EXTRACTION SYSTEM AND SLOPE STABILITY ANALYSIS FOR REMAINING COAL AROUND END-WALL SLOPE AT OPEN PIT COAL MINES IN CHINA

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論　文　要　旨

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論文題名	EXTRACTION SYSTEM AND SLOPE STABILITY ANALYSIS FOR REMAINING COAL AROUND END-WALL SLOPE AT OPEN PIT COAL MINES IN CHINA (中国・露天掘り石炭鉱山のエンドウォールでの採炭システムの開発ならびに斜面の安定性に関する研究)		

論　文　内　容　の　要　旨

Due to large mining depths, sometimes the stripping ratio becomes so large that some coal around the end-wall cannot be mined considering the economic factors at large-scale open pit coal mines in China. Also, to meet requirements of haul roads in the end-wall transporting system, wide transportation benches have to be left, which makes the slope angle of the end-wall slope smaller. Consequently, a large quantity of coal has to be left under the final end-wall slope. For these remaining coal resources, they will be buried again by the inpit dumping site and are impossible to be extracted once more in future. Therefore, how to recover the remaining coal around the end-wall slope with a safe and efficient extraction system before they are buried by the inpit dump is very urgent and valuable research for open pit coal mines in China. From these backgrounds, the extraction systems for the remaining coal around end-wall slopes in the open pit coal mines were proposed in this study, consisting of seven chapters as follows:

Chapter 1 introduces the background of this research including reasons for remaining coal around end-wall slopes in Chinese open pit coal mines, the foremost characteristics of remaining coal resources, study objectives, and an involved outline of the dissertation.

Chapter 2 describes some main characteristics of large scale open pit coal mines in China, and research site conditions of this study and an optimal initial slope model are given. Due to the small end-wall slope angle and large mining depth, a large quantity of remaining coal will be left under the end-wall slopes. It has been found that the remaining coal quantity is usually more than 100 Mt in most Chinese open pit coal mines; some can even reach nearly 400 Mt. Therefore, the total quantities of remaining coal in Chinese open pit coal mines are very considerable. In order to study the remaining coal extraction systems, a representative mine, the ATB open pit mine, was chosen as the research site. Based on the geological conditions of the end-wall slope in ATB open pit coal mine, an end-wall slope model was built with Phase2 software. As is commonly known, the element type, size and boundary range can obviously affect the simulation results for FEM software. Therefore, much significant research about the suitable element type, size and boundary range for slope stability analysis was implemented. Lastly, based on the optimal initial slope model, the safety factor of the initial end-wall slope in ATB coal mine is 1.52. Also, it is found that although the whole end-slope is very stable, some slight failures occur on the loess layer surface and the corner points of some benches. As a result, it has created a good condition for the end-wall remaining coal extraction.

Chapter 3 proposes a steep end-wall slope mining method, and the design methodology of the stripping ratio is described in detail. Because the stripping ratio of steep end-wall slope mining can determine the economic benefits of this method, the design methodology is described in detail. In particular, both conditions of when the thicknesses of the overburden layer and coal seam are stable and unstable for single and multiple coal seams were studied. Also, the economic benefit was analyzed after the mining method was adopted, including the annual profit and the whole profits during the steep end-wall slope mining. Based on these results, the steep slope mining was applied in benches below the No.4 coal seam in ATB mine. From the simulation results of steep mining schemes, it was found that the safety factor can reach 1.2 when the slope angles of both high benches were 70°, which can meet the safety design requirements. For this scheme, the maximum vertical downward displacement of all the haul benches was less than 30 mm; as a consequence, the displacements of the haul benches would not affect the regular transporting system. In terms of the hazardous zones of the slope, it can be seen that some failures occurred on the loess bench slope due to the weak mechanical properties of loess; other failures were located in the corners of the benches because of the stress concentration in the corners. Overall, these small-scale failures would not affect the stability of the end-wall slope and safety of haul benches. Finally the profit of steep slope mining in ATB mine was checked, and the results showed that this method had obvious benefits. However, the coal recovery quantity of this method is limited, and a majority of the remaining coal is still discarded. Therefore, an alternative mining system has to be introduced to extract the remaining coal under such conditions in a manner that is safe, economical and efficient.

Chapter 4 discusses an adit-strip pillar mining method, and the strip pillar width, mining strip width and shift analysis of adits are well provided. The design method of the main parameters for the system was studied, such as the mining strip width, coal pillar width, and shift analysis of the adits. For the adit-strip mining system in open pit mines, lower initial investment and mining and transportation costs are available, and the economic benefits are good. In addition to that, based on the progressive failure theory and tributary area theory, the coal pillar design methodology of the adit-strip mining system was studied. The coal pillar width equations were proposed. Meanwhile, the relation between the width of the yield zone and the thicknesses of the coal seam and cover in ATB mine was obtained. It was indicated that the coal pillar width would increase with increases in the mining strip width and mining height. However, the coal extraction ratio can be increased. Therefore, in order to improve the coal extraction ratio, we should increase the values of the mining height and strip width as much as possible under the suitable conditions. Furthermore, the reasonable mining height and mining width of the adit-strip system in ATB mine were obtained. The equation of the maximum shifting cycle for two adits was obtained. Meanwhile, if the two adits cannot be shifted in time, the normal advance of the working bench of the inpit dump near the end-wall slope side will be affected. It can be seen that the inpit dump occupied volume by the adits has a linear relation with the distances of the six pyramid pits in the directions of the end-wall slope and inpit dump working slope, and it has a power function relation with the adjacent height of the inpit dump, end-wall slope angle and the working slope angle of the inpit dump.

Chapter 5 studies the reasonable widths of strip and boundary pillars for the adit-strip system by numerical simulation. For the adit-strip system of a single coal seam, it was found that the strip coal pillar of a medium-thick coal seam and thick coal seam can be calculated by the Mark-Bieniawski equation. Meanwhile, the strip coal pillar width of a thin coal seam calculated by the Holland-Gaddy equation is acceptable. As a result, the strip coal pillar of Nos.4, 9 and 11 should be 13, 29 and 9 m, respectively. Meanwhile, for the adit-strip system of multiple coal seams, large-scale failures occur on the roof rocks above the coal seams and bring a large vertical downward displacement of the haul benches for the unequal width mining type. On the other hand, only small-scale caving zones occur in the roof rock layers and have acceptable vertical downward displacement for the equal width mining type. As a result, the mining strip width and strip coal pillar of Nos.4 and 9 multiple coal seams systems is 40 m and 24 m, respectively. Also, for the adit-strip system of a single coal seam in ATB mine, the boundary pillar of Nos. 4, 9 and 11 in ATB mine should be 45, 50 and 45 m, respectively. For the adit-strip system of multiple coal seams in ATB mine, the boundary pillar of Nos.4 and 9 coal seams should be 75 and 40 m, respectively. Then, the adit-strip pillar mining system can extract 6 Mt remaining coal and gain 126 M$ profits more than the steep slope mining method in ATB mine.

Chapter 6 concludes the results of this study.