor heaves are insignificant in roadway excavating stage and roadway stabilizing stage. When the 1204 pane was extracted, floor heaves were mostly found in a range of 0–60 m behind the advancing panel, and the accumulated floor heaves were 462 mm accounting for 75.3% in roof to floor convergence. Then the roadway deformation reached a stable stage and floor heaves sustained at a certain velocity. In order to ensure the normal use of the roadway, floor restoration was employed with an excavation depth of about 500 mm in the floor. During the extraction of the 1206 panel, the influence range of the front abutment stress was about 60 m, and the accumulated floor heaves were 520 mm accounting for 72.6% in roof to floor convergence.

2.2. Control of floor heaves in gob-side entry retaining

At present, available methods for controlling floor heaves include floor grouting, floor bolt, closed-form support, concrete inverted arch, stress-relief slot, stress-relief borehole, loosening blasting and the combined forms of the above methods [14–21]. However, when it comes to control of floor heaves in gob-side entry retaining, the much feasible implemented approach is floor bolt method.

Based on the analysis of currently available control methods and floor heave characteristics in gob-side entry retaining, this study innovatively proposes a new method, named as steel pile method, to control severe floor heaves in gob-side entry retaining. It is required that steel piles be installed in the floor corners with a certain interval before the influence of the dynamic pressure induced by current panel extraction. Firstly, floor boreholes are drilled using floor drilling rig. Then, steel piles with proper length, such as the used mine steel rails, are installed in the boreholes. Lastly, the gap between the installed steel piles and bore wall is filled with rocks refuses.

In view of the above engineering background, floor heave control patterns were separately designed with the floor bolts and the steel piles. Then, comparisons were made between the two patterns using FLAC3D simulation software. The detailed patterns are given in Table 1 and Fig. 2.

2.3. Numerical model establishment

Based on the stratigraphic diagram of the track roadway at 1204 panel, a numerical model (Fig. 3) was established using FLAC3D. The model is 107 m in length, 156 m in width and 56 m in height. The bottom side of the model is fixed and its four sides are restricted in the horizontal direction. The top side is the free boundary with 10 MPa stress (equivalent to the seam depth) imposed on. Mohr–Coulomb yield criterion was used for the coal, the rocks and the gob-side filling wall. According to geomechanics test results in this region, the coefficient of the horizontal pressure was 1.0. Physical and mechanical parameters for various strata are shown in Table 2.

2.4. Analysis of control effect

Monitoring points were set up at 40 m ahead of the advancing panel to record floor deformation in the roadway. The recorded

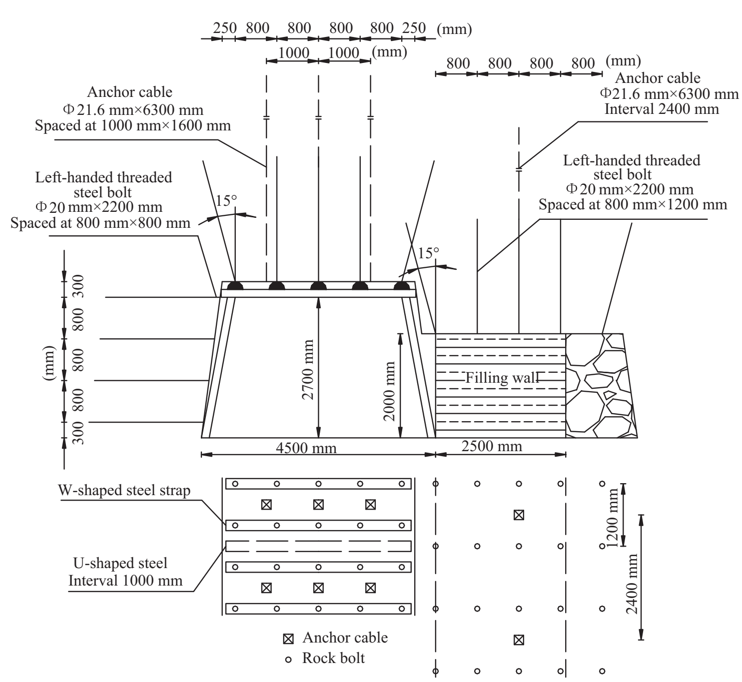

Fig. 1. Roadway profile and support pattern.