（様式２）

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論文題名：DEVELOPMENT OF LONGWALL MINING SYSTEM FOR STEEPLY INCLINED COAL SEAM AND ITS COUNTERMEASURES IN MONGOLIA（モンゴルにおける急傾斜炭層を対象とした長壁式採掘システムの開発とその対策に関する研究）

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論　文　内　容　の　要　旨

Mongolia has extensive geological coal resources, which are estimated to be approximately 162 billion tons. Total coal production is averaging between 55Mt and 60Mt, with 35Mt annually being exported to China. Due to unfavorable geological and economic conditions, especially steeply inclined coal seams, many open pit coal mines in the South Gobi regions are intended to transition from open pit to underground. It is inevitable and essential to present proper guidelines on the design and countermeasures for the steeply inclined coal underground mining method in transition areas. According to this background, developing an underground mining system, particularly the longwall mining method, for steeply inclined coal seam extraction is considered an effective means of enabling rapid transition and securing coal production in open pit coal mines in some regions close to China. This is an urgent issue that should be addressed through this study. Therefore, in this study, the design and maintenance measures for the optimal gateroads, underground excavations and longwall panels in steeply inclined coal seams are investigated by means of numerical analysis.

Chapter 1 introduces the current situation of the coal industry in Mongolia and the rest of the world as well as applicable mining methods and their principles and criteria. Moreover, the advantages and disadvantages of the longwall mining method and a brief introduction of support systems for gateroads and longwall faces have been presented. Research objectives, expected contribution to the coal mining field and thesis outlines were included.

Chapter 2 aims to present some essential conditions of analysis, such as in-situ stress conditions and possible lateral stress ratios that can be applied in numerical simulation and rock mass quality assessment. According to borehole data and other geological reports of the Narynsukhait coal mine, the rock mass rating system has been used to evaluate rock mass strength in certain quantities. Based on tentative assessment work, RMR (Rock Mass Rating) and GSI (Geological Strength Index) values were calculated as 45 and 40, respectively. These values show that rock mass can be classified as fair rock and class III. Also, some information on the research field has been referenced in this section.

Chapter 3 investigates the stability of gateroads and effectiveness of passive and active type supports ahead of longwall panel retreat by means of FLAC3D. In terms of longwall face direction, “along the strike” was proposed and gateroads and panels are driven horizontally, which can tackle many problems related to stability issues. Various seam dips, mining depths, in-situ stress conditions and rock deterioration approaches have been considered in analysis, and the effects have been discussed in each section. The effect of several seam dips is negligible, while mining depths significantly affect the displacement and fracture zone. Moreover, the rock mass

condition has dramatically worsened in the case of lateral stress ratio “K-ratio” increases from 0.5 to 2.0. It shows that the higher stress ratio and horizontal stress regime result in high displacement and large fractures around underground openings. Although passive type support, such as a steel arch, is more effective than active type support, like a rock bolt, steel arch support has adverse impacts in which it resists the airflow through the openings and elevates the risk of accumulation of methane gas and spontaneous coal combustion. Additionally, installation is relatively expensive and complex.

Chapter 4 discusses the effects of the various geotechnical and geological conditions and face support characteristics in three different phases; ahead of the panel retreat, half of the panel retreats, and the entire panel retreats. Similarly, seam dips do not substantially influence gateroad stability, while the mining depths and lateral stress ratios are significant. Otherwise, due to the mechanical properties of the intact rock mass used in laboratory experiments, the analysis results seem relatively stable and safe. Therefore, in order to make the numerical analysis conditions similar to actual site characteristics, rock mass deterioration by reducing the GSI value by 25% and 50% has been utilized, resulting in dramatically worsened mining conditions. Moreover, the fully mechanized shield support and choke shield support are not appropriate for steeply inclined longwall coal mining because of their massive weight and technical difficulties associated with stabilizing in an inclined face. Thus, hydraulic prop, a common example of manual support, was employed in face excavation. Even though initial conditions of stress, depth and seam dip were varied, the beam axial stress and vertical displacement of prop support installed in the face with certain spacing have been distributed systematically along the face direction. However, after deteriorated rock mass was applied in analysis, the condition of the lower end of the longwall face drastically worsened, and beam axial stress increased substantially.

Chapter 5 discusses the relationship between the orientation of gateroad and major horizontal stress. In a variety of historical data, when the gate entries intersect the major horizontal stress direction, a high frequency of serious rock failure and damage has been observed. So, designing an adequate gateroad layout that involves the orientations and high horizontal stress direction can be a key factor in improving safety issues associated with ground control and stability, as well as enhancing the economic diversity of underground coal mining projects, especially in terms of longwall mining. Three different phases were considered; the K-ratio is 1, the gateroad intersects and is parallel to the major horizontal stress direction. In that case, high horizontal stress intersecting with the gateroad dominantly results in serious deformation and large fracture zone propagation in the surrounding rock mass, particularly on the roof and floor. For the Narynsukhait coal mine, it is more appropriate that the longwall face direction can be in-between “along the strike” and “down the seam dip”. By applying this design of face direction, there will be numerous advantages that can be followed up on. Although the gateroad becomes inclined, the inclination of the longwall can be reduced and provide an opportunity to mitigate the adverse impacts of the orientation of the gateroad and high horizontal stress.

Chapter 6 concludes the results of the research.