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論文題名：APPROPRIATE DESIGN OF LONGWALL COAL MINING SYSTEM UNDER WEAK GEOLOGICAL CONDITIONS IN INDONESIA（インドネシアの軟弱地山を対象とした長壁式採炭システムの最適設計に関する研究）

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論　文　内　容　の　要　旨

Indonesia is one of the largest coal producers and exporters in the world. The coal production of Indonesia has increased significantly in recent years. Indonesia exports 70%-80% of the total coal production abroad and the remaining is consumed in domestic markets. In Indonesia, the coal is mainly produced from the surface mines. Recently, the conditions of surface mines have worsened each year because stripping ratio has increased due to the increase in mining depth. The resource of high quality coal located in accessible areas has decreased due to the rapid expansion of coal production. Moreover, the development of a new surface mines is constrained due to its environmental impacts and protection law. Therefore, in order to meet the increased demands of the coal, underground coal mines have to be developed in Indonesia. According to the experiences of underground coal mining in Indonesia, due to the coal measure rocks becoming very weak and the design guidelines of underground mining under weak geological conditions not being developed, ground control issues have occurred frequently. As a result, some underground coal mines have been abandoned. From these backgrounds, the purpose of this research is to develop an appropriate design guideline of underground mining system under weak geological conditions. To accomplish the purpose of this research, The PT Gerbang Daya Mandiri (GDM) underground coal mine in Indonesia, where the rocks are weak and the coal is planned to be mined by the longwall mining method, is chosen as the representative mine site. This 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, geotechnical issues and technology related to the longwall mining method, and objectives and outlines of the dissertation.

Chapter 2: This chapter describes the conditions of the PT Gerbang Daya Mandiri (GDM) mine site. Based on the results of laboratory tests, the rocks of this underground coal mine are classified into very weak and low strength rock masses. Furthermore, this chapter also discusses the current situation of the main roadway stability at the shallow depth. According to the field measurement data, a small roof displacement occurs when the roadway is excavated in the undeteriorated claystone, and when the coal layer is present in the roof. The current support system using the steel arch SS400 with 1.0 m spacing is effective to control the main roadway stability, although, a very large roof displacement occurs when the roadway is excavated in the deteriorated claystone. Under this situation, the use of stronger steel arch SS540 with 0.5 m spacing should be adopted.

Chapter 3: This chapter focuses on the stability analysis and support design of the main roadway prior to longwall mining at the deeper depth. The stability of the main roadway at the GDM coal mine under various depths and stress ratios is studied by means of numerical simulations. According to the results of a series of numerical simulations, the stability of the main roadway decreases by increasing the depth and stress ratio. Ground control problems such as falling roof, sidewall collapse, and floor heave can be expected unless an appropriate support system is provided. Three support systems, i.e. friction rockbolt, steel arch (SS540), and shotcrete, are discussed as methods to stabilize the roof and sidewalls of the main roadway. The steel arch is considered to be the most effective support system comparing with other systems. The steel arch meets the qualifications of stability control. The steel arch with closer space and larger size of cross section provides a better stability condition to the roof and sidewalls of the main roadway. Although the stability of roof and sidewalls of the main roadway can be controlled by steel arch support, the occurrence of floor heave can be expected according to the increase of mining depth. Therefore, three techniques using cablebolt, invert-arch floor, and grooving method are selected and discussed in order to control the floor heave. Heaving of the floor is controlled effectively after the cablebolt, invert-arch floor, and grooving methods are employed. However, controlling the floor heave by cablebolt support may be the most appropriate technique in GDM coal mine compared with other methods in terms of installation process, providing a flat and safe working condition of floor, and economy. In addition, the cablebolt with closer row space and longer length works more effectively to control the floor heave.

Chapter 4: This chapter studies the effect of longwall mining on the stability of main and gate roadways at GDM coal mine. According to the results of a series of numerical simulations, the extraction of longwall panel significantly affects the main and gate roadway stabilities. The stability of main or gate roadways decreases by decreasing the barrier or chain pillar width, especially when a wide panel width of 130 m is applied. Here, the barrier pillar is the coal pillar left between the longwall panel and main roadway and the chain pillar is the one left between the adjacent longwall panels. Ground control issues are to be expected under the event that an appropriate width of barrier/chain pillar is not provided. In the case that the main and gate roadways are supported by 0.5 m spaced steel arches (SS540), a 20 m barrier pillar width and a 30 m chain pillar width can be used sufficiently at 50 m, 100 m, and 150 m depth, while a wider barrier pillar width of 35 m and a wider chain pillar width of 50 m should be applied at 200 m depth in order to keep the main and gate roadways stable during the extraction of longwall panel, respectively. The simulation results also reveal that the effect of a longwall panel extraction on the stability of main and gate roadways can be minimized by decreasing the width of a longwall panel. By applying a narrower longwall panel, not only the main/gate roadway stability can be improved, but also a smaller barrier/chain pillar width can be adopted. At a 200 m depth, the stability of the main roadway can be controlled effectively by a smaller barrier pillar width of 20 m, while the stability of gate roadway can be maintained efficiently by a smaller chain pillar width of 30 m, when a narrower panel width of 100 m is applied. Therefore, as the mining depth is increased, the coal recovery can be increased under the better mining conditions by applying narrower panel width.

Chapter 5: This chapter discusses the surface subsidence induced by extracting longwall panel at GDM coal mine. The characteristics of surface subsidence induced by single-panel and multi-panel mining under various depths are discussed. Based on the results of a series of numerical analyses, a large surface subsidence can be expected at all mining depths (50 m, 100 m, 150 m, and 200 m) when a wider panel width of 130 m is applied. When a single panel is extracted, a larger surface subsidence occurs at the shallow depth; therefore, a narrower panel width should be applied at the shallow area. After several panels have been mined in a series, the surface subsidence increases with increasing mining depth. This indicates that a wider chain pillar is needed at the deeper depth. In order to control the surface subsidence, three countermeasures, i.e. applying a wider chain pillar, a narrower panel width, and a backfilling system, are investigated. As a wide panel width of 130 m is applied, a large surface subsidence still occurs at all depths, even though the chain pillar width is increased from 30 m to 60 m. From these results, it can be considered that the width of longwall panel should be decrease and/or a backfill system should be applied in order to control the surface subsidence. The surface subsidence decreases significantly by decreasing the panel width. A small chain pillar width of 30 m can be used sufficiently at all depths when a 100 m or 70 m panel width is applied. Although the surface subsidence can be controlled effectively by decreasing the panel width, a decrease in coal recovery can be expected when a narrower panel width is used. On the other hand, the surface subsidence can also be controlled effectively by using a backfilling system with cohesive material. A small surface subsidence occurs after backfilling. The simulation results also indicate that a backfilling system with cohesive material may be the most appropriate countermeasure for control surface subsidence and the coal recovery can be increased because a narrow chain pillar width of 30 m can be used with a wider panel width of 130 m. Moreover, based on the results of a series of numerical simulations, the prediction curves for the maximum subsidence due to the extraction of longwall panel in GDM coal mine was proposed. Besides, the measure for rehabilitation of subsided area is also discussed.

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