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論文題名：STUDY ON THE APPLICATION OF PIPE JACKING TECHNOLOGY TO PIPELINE CONSTRUCTION IN COLD REGIONS (推進工法の寒冷地における管埋設への適用に関する研究)

区　　分：甲

論　文　内　容　の　要　旨

It is increasingly important to rationally utilize underground space in consideration of sustainable development of cities such as subways, sewage systems, electricity, gas, and utility tunnels. Pipe jacking technology has been widely used in underground construction all around the world. Meanwhile, as the expansion of economic activity range of human being, the development of energy resources and the construction of infrastructure have greatly increased interest related to frozen ground development especially in the Northern Hemisphere, such as in Northern Europe, Russia, Northern China and Northern America. Yet, to date, there is little researches focused on the application of pipe jacking technology in frozen ground. From this background, the purpose of this research is to investigate the geotechnical issues when pipe-jacking technology is applied to pipeline construction in frozen ground and to develop the guidelines for its application and control technique. Namely, this thesis mainly focuses on the key technical points which may occur as pipe-jacking technology applies to pipe line construction in frozen ground, such as tunnel face stability, ground behavior and the estimation of jacking force, etc. In order to achieve those goals, a series of numerical simulations and comparative analyses with theoretical solutions were conducted to discuss the appropriate face pressure, the ground behavior due to drivage, the surface friction force of the pipe, and a jacking force that represents the sum of face pressure and the surface friction force of the pipe under different ground temperatures and characteristics of the ground. This dissertation consists of six chapters and the main contents in each chapter are listed as follows:

Chapter 1: As to the problems and research issues related with drivage in frozen ground, this chapter describes the geotechnical issues related with the frozen method, which is one of the soil improvement methods, and the application of pipe-jacking technology to the frozen ground. The outline and objectives of the dissertation are described in this chapter.

Chapter 2: In order to understand the effect of drivage operation in frozen ground by using pipe-jacking technology, ground behavior around the cutting face under different geological and operational conditions are discussed by means of finite differential software “FLAC3D.” Namely, as the drivage direction of the machine in the pipe-jacking method is controlled precisely when the pipeline is installed, ground behavior around and ahead of the cutting face have to be made clear and the appropriate face pressure has to be determined when the mechanical properties of frozen ground such as a cohesion and a friction angle are changed due to the temperature change of ground and the operational condition such as diameter of the pipe and installation depth are changed. Here, the type of soil is a silt and the range of ground temperature is -5□ to -20 □. Based on the results of a series of numerical simulations, it was made clear that in drivage work in frozen ground, the ground deformation around the cutting face towards the surface cannot be seen obviously even when a large face pressure is applied. This is because the mechanical properties of frozen ground are larger than those of unfrozen one. It can be also recognized that the deformation of the upper part of the cutting face is larger than that of the lower part of it even homogeneity ground conditions due to the distribution of temperature in the ground. Namely, as the temperature in the ground is different with different depth according to the geothermal gradient, the mechanical properties of ground are also changed due to the depth. In these conditions, the occurrences of the indirection of drivage and/or the stoppage of drivage operation due to the instability of cutting face can be expected. Hence, precise control of face pressure is of great importance for safe drivage operation

in frozen ground. Moreover, it can also be seen that the lower the temperature of the frozen ground is, the smaller the deformation ahead of the cutting face is. As deformation of the ground ahead of the cutting face increases via increasing the diameter and/or installation depth of the pipe, larger face pressure has to be applied in order to maintain the stability of the surrounding ground. For example, when the ground temperature is relatively high as a frozen ground about -5□, at which the cohesion and friction angle of the frozen ground are small, and the diameter and installation depth of the pipe are large, a larger face pressure has to be applied at the cutting face. Besides, the injection of mud-slurry at normal temperatures into the cutting face makes the frozen ground thaw and deformation ahead of the cutting face is increased dramatically. Hence, the thawing effect of the frozen ground has to be taken into consideration, when an appropriate face pressure is determined.

Chapter 3: The key for success of the installation of the pipe in frozen ground by using Pipe-jacking methods is the control of the deformation of the ground. Hence, the ground behavior around the cutting face is discussed under different ground temperatures and lubricants injected in the over-cutting area. From the results of a series of numerical analyses, it can be said that the surface subsidence along the cross section perpendicular to the drivage direction can be represented as the error function in which the center point is the axis of the installation pipe. Besides, the higher the temperature the frozen ground is the larger the maximum value of subsidence and the narrower the area of surface subsidence are. It can also be recognized that the surface subsidence trough ahead of the cutting face due to the drivage is formed as a funnel shape and the amount of surface subsidence gradually converges due to the injection of pressurized lubricants into the over-cutting area. Different temperatures of injection materials also have an obvious impact on the amount and area of surface subsidence. The amount of subsidence increases with increasing the temperature of lubricants along the cross section perpendicular to the drivage direction due to the thawing effect on the frozen ground.

Chapter 4: During the pipe jacking process, once the jacking force exceeds the strength of the installation pipe, the construction work cannot be continued. Hence, a series of numerical simulations were conducted in order to discuss the jacking force and the allowable jacking length under different surface friction forces of the pipe, considering different contact situations between the pipe and surrounding soil in the over-cutting area. It was found that the jacking force increases with the increasing jacking length linearly. Moreover, the jacking force also increases with decreasing ground temperatures from -5□ to -20□ due to the increase of resistant forces between the frozen ground and pipe. Besides, it was also made clear that the injection of lubricant into the over-cutting area makes the frozen ground thaw and the surface friction force of the pipe decreases. Therefore, the allowable jacking distance increases with the injection of lubricant to the over-cutting area not only due to the lubricating effect but also the thawing effect.

Chapter 5: A calculation model for prediction of jacking force in frozen ground under different ground temperatures was proposed based on the results of a series of numerical simulations under different contact conditions between concrete pipes and frozen ground. In this prediction model, the static friction force calculated by taking into consideration of the contact condition between pipe and frozen ground in the overcutting-area was applied to the surface friction force of the pipe. Compared with the measurement data obtained from drivage operation in frozen ground and the jacking force predicted by using the new equations, it can be seen that a jacking force predicted by using the new prediction model was in agreement with the measured data and the new prediction model can simulate actual jacking force in frozen ground more precisely than the conventional ones. Hence it can be concluded that the proposed prediction model considering the effect of ground temperature and the contact condition between pipe and frozen ground is reasonable and valuable to estimate the jacking force of pipe jacking in frozen ground.

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