Optimization of Horizontal Freezing Scheme for Complex Curtain

Changyi Yu1,2,3,4, Mingyue Lu5*

1 CCCC-Tianjin Port Engineering Institute, Ltd., Tianjin 300222, China
2 CCCC First Harbor Engineering Company, Ltd., Tianjin 300461, China
3 Key Laboratory of Geotechnical Engineering, Ministry of Communications, Tianjin 300222, China
4 Key Laboratory of Geotechnical Engineering of Tianjin, Tianjin 300222, China
5 Tianjin Survey And Design Institute For Water Transport Engineering, Tianjin 300000, China
*Corresponding author’s 874801845@qq.com

Abstract. In view of the difficulty of theoretical calculation for complex curtain with complex form of subway connecting passage freezing method, this study simulates the subway connecting passage freezing method construction with finite element method based on a practical project. The effects of different temperature cold sources, different thermal insulation materials around the subway tunnel lining, and different layout of freezing pipes on the freezing period are mainly studied. The results show that the thermal insulation materials around the subway tunnel lining have little influence on the freezing period, while the freezing cold source temperature and the arrangement of freezing pipes have great influence on the freezing period. The research content of this paper provides an effective reference for the freezing construction of subway connecting passage and an effective analysis method for designers.

1. Introduction
Artificial freezing method has a history of more than 100 years and has been widely used in urban construction and coal mine construction. The theoretical research and numerical simulation are still in continuous improvement. At present, the numerical simulation of artificial freezing method is mostly limited to subway tunnel construction, and the freezing area is divided artificially in the simulation process. For actual freezing projects, the freezing process in soil is an irregular, three-dimensional and time-varying process[1, 2]. For construction personnel, freezing construction needs to consider freezing construction period, and a rough estimation of construction period is required on the construction site, and the time limit proposed in the design is verified through detection means[3]. As the construction conditions become more and more complicated, the construction of the connecting passage becomes more and more complicated, and there is no standard to check and no basis to refer to for the design[4]. Therefore, it is necessary to optimize the preliminary design scheme. Numerical simulation can adapt to complicated geological conditions and complicated construction conditions due to its strong adaptability[5]. In this paper, combined with practical engineering, finite element method is used to simulate the freezing method construction of subway connecting passage, focusing
on the effects of different temperatures of brine freezing, different thermal insulation materials used around subway tunnel lining, and different freezing pipe layout on the freezing period.

2. Influence of different arrangement of freezing pipes on freezing effect

During the freezing construction, the construction site and design requirements of the project are different, and there will be different layout forms. For subway connecting passages, the excavation form is straight wall arch. According to past experience, the layout form of freezing pipes is also straight wall arch, but the spacing between freezing pipes needs to be calculated according to the construction period and freezing requirements. In the following, the relationship between freezing time and spacing of freezing pipes with different spacing of straight wall arched connecting channels is studied. The values of arrangement spacing of freezing pipes are shown in Table 1 below.

| Num  | group 1 | group 2 | group 3 | group 4 | group 5 |
|------|---------|---------|---------|---------|---------|
| pipe spacing (m) | 0.29   | 0.51   | 0.62   | 0.95   | 1.11   |

When the data of pipe spacing is taken as group 1, a total of 79 pipes are arranged, with an average pipe spacing of 0.29m as shown in figure 1.

Figure 1. The first group of pipe layout forms

When the data of pipe spacing is taken as group 5, a total of 20 pipes are arranged, with an average pipe spacing of 1.11m as shown in figure 2.

Figure 2. The fifth group of pipe layout forms

According to the research method of temperature field by temperature conductivity coefficient the temperature of each point in the extraction model is extracted, and the average temperature variation value of frozen soil curtain with different thickness with time is extracted as shown in figure 2.
As shown in Figure 3, the larger the average pipe spacing, the longer the freezing time required. The thicker the design freezing curtain, the longer the freezing time required.

3. Influence of Different Refrigerant Temperatures on Freezing Effect

In the freezing method construction design, due to the requirements of funds and equipment, the refrigerant in the freezing pipe is different, some are frozen with liquid nitrogen, some are frozen with cold brine, and different refrigeration equipment makes the temperature of the refrigerant different. Therefore, it is necessary to study the influence of different freezing pipe temperatures on freezing effect, so as to coordinate the refrigerant temperature according to the construction period and equipment, so that the project can be completed on time and the project funds can be saved.

The specific values of refrigerant temperature are shown in Table 2 below.

| Num | Temperature/℃ | Group 1 | Group 2 | Group 3 | Group 4 |
|-----|----------------|--------|--------|--------|--------|
| Temperature/℃ | -15 | -20 | -25 | -30 |

The temperature of each point in the extraction model is extracted, and the average temperature of frozen soil curtain with different thickness changes with time is extracted as shown in Figure 4.
4. Influence of Different Tunnel Lining Insulation Measures on Freezing Effect

During the freezing construction of the subway connecting passage, the temperature in the subway tunnel has been kept at a relatively high temperature, which continuously supplements heat to the soil around the subway tunnel. This is a bad influence on freezing construction. It is necessary to take thermal insulation measures on the lining surface of subway tunnel at the exit of the connecting passage to avoid adverse effects on the frozen curtain. However, different materials have different cost and heat preservation effect, so different materials should be used for construction according to the actual situation. The effect of different heat preservation measures on freezing effect is calculated below. Different thermal insulation materials mainly consider their thermal insulation performance in the simulation process, i.e. their different heat dissipation coefficients.

Heat dissipation coefficient is also called heat transfer coefficient, generally for convection heat transfer, the unit is W/m²·℃. Under the condition of stable heat transfer, the air temperature difference between the two sides of the enclosure structure is 1 degree, and the heat transferred through an area of 1 square meter within 1 hour.

It is assumed that all parameters except the heat dissipation coefficient in the soil are unchanged, only the heat dissipation coefficient on the tunnel surface changes. The specific values are 0.6/2/8 W/m²·℃.

The tunnel heat dissipation coefficient has little effect on the freezing time. The thicker the design freezing curtain, the longer the freezing time required.

5. Conclusion

This chapter carries out detailed calculation and analysis for various working conditions in different construction processes, and mainly obtains the following conclusions.

Firstly, the layout of freezing pipes of straight wall arched connecting passage is analyzed and calculated. Five kinds of spacing are calculated respectively. The freezing time at different spacing is obtained. Curves of different design freezing thicknesses at different freezing spacing are drawn. The curves reflect that the spacing of freezing pipes has great influence on the freezing time. The smaller the spacing of freezing pipes is, the longer the freezing time is required when the design freezing thickness is constant.

Then, the freezing effect of refrigerant medium with different temperatures in the freezing pipe was numerically simulated, and the temperature field distributions of -15℃, 20℃, 25℃ and -30℃ were calculated respectively, and the numerical values were extracted. The freezing conditions within 100 days were simulated at -15℃, and the results showed that the freezing requirements could not be met at -15℃. At other temperatures, the design requirements can be met, and the extracted data can be drawn into different design frozen thickness curves at different temperatures. The curve shows that the refrigerant temperature has a great influence on the freezing time when the arrangement of freezing pipes is fixed. The lower the refrigerant temperature, the shorter the freezing time required.

Finally, numerical simulation is carried out for the thermal insulation of tunnel lining. The heat dissipation coefficient of tunnel is 0.6/2/8 W/m² respectively. The time required for freezing curtains with different design thicknesses under different tunnel heat dissipation coefficients is obtained by extracting numerical values from the calculated temperature field results, and curves are drawn. The curve drawn shows that the tunnel heat dissipation coefficient has little influence on the construction period. However, it has certain influence on the freezing effect of frozen soil curtain around the subway tunnel.

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