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Joint Construction Using Grouting and Freezing Method

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ABSTRACT

Artificial freezing technology is increasingly applied in engineering practice due to its advantages of not being limited by the scope and depth of support, effectively preventing water inrush, and controlling soil deformation. However, how to avoid the impact on the structure and environment caused by soil frost heave and thawing settlement has always been a problem for engineering and technical personnel. Grouting technology is an important auxiliary technology in underground engineering construction, which has mature applications in lifting and strengthening strata, as well as anti-seepage and plugging of strata. This article discusses the feasibility of the combined construction of grouting and freezing method from the perspective of the combination application of two technologies.

KEYWORDS

Manual freezing; Engineering practice; Grouting; Grouting freezing method

1. INTRODUCTION

When encountering more complex engineering geological conditions, it is often necessary to adopt some formation strengthening methods to strengthen the weak strata first, and then carry out excavation after the formation strength reaches the requirement. Freezing method is one of the many reinforcement methods. It is to bury cooling equipment inside the body and freeze the soil through the cooling circulation system, so that the strength of the soil is increased, the permeability is reduced, and the integrity is enhanced, thus creating favorable conditions for the safe construction of underground engineering. In recent years, freezing method has been more and more applied in the development of urban underground space. However, everything has advantages and disadvantages. While the freezing method is effective in strengthening the strata, the volume of the soil will expand during the freezing process. During the thawing and thawing process, due to the drainage and consolidation of the frozen soil and the reduction of the frozen soil volume, it will cause large compaction settlement and surface melt settlement, which will have a certain impact on tunnels, road pipelines and nearby buildings [1-3]. When the surrounding environment of the project site has strict control of deformation requirements, this problem is more prominent and needs to be solved urgently. How to effectively prevent frost heave and melt settlement, in addition to taking measures from the freezing process, in all the foundation improvement methods, grouting reinforcement is a common one, which is by pouring slurry into the rock and soil body to spread, gel and solidify to form a new structure, so as to achieve the purpose of lifting the soil, strengthening the soil and preventing seepage and plugging the soil. By means of grouting, the stratum is strengthened and improved first, and then frozen.

2. FREEZING METHOD CONSTRUCTION

The construction technology of artificial freezing method is to form a freezing wall with certain thickness and strength to isolate the connection between groundwater and structure , by using artificial refrigeration method, so as to carry out tunnel excavation and structure construction under the protection of freezing wall. Freezing temperature control The thickness, strength, water insulation effect and stability of the freezing wall, the arrangement of the freezing tube and the later thawing strength are the key factors to determine the artificial freezing. The freezing method originally originated from natural freezing, and gradually used in engineering with the emergence of artificial refrigeration technology. After more than 100 years of development, a special engineering freezing construction technology has been formed today. In 1862, the British first used artificial refrigeration technology to strengthen the soil in the construction of the building foundation in South Wales, which opened the prelude to the application of artificial freezing method in engineering. The first successful application of artificial freezing technology in China was in the Kailuan Coal mine shaft construction project in 1955.

2.1. Shortcomings of the Freezing Method

While strengthening the formation effectively, the freezing method will cause frost heave and thaw subsidence deformation of the surrounding soil, resulting in deformation and destruction of the surrounding ground structures and underground pipelines.

2.1.1. Frost heave.

The phenomenon of swelling caused by the freezing of water in the formation is called frost heave. Frost heave is caused by the freezing of water in soil and the growth of ice body (especially convex mirror ice body), which causes soil swelling and uneven surface uplift. Frost heave generally causes deformation of the ground, forming frost heave ridges. The causes of frost heave include the expansion of the volume of frozen water in the soil; At the same time, in the process of soil freezing, the water in the lower unfrozen soil migrates and accumulates to the frozen surface, the water is relatively concentrated, and the difference between water and soil particles forms an ice lens or a frozen interlayer, which causes the volume of soil to expand. The frost heave deformation includes the following forms: ground cracking, surface uplift and non-uniform deformation.

2.1.2. Thaw settlement.

The phenomenon of geological subsidence caused by the melting of frozen soil is called thawing settlement. Two opposite processes occur when permafrost melts: compaction and expansion.Compaction: the volume of all kinds of ice in frozen soil shrinks after melting, making the soil sink due to its own weight; As the ice becomes water, it gradually drains through pores, compacting the soil and further sinking. Swelling: Soil particles and their aggregates expand as they melt due to hydration. Under normal circumstances, when permafrost melts, the compaction is greater than the expansion, so the melting subsidence. When the permafrost of the whole cryogenic structure melts, the amount of melt settlement is generally not large. However, when the frozen soil of stratified and reticulated cryogenic structures melts, it often has obvious settlement and sometimes abrupt subsidence occurs. When permafrost melts quickly, the rate at which ice becomes water is greater than the rate at which water can be drained from the soil, resulting in increased pore pressure in the soil and often destabilizing slopes and structures. Thawing settlement is the main cause of damage to buildings in permafrost regions.

3. PREVENTION AND CONTROL MEASURES OF FREEZING CONSTRUCTION

In order to solve the frost heave problem caused by freezing construction, the following treatment methods are usually adopted in engineering: (1) intermittent freezing and zoning freezing to control the formation range and development speed of freezing wall; (2) Excavate pressure relief hole to release frost heave pressure in time; (3) Under the premise of meeting the strength requirements, the frozen volume of the soil should be appropriately reduced; (4) Use vacuum pump to extract excess water. Hu Xiangdong [4] studied the freeze-heave and thawing deformation characteristics of cement-improved soil through laboratory experiments, and the test results showed that after adding cement, soil permeability was reduced, water migration in soil was weakened, and the amount of ice formation was greatly reduced, which significantly controlled the freeze-heave deformation of soil.

In view of the problem of melt settling after freezing construction, tracking grouting is often adopted to reduce the melt settling deformation. Li Wenyong et al. [5] proposed that compaction and splitting are still the two main motion forms of slurry in melt settling grouting. In the process of grouting, the pores in melt soil are filled with slurry and the soil is compacted. Yu Xuemin [6] conducted an indoor freezing strength test on the silty sand soil sample, compared the relevant strength indexes of the sample under grouting and non-grouting conditions respectively, and proposed that grouting could reduce the thickness of the frozen soil curtain while strengthening the soil, preventing seepage and water sealing, and preventing deformation, thus reducing the investment of the project.

To sum up, artificial freezing technology is necessary to combine with other construction methods to strengthen the formation. This paper puts forward the construction method of artificial freezing comprehensive grouting method to strengthen the formation. On the one hand, because artificial freezing has a good water blocking and reinforcement effect, it can supplement the shortcomings of grouting construction method. On the other hand, the artificial freezing method is suitable for soft soil, fluid sand layer, gravel formation and high water pressure or high earth pressure formation. Able to adapt to complex engineering geology and hydrogeology; The freezing tube arrangement is arbitrary. The shape of frozen soil wall is not limited by the reinforcement occasions. The frozen soil wall is water-proof, so it is not necessary to drain foundation pit, which can avoid the influence of foundation settlement caused by pumping on adjacent buildings. The frozen stratum has the resilience, the soil layer is restored to the original state after the construction, the damage to the soil layer is small, and will not affect the future construction of the pipeline.

4. GROUTING TECHNOLOGY

Grouting technology is a highly practical engineering technology with a wide range of applications. It uses hydraulic, pneumatic or electrochemical methods to inject some slurry that can be well consolidated with rock and soil body into the pores and cracks of rock and soil body to make rock and soil body become a new structure with high strength, good impermeability and high stability, so as to achieve the purpose of improving the physical and mechanical properties of rock and soil body. According to the conventional classification of grouting technology can be divided into static pressure grouting and high pressure jet grouting two categories. According to geological conditions, grouting pressure, action mechanism of grout on soil, motion form of grout and alternative method, grouting can be divided into four types: penetration grouting, compaction grouting, split grouting and jet grouting.

4.1. Research on Grouting Technology

Through a series of grouting simulation experiments, S.K.A.A.U et al. [7] found that the lifting effect of overconsolidated soil is greater than that of normal consolidated soil. The use of small-spacing

grouting can reduce the scale and size of overconsolidated pore water pressure and reduce the later consolidation settlement, thus improving the effect of grouting. Through simulation, the compensation effect of grouting uplift on stratum is verified by comparison with analytical solution. Hou Yanjuan et al. [8] summarized the four stages of grouting uplift, that is, soil filling and compaction, formation of grouting wall, generation of lift force, and finally the overall uplift of the structure, and analyzed the influence of the retaining stiffness and lift force of grouting wall on formation uplift by means of numerical simulation. Chen Yujiong [9] pointed out that for the foundation with poor permeability, splitting and compaction are still the two main reinforcement forms of grouting. Wang Guangguo et al. [10] found that the excess pore water pressure generated in the grouting process gradually dissipates with the increase of time, thus causing the consolidation and compaction of the soil, making the effective stress in the soil increase continuously and the strength increase accordingly. Li Shucai et al. [11] used a self-made test device to conduct a model test study on water inrush grouting of surrounding rock under dynamic water conditions, described the diffusion and propagation process of cement grout, summarized the diffusion law of grout, and verified the sealing effect of grout on permeable water.

It can be seen from the comprehensive research and practice results of grouting technology that grouting technology has become a very mature means of foundation reinforcement, which provides conditions for the joint application of grouting technology and other construction methods.

5. GROUTING AND FREEZING METHOD COMBINED CONSTRUCTION

Artificial freezing technology is more and more applied in engineering practice because it is not limited by support range and depth, can effectively prevent water gushing, control soil deformation and so on. However, due to the problems of frost heave and melt subsidence in the construction of freezing method, excessive frost heave and melt subsidence will cause harm to the surface buildings and underground pipelines. Grouting technology is an important auxiliary technology in underground engineering construction, which has a mature application in elevating stratum, strengthening stratum and preventing stratum seepage and plugging. Therefore, the formation is strengthened and improved by means of grouting first, and then frozen construction is carried out. The strength, water retention and overall stability of the foundation strengthened by injection have been significantly improved, and the frost heave and thaw settlement problems caused by freezing construction have been effectively suppressed, which is considered to be an effective supplement to the artificial formation freezing method.

5.1. First Grouting and Then Freezing

The manual freezing method mainly has two disadvantages: insufficient local strength and frost heave and thaw settlement, while the pre-grouting method can strengthen the soil, resist seepage and prevent deformation, it just makes up for the frost heave deformation during the freezing process and the lack of strength, water leakage and large thaw settlement deformation during the thawing period.

To sum up, before freezing construction, the soil mass should be improved by grouting reinforcement, and then frozen construction should be carried out on the foundation of the pulverized-soil complex, which can effectively restrain the frost heave and thaw settlement deformation of the upper body, reduce the influence of soil frost heave and thaw settlement on the surface and tunnel supporting structure, and ensure the safety of the engineering side environment and supporting structure.

6. SUMMARY

To sum up, the strength, water retention and overall stability of the foundation strengthened by grouting have been significantly improved, and the frost heave and thaw settlement problems caused by freezing construction have been effectively suppressed.

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