（様式２）

氏　　名：Cho Thae Oo　（チョウ　テ　ウー）

論文題名：APPROPRIATE DESIGN OF UNDERGROUND MINE FOR VEIN TYPE TIN-TUNGSTEN DEPOSITS IN MYANMAR（ミャンマーにおける鉱脈型スズ－タングステン鉱床の最適坑内採掘設計に関する研究）

区　　分：甲

論　文　内　容　の　要　旨

Myanmar is rich in mineral resources such as base metals and rare earth elements and is one of the major tin and tungsten producing countries in the world. Although large-scale exploitation of Myanmar's mineral deposits began in the mid-1970s, many deposits of these mineral resources found in Myanmar so far have still not yet been developed. Many of the major mines currently in operation were developed in the early 20th century, others are still unplanned. Most of the operating mines are small-scale and manual extraction is conducted. In order to increase the production and maintain stable supplies of mineral resources, it is indispensable to expand the mining scale and improve the mining efficiency by mechanized operations in the future. The stability of underground excavations has become an important issue in the underground mining operation due to mine enlargement and extraction of deeper mineral resources. Open stope mining method and cut-and-fill mining method are commonly used as underground mining methods for vein type deposits. However, the application of open stope and cut-and-fill methods for underground mining generally encounter failures due to the geological structure and high regional stress condition. Although the stoping method is influenced by environmental effects related to the induced stress of natural conditions, the structure and geometry of the quartz-vein type, which is a typical (Sn-W) deposit in this study area, could also have influence. Controlling the stability of stope is crucial, not only for the safety of the mineworkers and equipment but also for preventing the environmental damage due to the mining activities. For this reason, it is an urgent task to study and introduce an environmentally friendly mining method that can minimize the environmental impact due to the expansion of the mining scale. The Hermyingyi Sn-W mine which is targeted in this research is one of the major Sn-W mines in Myanmar located in the Daewi region. In this mine, greisen and mineralized quartz veins are extracted by the overhand open stope mining method. However, the mining method is still small scale by manual operations. Due to the high grade of Sn-W deposits in this area, it is necessary to expand the cross section of the mining face for introduction of equipment in order to increase the production and improve the safety. From these backgrounds, the purpose of this research is to understand the geotechnical features of vein type Sn-W deposits and to develop an appropriate design of underground mine by means of field investigations, laboratory tests and numerical simulations with FLAC^{3D} ver. 5.0 and Phase^{2} ver. 7.0 software. 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 and the general information of Sn-W deposits in Myanmar, the background of this research, the types of mining methods for vein type deposit and their features, the factors influencing the stability of stope and subsidence due to the underground mining activity. The outline of the dissertation is also described in this chapter.

Chapter 2: This chapter describes the mining conditions of Hermyingyi Sn-W underground mine. The exploration works around this mine area have been conducted in the 1900s. The mining area is located in the southern part of Myanmar which is characterized by complex tectonic structure exacerbated by the Sagaing fault which crosses the mine site. According to the geological setting, the host rocks are Mergui (meta-sedimentary) group, alluvial, and Irrawaddy formation. The major granite and associated Sn-W Deposits is in the Southeast Asia Tin Belt. The Sn-W ores occur in granite, aplite, pegmatites, greisen, and quartz veins. The overhand open stope mining method is applied in this mine with small scale and manual excavation. From the results of field investigations and laboratory tests, it was found that the rock mass condition in this mine site is very poor due to the fracture system especially at shallow depth. The problem statement of the research area, which is associated with the current mining method being used, and the objectives of the research are also presented in this chapter.

Chapter 3: This chapter discusses the stability of the stope and sill pillar for a single vein extraction in different geological and mining conditions. The sill pillar is the ore/rock mass left between the adjacent stopes in order to prevent the collapse of working stope. The open stope mining method and cut-and-fill mining method are considered to be applied. From the results of a series of numerical simulations with FLAC^{3D}, it was

found that the stabilities of the stope and sill pillar are decreased significantly with decreasing Geological Strength Index (GSI) of rock mass, increasing the width of the stope and the stress ratio of the horizontal ground stress to the vertical one. In cases where the GSI of a vein and hanging wall and footwall rock masses are smaller than 38, the open stope mining method cannot be applied and the cut-and-fill mining method has to be applied in order to maintain the stabilities of the stope and sill pillar. Moreover, in the current mining condition that the GSI is around 30, the dip of the vein is 80 degree, the height of the mining section is 40 m, the stress ration is 1.0, the depth is 150 m, if the width of stope is changed from 2.0 m to 5.0 m, the cut-and-fill mining method with waste rock fill should be applied and the sill pillar should be left at least 10 m in thickness.

Chapter 4: This chapter discusses the stability of the stope and the crown pillar in different geological and mining conditions in order to extract shallow deposit by using Phase^2. The crown pillar is the ore/rock mass remained between the uppermost stope and the surface in order to prevent surface subsidence due to the mining activities. From the simulation results, in the case that the rock mass condition is less than 55 in GSI, and the dip of the vein is gentler than 70 degree, the stabilities of the hanging wall of the stope and the ground surface are decreased significantly. Especially, in the case that the rock mass condition is around 30 in GSI and the overhand open stope mining method is applied, as the failure zone around the stope is expanded and reach to the surface, 30 m or more thickness of crown pillar has to be left in order to prevent the surface subsidence due to the mining activities. Based on these results, the applications of support systems such as rock bolt and shotcrete and backfilling system were discussed as countermeasures for stabilities of the stope and the crown pillar. As the stope is supported by 5 m length of cable bolt and shotcrete, the thickness of crown pillar can be decreased from 30 m to 25 m. Moreover, as the stope is backfilled with cement and waste rocks, the crown pillar can be decreased up to 20 m. It can be concluded that the optimum mining operation can be done according to the grade and/or price of ore by applying these countermeasures.

Chapter 5: This chapter discusses the appropriate mining method for extraction of multiple veins in different geological and mining conditions by means of Phase^2. In the case that the rock mass condition is around 30 in GSI, the depth is150 m, the dips of veins are 70 degree, the width of the stope is 5 m, the stabilities of the adjacent stopes is dramatically decreased when the distance between them is less than 15 m. Therefore, 5 m length of rock bolts have to be installed with 1 m spacing in the hanging wall and footwall of each stope. Moreover, when the shallow deposit is extracted, in situations where the rock mass condition is around 30 in GSI, the dips of the veins are gentler than 60 degree, the stabilities of the hanging wall of the uppermost stope and the ground surface are decreased obviously and the potential of surface subsidence becomes high. In this condition, the uppermost of the veins can be extracted with cable bolts and shotcrete applied. After an artificial strong layer is formed by backfilling the uppermost stope with cement paste, the lower veins can be extracted. By applying this countermeasure, the effect of mining activities of multiple veins extraction on the surface can be controlled and the stability of working stope can be improved.

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