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Technical Note

Design and construction of entry retaining wall along a gob side under hard roof stratum

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1. Introduction

In recent years, gob-side entry retaining technique has been widely used in China [1,2]. Gob-side entry retaining is one type of roadways without pillars [3] that the former entry roadway is retaining as the tailgate for next panel mining by constructing an artificial wall along the gob side lagging behind excavating coal face. The application of this retaining technique can not only achieve huge economic benefits and increase coal recovery rate, but also can mitigate environmental pollution of waste rock. However, a large number of field tests showed that the gob-side entry retaining technology cannot be successful for many roof situations in coal mines [4,5]. For instance, gob-side entry retaining is valid in the case of roof easy to collapse [6], but is poor in case of hard roof. Thus, investigations on the proper geological conditions for using gob-side entry retaining techniques and designing reasonable support are necessary. After reviewing previous investigations, we found that the safety of gob-side entry retaining roadway depends on both primary supporting and gob-side wall support [7,8]. The primary supporting is to ensure the integrity of surrounding rock mass of roadway in less fracture after being developed in the early stage, while the gob-side wall support is to withhold the deformation during roof weighting and can maintain stable when mining undergoing.

Artificial wall techniques for gob-side entry retaining are increasingly used at mine sites. For instance, gob-side support with enter-in packing on its original location in fully-mechanized coalface [9], gob-side support with in-situ stratified filling [10] and gob-side support with whole casting [11] have been widely utilized. Compared with other god-side retaining wall support such as narrow coal pillar and metal supports, gob-side pack is higher in support intensity and better in impermeability. There are five ways to construct gob-side pack: concrete block, waste rock, gangue concrete, paste filling and high-water rapid-solidifying material. However, field investigations showed those gob-side packs are weak and fail to bear hard roof quick subsidence [12,13].

In this paper, in order to apply the gob-side retaining technique to conditions of hard roof strong weighting and quick subsiding behaviors, a new type artificial composite wall namely "flexible-hard" combination supporting was proposed. Based on the mechanical model, gob-side supporting force and permitted compression were determined. At last, a field case study in the Jiang Jia-wan Mine, Datong Coal Mine Group Co., Ltd, China, was presented.

2. Mechanical model

Field investigations showed [14–17] that load bearing and compression of an artificial wall in gob-side entry retaining can be divided two stages under the hard roof condition:

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Stage I - From the start of roof strata subsidence to main roof touching caved rocks. The roof strata in working areas can be idealized as a rock beam. As coalface advances, tensile stress in roof increases with roof span. When the maximum tensile stress reaches its limited strength, immediate roof collapses at first. Then hard main roof beam begins to subside, causing crack generation and propagation in roof strata. Once crack coalesce into large fractures, the occlusal support force from neighbor-rock cannot keep the balance of fractured main roof, and then main roof begins to subside rapidly until fractured main roof touches collapsed rocks in gob. During hard roof quick subsiding, coal bump disaster easily occurs.

Stage II - From the moment of main roof touching caved rocks to caved rocks being compacted. After fractured main roof touching collapsed rocks in gob, its subsidence becomes slow until collapsed rocks are compacted tightly. In this period, the compressed deformation of gob-side wall is relatively less.

In order to endure the hard roof weighting behavior, the function of gob-side wall support should meet the requirement of both large compressibility and high bearing capacity. For this purpose, a composite wall containing of flexible layer and hard layer was proposed. The upper layer is soft and flexible, which has enough compressibility to undertake hard roof quick subsidence at stage I, while the lower layer is strong enough to bear the load from main roof. This new type artificial wall was named as "flexible-hard" combination supporting wall.

As a matter of fact, the support force assigned to artificial wall relies on the contribution of coal seam and caved rocks. Hence, the development of an analytical model for god-side wall supporting, should integrate coal seam support part (Part A), caved rocks (Part B) and god-side wall supporting part (Part C) together (Fig. 1). These three parts commonly undertake the load from main roof and immediate roof.

2.1. Coal seam wall

Once main roof fractured, it begins to subside and transfers its weight to coal seam wall. The supporting stress to fractured main roof by coal seam wall is assumed as a linear distribution correspondingly with compressed morphological characters of coal seam. Supposing that supporting force intensity from main roof end-fracturing location to wall is from q_1 (Pa) to q_2 (Pa) linearly, as shown in Fig. 1 (Part A), both of q_1 and q_2 can be acquired by borehole stress-meter. Then, supporting force by coal seam wall, F_A, can be expressed as

$$F_A = \frac{1}{2}L_1(q_1 + q_2) \tag{1}$$

where L_1 is the horizontal distance from main roof beam end-fracturing to roadway.

2.2. Caved rocks

Primarily, caved rocks are unconsolidated and have less bearing capacity generally. After compressed by overlying rock strata subsidence, loose caved rocks begin to be consolidated and its bearing capacity begins to increase. Bulking degree of caved rocks is indicated by expansion factor, K_A, ranging from 1.0 to 1.4 approximately [18,19], which is the volume ratio of rock strata after cave and before cave. Obviously, the larger expansion factor is, the more easily caved rocks are compressed. In other words, the expansion factor of caved rocks positively varies with the subsidence of overburden roof strata, and its variation is also simplified to follow a linear relationship. When expansion factor, K_A, approaches one, i.e. caved rocks are nearly reconsolidated to original consolidation state, and its bearing capacity of caved rocks approximately increases to the maximum.

Thus, the mechanical relation between main roof subsidence and caved rocks supporting can be established. As shown in Fig. 1 (Part *B*), the inclined subsidence of main roof results in the non-uniform distribution of the reaction force of caved rocks to main roof. Caved rocks supporting width can be easily derived as follows:

$$L_4 = L_0\left(1 - \frac{S_A}{h}\right) \tag{2}$$

where L_0 is the lateral fracturing span of main roof (m), S_A is the main roof subsidence when touching caved rocks (m) and h is mining height (m). By using geometric equivalence relation, the expression of S_A can be obtained by using immediate roof thickness, M_Z, and mining height, h, as follows:

$$S_A = h - (K_A - 1)M_Z \tag{3}$$

Laboratory tests showed that caved rocks supporting force is an exponential function of compressive strain ratio [20–24]. In order to simplify the calculation, it is assumed that the supporting force intensity distribution is in a linear manner, varying from 0 to q_4, where q_4 is supporting force intensity of the caved rock at the location of main roof maximum subsidence. Then, caved rocks

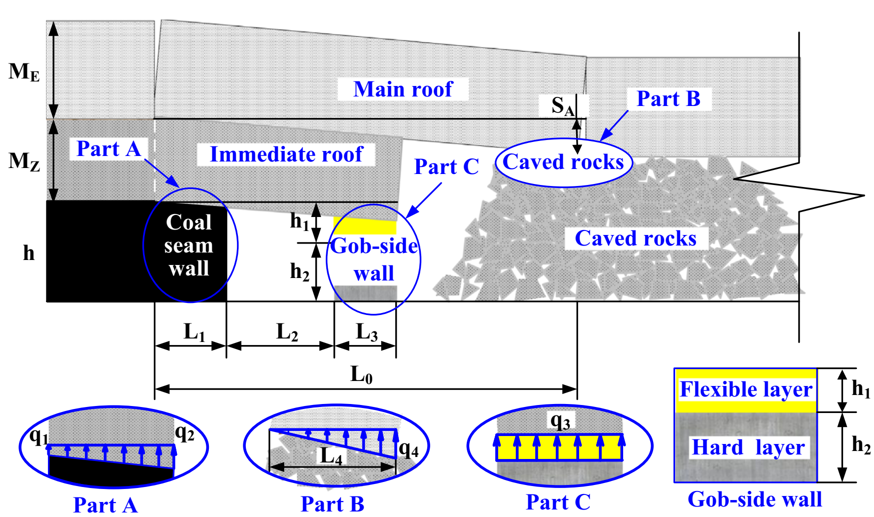

Fig. 1. "Flexible-hard" gob-side entry retaining model.