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論文題名：STUDY ON THE OPTIMIZATION OF DUMPING DESIGN FOR OPEN PIT METAL MINES IN MONGOLIA: A CASE STUDY OF THE ERDENET MINE (モンゴルの露天掘り金属鉱山における廃石堆積場の最適設計に関する研究:エルデネット鉱山を事例として)

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論　文　内　容　の　要　旨

Deeper and larger scale open pit mines have developed in last 10 years and mainly operate in copper ore and hard coal mines in Mongolia. The depth of open pit mines was mainly less than 150 m before the 2000s. However, the depth and scale of open pit mines has been increasing with mining capacity, mineral products and high economic growth in major projects. Most deposits were explored and feasibility studies were conducted before the 1990s. The main problems in these open pit mines commenced before the 1990s are optimizations of their mine designs including locations of waste dumps and other surface structures based on the results of feasibility studies and other studies developed on different politics and economic situations. The estimations of price increases of mineral products and future growth of resources are not compatible with the current economic and technical conditions. Furthermore, the geotechnical and geological data are insufficient for many deposits. In order to develop appropriate open pit and waste dump designs, these investigations must be conducted. In addition, the geotechnical and economic data has to be collected and optimizing their open pit and dumping area from slope stability and economic points of view are urgent issues for further developments of open pit mines. From these backgrounds, this study described and discussed the optimization of waste dumping considering stability and economical situations.

This dissertation consists of seven chapters in which the contents are described as follows:

Chapter 1: describes conditions of the country and mining sector in Mongolia, problem descriptions of open pit mines and the general background of studies including the processes of optimization procedures of open pit mining and dumping, a problem description and literature reviews and a survey of previous studies. The objective and outline of this dissertation were introduced.

Chapter 2: describes the research site condition of the Erdenet Cu-Mo Mine such as geological and operational conditions and problem descriptions. The Erdenet Cu-Mo deposit is the biggest porphyry copper-molybdenum deposit in eastern Asia and the majority of the state budget being created as the main pillar of the country’s economy. Based on the current world price of mineral products and conditions of economic situations, it is necessary to optimize the Erdenet open pit mine boundaries, to explore the possibility of mining operations below 905 m and to optimize the location and design of dumping areas and surface structures in relation to the pit boundaries. Having taken insufficient geotechnical and operational investigations and economic data analyses, the planning and stability problems of the open pit mine and waste dump area in the Erdenet mine are considered from the perspective of mining activity. Reviewing current planning, management and developing corrective actions are required in order to design and optimize an appropriate open pit and waste dumping area.

Chapter 3: discusses about the determination of the ultimate pit limit of the Erdenet Cu-Mo deposit and an open pit optimization studies based on the current price of mineral product, the revised geological models and rock mass characterization. The size, location and final shape of an open pit should be optimized based on prospective production prices and open pit revenue factors which are important in planning the location of waste dumps, stock piles, processing plants, access roads and other surface facilities. The current concept of the Erdenet mine has a total of 950 million tons of ore at the open pit mine depth at 905 m above sea level. The results of a pit optimization analysis showed the possibility of

open pit mine depth considering stability conditions reaching the elevation of 780 m above sea level. This means that another 125 m depth can be developed and more than 550 million tons of ore can be extracted under the current conditions of the Erdenet mine. The average dip of final pit slope should also be changed from 40 degrees to 35 degrees. From these results, the total amount of waste rock increases about 20% compared with that of the previous mining design. Moreover, the pit boundary is going to expand and almost reaches to the current waste dumps. Therefore, the replace of current waste dumps are urgent issues in this mine. Hence, for future development of the Erdenet mine, the appropriate design of waste dumping area including the stability of waste dumps, the buffer zone between the pit boundary and waste dumps, the construction procedures of waste dumps, has to be developed.

Chapter 4: discusses the formation mechanism of waste dump. It consists of experiment methods and results, and simulation for the effect of dumping operations on stability of the dumping area. A series of experiments and numerical simulations were performed to determine the formation mechanisms on stability of the dumping area. The design for blasting is modified to make the particle size of waste smaller. From the results of stability analysis in regards to different dump heights, the stability of the dumping area slightly decreases with increasing height of the waste dump. Meanwhile, the volume capacity of the dumping area increases as the height of the waste dump increases. The total capacity requirement of the dump can be reached at 200 m of height. The height of bench can be as high as possible, up to the allowed safety values of workers and working equipment. Another simulation was conducted about the stability of 200 m of height dump design with different dump benches. The simulation provides the bench height of 100 m for two benches and safety berms increase by a 20 m interval in 30 m to 110 m berm width to simulate the relationship between width of safety berm and stability of the dumping area. In the selection process of the dumping area, a gentler floor is better than steeper one. Designs of the dumping operation must consider the total efficiency of ground leveling, operation and formation works of dumping area.

Chapter 5: Waste dumps adjacent to the pit gives advantage in regards to waste hauling cost. However, from the geotechnical point of view, constructing a waste dump alongside the pit should be planned well particularly distance between final pit's boundaries to waste dumps which is referred as a buffer zone. This chapter discusses about buffer zone's design for a particular pit wall as well as a waste dump configuration. From the results of simulations, in case the waste dump was located adjacent to the pit boundaries, as the load of waste dump affects the pit wall, the high shear strain zone was formed from the toe of the pit wall to the top of the waste dump, and then, in worst case, the occurrence of a large slope failure can be expected along the high shear strain zone. On the other hand, the size of a high shear strain zone and the value of shear strain decreases with increasing the length of buffer zone obviously and then SRF (Strength Reduction Factor) of pit wall is increased. Therefore, the stability of pit wall and waste dump can be improved by installation of buffer zone and the length of buffer zone should be determined so that the high shear strain zone of pit wall is not connected with that of waste dump.

Chapter 6: describes a methodology to model and optimize the design of a mine dump by minimizing the total haulage cost in order to optimize fleet efficiency and utilization through a detailed haulage analysis and to identify any potential cost savings available within the dumping operation of the Erdenet mine. The methodology consists on the optimization of a dump model based on multiple relevant parameters and solves by minimizing the total cost using programming and determines a preliminary dumping design. The detailed material movement, haulage analysis and cost modeling were generated for different dumping heights and dumping directions from the far side to the near side of the pit boundary and vice versa. For example, in case of 100 m dumping height, the dumping cost in both dumping directions were relativity low and no obvious differences between two scenarios. On the other hand, in case of 200 m dumping height, the dumping cost was larger than that of 100 m dumping height. Moreover, the dumping cost when the damping direction was from the far side to the near side of the pit boundary was larger than that when the dumping direction was from the near side to the far side of the pit boundary. From these results, in case that the area of dumping site is limited, the dumping cost is increased due to the increase of dumping height and the dumping direction has an obvious impact on it.

Chapter 7: concludes the results of this research.