（様式２）

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論文題名： STUDY ON ASSESSMENTS AND COUNTER MEASURES FOR THE STABILITY OF STOPE DUE TO THE PREVIOUS MINED-OUT ACTIVITIES IN CUT-AND-FILL UNDERGROUND GOLD MINE IN MYANMAR（ミャンマーの充填式採掘法を用いた坑内掘り金鉱山における採掘空洞の安定性に及ぼす採掘跡地の影響評価およびその対策に関する研究）

区　　分：甲

論 文 内 容 の 要 旨

In Myanmar, as the development of high-grade ore existing in the shallow area becomes to be important in recent years, the cut-and-fill method is suitable among the various underground mining methods for maintaining the stability of working stope and minimizing the impact of mining activities on the surface. Since the stope is filled with backfilling material such as waste rock, cut-and-fill method is a method that can control the stability of rock mass around the mined-out area and prevent surface subsidence. Hence, the environmental impacts due to the mining activities become to be small. Besides, the sill pillar is the ore that is left below the mined-out stope to prevent the collapse of working stope. The ore between surface and stope is also left as the crown pillar to maintain the stability of working stope and prevent the occurrence of subsidence. Modi Taung gold mine which is targeted in this research is one of the largest underground gold mines in Myanmar and applies as an overhand cut-and-fill method. Since the rock mas condition in shallow area is poor and mechanical properties of rocks is weak, not only much supports have to be installed in the working stope but also a plenty of ore has to be left as sill pillar and/or crown pillar in order to maintain the stability of working stope and control surface subsidence. Moreover, the conditions of previous mined-out area also have an obvious impact on the stability of working stope and surrounding rock mass. From these backgrounds, the purpose of this research is to develop appropriate design guidelines and effective stabilization measures for sill pillar and crown pillar considering with the influence of previous mining activity. An attempt has been made to investigate the optimum design for sill and crown pillars and the effectiveness of stabilization measures by means of FLAC3D. This dissertation consists of six chapters and the main contents in each chapter are listed as follows:

Chapter 1: This chapter describes the mining industry in Myanmar, the background of this research, the overview of cut-and-fill mining method, the factors influenced on the stability of stope and subsidence and then the overview of problem statements in this research area. The objectives and the outline of the dissertation is also described in this chapter.

Chapter 2: This chapter describes the mining conditions of Modi Taung gold mine. The exploration works for this mine area have been conducted since 1996. The gold deposit is hosted in the sedimentary units of the Mergui Group, which is mainly composed of mudstone, sandstone, limestone and igneous intrusions. The cut-and-fill mining method is applied in this mine. Based on the results of laboratory experiments, the intact rocks in this underground mine are strong. However, according to the field observation and bore hole core logging, the rock mass in this mine has many discontinuities. From the results of laboratory tests and field investigations, it can be found that the rock mass condition in this mine site is very poor condition within 30 m depth from the surface, and poor to fair condition deeper than 80 m depth from the surface. Additionally, as heavy rain is a common in this mining region, the conditions in the underground openings at Modi Taung gold mine are very humid with meteoric water seeping through the geological structures. As a result, weathering of the rock mass and backfilling material in the previous mined-out area was found and these conditions should be paid attention to the safety in order to prevent accidents due to the instability of rock mass around and inside of the stope.

Chapter 3: This chapter discusses the effect of previous mined-out area on working stope. The mining operation in Modi Taung gold mine has been developed in shallow regions so far due to their easy access. Hence, the mining activities are going to extend the deeper levels below the previous mined-out area. Accordingly, a new stope developed below the previous mined-out area is influenced by not only its own induced stress but also the stress redistributions from the previous mined-out area. In order to evaluate the stability of working stope below the previous mined-out area, a series of numerical investigations are carried out in different geological and mining conditions in order to fully understand the stability of the stope and sill pillar due to the influence of previous mined-out activities. From the simulation results, it can be found that the stability of rock mass around the stope obviously decreases with progression of the stope operation towards the upper slices, and then the failure zone propagates to the upper previous mined-out area. Therefore, the sill pillar should be left at least 3 m in thickness in order to stabilize the working stope for safe operation. The stability around the stope also decreases when the distance between the working stope and previous mined-out area is larger than 5 m, the monitoring of the rock mass around the stope should be conducted. As the feasible instability of rock mass is likely to occur more in lower vein dip, more severe geological conditions, wider stope width and higher horizontal-vertical stress ratio, wider sill pillars are required. Moreover, when the mining activities are carried out below the previous mined-out area, the effect of the conditions of backfilling material in previous mined-out area such as the deterioration of backfilling material and surrounding rock mass, filling rate with backfilling material, have to be taken into account. For the considerations of the deterioration of backfilling material in the previous mined-out area, in the case that the mechanical properties of backfilling material decrease to 25 %, the thickness of sill pillar should be more than 3.5 m as the area of unstable rock mass around the stope and pillar increases. In addition, in the case of no backfill condition during mining activities in previous mined-out area, the sill pillar should be left more than 4 m in thickness in order to ensure the stability of the sill pillar and working stope under the previous mined-out area. From the above results, it can be concluded that not only geological and mining conditions but also the condition of mind-out area have an obvious impact on the stability of the working stope. Therefore, the condition of mined-out area adjacent of the working stope has to be investigated before designing the sill pillar and the support of the working stope.

Chapter 4: This chapter discusses the effect of the mining activity on the stability of the slope surface in different geological and mining conditions because most of the primary deposit of metal mines in Myanmar are located in mountainous regions and the stopes have been developed close to the slope surface. From the results of a series of numerical simulations, it can be found that rock mass under the slope surface is affected by unequal differential stress due to the weight of overlaying rocks, the instability of rock mass around stope arises and the failure zone can develop around the mining activities increase with decreasing the distance between stope and slope surface, especially in case that the distance is less than 25 m. Subsequently, mining activities under slope topography are affected more by the variation of stress and failure zones than other places of rock mass due to the influence of the slope condition. Moreover, as the failure zones around the stope are propagating to the slope surface when the distance between the stope and surface is less than 15 m. The subsidence of the slope surface may occur, and subsequently it may induce a slope slide. Therefore, the crown pillar should be left more than 20 m in thickness. Additionally, the monitoring should be conducted when the distance between the stope and stope surface is less than 25 m in order to detect ground movement and prevent subsidence of slope and slope slide.

Chapter 5: This chapter discusses the countermeasures for maintaining the stability of the stope and surrounding rock mass affected by the previous mined-out activities and the slope surface. Two types of countermeasures, the installation of a cable bolt and shotcrete, are selected and used to improve the stability of stope and pillars. From an economical point of view, the installation of a cable bolt is preferred to that of shotcrete due to its lower cost and faster installation, however the countermeasure with higher supporting capacity should be considered where the potential of rock failure is large. From the results of a series of numerical analyses, in the case where a new stope is developed below the previous mined-out area, it can be made clear that even though the stability of the rock mass around stope can be improved by the installation of cable bolts, the stability of sill pillar is not improved obviously and more than 3 m thickness of the sill pillar still needs to be left. On the other hand, the installation of shotcrete can improve the stability of the rock mass around the stope effectively and the thickness of sill pillar can be decreased from 3.0 m to 2.5 m. Moreover, it is also effective in wider stope and higher stress conditions. When the stope is developed near the slope surface, it can be said that the installation of cable bolts has no obvious impact on the stabilities of stope and slope surface. On the other hand, the installation of shotcrete can effectively improve the stability of the crown pillar the thickness of crown pillar can be reduced from 20 m to 10 m. Therefore, it can be concluded that the optimum mining operation can be done according to the grade of ore by applying shotcrete.

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