（様式２）

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論 文 題 名 : STABILITY OF RETAINED GOAF-SIDE GATEROAD UNDER DIFFERENT ROOF CONDITIONS BY LONGWALL MINING IN DEEP UNDERGROUND COAL MINE（長壁式採掘システムを用いた深部石炭鉱山における異なる天盤条件下の払跡側片盤坑道の安定性に関する研究）

区　　分 : 甲

論 文 内 容 の 要 旨

In China, coal production has been increasing quickly in recent decades with accelerating economic development and industrialization in China. Coal production makes up more than 55% of total energy consumption and produces 3.8 billion tons per year. The mining level of the underground coal mines in China is quickly becoming to be deep, which is the result of growing coal production and limited shallow coal resources, especially in East area. About 80% of the underground coal mines with a depth of more than 1,000 m are located in East China. As mining depth increases, however, it is very difficult to apply the conventional U type longwall mining system in deep mining environment, such as high in-situ stress and high gas emission environments because of decreasing coal recovery and the high risk of gas explosions at the face. Recently, Y type gateroad layout has been widely employed in deep underground longwall mining systems in order to increase the coal recovery rate and reduce the risk of gas outbursts through the optimization of ventilation systems and eliminating gateroad protection coal pillars. In this system, a previous gateroad, which is abandoned in the conventional U type settings after coal face passes by, is maintained by constructing artificial packfillings along the goaf side when the longwall face passes. The retained gateroad behind the longwall face is referred as Retained Goaf Side Gateroad (RGSG). RGSG plays a crucial role in the Y type longwall system, however, it is difficult to control due to high in-situ stress and soft rock mechanics which are prevalent in deep underground environments. Conventional roadway supporting technology cannot maintain the stability of the deep RGSG. Therefore, the purpose of this research is to develop effective RGSG supporting methods in deep mining environment under different roof conditions. The dissertation consists of six chapters and the main contents in each chapter are listed as follows:

Chapter 1: This chapter introduces the background of this research, mining technology, geotechnical issues related to this research topic and an involved outline of the dissertation.

Chapter 2: This chapter describes the roof structures over the goaf and RGSG. After the coal seam is mined, overlying main roof follows O-X breakage style orderly and periodically when the coal face advances continually. As a result of this O-X style breakage over the goaf, a rock cantilever forms over the RGSG that is located at the side of goaf. The RGSG is seriously damaged due to the movements of the roof cantilever. The thicker the main roof is and the thinner the immediate roof is, the more serious the influence is. Therefore, the optimization of the roof structure over the RGSG when it is covered by thick main roof directly is proposed by shortening the length of roof cantilever. After the main roof is pre-split along the outer edge of the packfillings, mechanical connection between the roof over the RGSG and other part over goaf is cut off, and the rotation and sink of the roof cantilever over the RGSG can be decreased considerably. Then, the damage to the RGSG due to the movement of the roof of the goaf can be reduced.

Chapter 3: This chapter discusses the alteration of stress and deformation of the rock mass around the RGSG due to an advance of the longwall face in different roof conditions by means of FLAC3D numerical software. Simulation results show that the confining stress normal to the surface of roadway surrounding rock decreases considerably and the bearing strength of the rock mass around RGSG reduces reasonably during roadway excavation. Consequently, the rock mass around RGSG breaks and deforms towards the inside of the roadway. During coal panel retreating, the influence of abutment stress induced by coal extraction can be divided into three stages: no influence farther than 40 m; severe influence from 40 m ahead of coal face to 60 m behind the coal face; slight influence from 60 m behind the coal face to 120 m behind the coal face. After experiencing these stress disturbances, the rock mass around the RGSG undergoes large deformations and the boltability of cable bolts and rock bolts in the surrounding rock of roadway becomes considerable lower because plastic zone in the rock mass around the RGSG is expanded gradually. As the thickness of the main roof increases and the thickness of the immediate roof decreases, the deformation of the rock mass around RGSG decreases during roadway excavation, however, the deformation increases considerably during coal panel retreating. The deformation of the rock mass around RGSG reaches the maximum value when the coal seam is directly beneath a hard main roof of 12 m thickness.

Chapter 4: This chapter proposes the four control measures of roadway stability including the staged supporting method, pre-split method for hard roof, grout bolting method and grouting reinforcement method. Basically, a staged supporting strategy is proposed to maintain the stability of the RGSG. In the first supporting stage, a pre-stressed bolting system aiming at providing high lateral confining stress is proposed to maintain the stability of the RGSG during roadway excavation. In the second supporting stage, a cable bolt system with a larger length is suggested within the influencing range of mining induced abutment pressure, considering the widening of the plastic zone in the surrounding rock of the roadway. In the third supporting stage, packfillings with gradually increasing strength and reinforcement to the roof over packfillings should be put into mind because of the continually increasing abutment stress behind the coal face. Pre-split technology is proposed to optimize the hard roof structure over the RGSG. Pre-split technology is applied to optimize the roof structure by shortening the length of the roof cantilever. The deformations of the RGSG surroundings are reduced considerably as expected after roof is pre-split. According to the results of simulations, a floor heave of RGSG decreases most obviously by 57%, followed by a roof sag reduction of 55%. The deformations of the left and right sidewalls are also reduced by 25% and by 24%, respectively. Improved grout bolting technology is proposed to control the large deformations of RGSG sidewalls. The final deformations of the RGSG sidewalls are still very large (more than 700 mm) although some improvements have been achieved by the application of roof pre-splitting. To control the large deformed sidewalls, a modified grout bolting technology is proposed. This modified technology not only can provides higher confining stress at the installation stage, but also controls the induced cracks more effectively and has larger bearing capacity during the followed grouting stage. These improvements play a crucial role in reducing the size of the plastic zone in the RGSG sidewalls. Grouting reinforcement is proposed to control the large heaved floor. After applications of roof pre-splitting and sidewall grout bolting technology, the deformation of RGSG floor that is not supported, plays the leading role in roadway section shrinkage again. Grouting reinforcement is proposed to reduce the floor heaves by considering the weak rock mechanics of the mudstone, and only 1 m within the floor is grouted because the heaving within 1 m of the floor strata accounts for 72% of whole floor heaving. When the residual cohesion is increased to 30%, 50% and 70% of the original value, the amount of floor heaves are reduced considerably to 273 mm, 202 mm and 194 mm from 516 mm. After grouting, the plastic zone is effectively reduced.

Chapter 5: This chapter describes the applications of four control measures of roadway stability proposed in Chapter 4 in three typical deep underground coal mines. Firstly, the staged supporting method has been applied in the Zhuji underground coal mine. After the application of this measure, deformations of the RGSG are controlled effectively. However, the right sidewall convergence and floor heave are still large so that this RGSG has to be enlarged before the second coal panel retreating. Roadway section enlarging processes including floor dinting and sidewall widening are conducted. Secondly, in order to reduce the deformations of RGSG surroundings in deep mining environment during first coal panel mining and to avoid roadway section enlarging to the RGSG before the second coal panel mining, the grout bolting method has been applied in the Pan Yidong coal mine. After installation of the grouting cable bolt, the integrity of the cracked surrounding rock is improved, and the separations in the roof strata are controlled effectively. The final profile is found to be large enough for the second longwall panel mining. Thirdly, the rock pre-split blasting method has been applied in the Pingdingshan underground coalmine of 18 m hard main roof to reduce the influence of long roof cantilever movements on the surrounding rock of RGSG. When the first coal panel extraction is finished, and it can be reused during retreating of the adjacent coal panel.

Chapter 6: This chapter concludes the results of this research.