Sensitivity Analysis of Uniaxial Compressive Strength Characteristics of Artificial Frozen Soil

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. Uniaxial compressive strength is the most basic mechanical property of frozen soil and a necessary mechanical parameter in frozen soil design and construction. Therefore, uniaxial compression test of frozen soil is one of the important test contents of frozen soil test. On the basis of field sampling, this paper conducts a series of uniaxial compression tests on silty clay and silty soil in Binhai New Area under different freezing temperatures. Through analysis and research, the uniaxial compression stress-strain relationship of frozen soil with different soils is established, and the variation law of uniaxial compression strength with freezing temperature is summarized. The results of this paper provide effective guidance for frozen soil design and construction.

1. Introduction
Haixin district is located in the sea-land interaction-coastal sedimentary soft soil area, which has poor engineering properties and features of large water content, large compressibility and large thickness. At the same time, the interaction between marine and continental sediments in this area is clear, the terrain is low and flat, the underground water level is deep and shallow, and the soil salinization is serious[1]. Compared with other areas, the stratum soil in the new coastal sea area has its own characteristics[2]. In order to accurately ascertain the physical properties of frozen soil layers in the subway planning area of Binhai New Area, based on the previous investigation and in combination with the geological characteristics of soil layers and the subway planning situation in Binhai New Area, large-scale on-site sampling in different areas is carried out in Binhai New Area[3]. The subway planning area along Binhai New Area is the key sampling research area[4]. At the same time, borehole sampling is carried out in Jinnan as a supplementary comparative test, and on-site borehole sampling is carried out in each area[5]. The distance between holes is about 10m, the depth of soil taken is about 40m, and 2-3 samples are taken per meter. In this frozen soil test, more than 1430 samples have been taken cumulatively, and a large number of experimental studies have been carried out, thus improving the reliability of test results and reducing the discreteness of test results. In order to ensure the accuracy of test results and the original physical state of soil samples, in the process of on-site sampling, the
undisturbed soil samples drilled in the field should be screened, and the continuous and well-preserved soil samples in the stratum should be selected first\(^6\). Secondly, wax sealing shall be carried out immediately on the basis of on-site packaging to prevent water loss. At the same time, the selected samples shall be numbered in combination with on-site sampling\(^7\). After the selected soil sample on site is transported back to the laboratory, it shall be prepared immediately. The unprocessed soil sample shall be placed in a special soil box that is protected from light, moist and stable in internal environment to fully ensure the original properties of the soil sample\(^8\).

According to the on-site investigation and sampling, it is concluded that silty clay and silty soil are most widely distributed in the area with an underground depth of about 40 meters in Binhai New Area, and the soil quality is relatively uniform, the stratum is relatively continuous, and the thickness of soil layer is relatively large, with the maximum thickness being over 5 meters. Therefore, it is of great significance to select the above two kinds of soil quality for key research.

2. Uniaxial Compression Test

After the soil sample is completely made, the soil sample shall be packed and sealed with plastic wrap to prevent water loss. meanwhile, a label corresponding to the label of the sample shall be affixed to the outside of the sample, and the sample shall be frozen at three constant temperatures of -5 c, -10 c and -15 c for 48 hours. the sample preparation process is shown in figure 1.

![Figure 1. Sample preparation process](image1)

During the test, the data acquisition system can simultaneously record the corresponding real-time test data, draw the stress-strain relationship curve in real time and display the test progress.

![Figure 2. Test Instrument](image2)
3. Test results
The uniaxial compressive strength of frozen soil increases with the decrease of freezing temperature, and the increase is obvious. The frozen soil strength increases by 0.19 MPa to 0.33 MPa on average every time the temperature decreases by one degree. Among them, the strength of continental silty clay, silt and silt at-10 C can reach 3.3~4.3 MPa. Silty clay and marine silty clay have low strength (1.7~3.0 MPa) at-10 C. Freezing should be strengthened in practical engineering to meet the strength and stability of frozen soil curtain.

Figure 3. Relationship between uniaxial compressive strength and water content

In the process of water content increasing from 15% to 40%, the uniaxial compressive strength of frozen soil samples increases first and then decreases, but the water content corresponding to the maximum strength of different soil properties is different. When the water content of silt sample is 25%, its strength reaches the maximum of 3.14MPa; when the water content of silt sample is 30%, its uniaxial compressive strength reaches the maximum of 2.77MPa; when the water content of silty clay sample is 35%, its uniaxial compressive strength reaches the maximum of 2.83MPa; when the water content of clay sample is 35%, its uniaxial compressive strength reaches the maximum of 3.47MPa.

The uniaxial compressive strength of remolded soil sample increases linearly. When the dry density increases from 1.25 GCM-3 to 1.55 GCM-3, the uniaxial compressive strength of remolded silt frozen samples increases from 2.65MPa to 4.2MPa. The compressive strength increases by 0.052MPa for every 0.01 GCM-3 increase in dry density. Silt, silty clay and clay have similar laws.

4. Conclusion
The most important factor affecting frozen soil strength is the freezing temperature of the sample. The results of analysis and test show that the uniaxial compressive strength of artificial frozen soil increases with the decrease of freezing temperature and is basically linearly related. Different soils have different linearity. The uniaxial compressive strength of frozen soil increases by 0.19 MPa to 0.33 MPa every time the freezing temperature decreases by 1℃. Therefore, the bearing capacity of frozen soil curtain can be improved and its deformation reduced by lowering freezing temperature in practical engineering. Among them, when the freezing temperature is -10℃, the strength of marine muddy clay and silty clay is relatively low. In order to ensure the bearing capacity of frozen soil curtain, the freezing temperature should be below -10℃. The temperature strength of continental silty clay and silty soil can reach 3.3~4.3MPa at -10 C, and the freezing temperature of field engineering can be controlled at -10 C.

Water content is another factor that greatly affects the uniaxial compressive strength of frozen soil. When the water content is low, the frozen soil strength increases with the increase of the water content,
specifically, the compressive strength increases by 0.05~0.12MPa; for every 1% increase of the water content. However, when the soil reaches saturation, the compressive strength decreases by 0.08~0.12MPa for every 1% increase in water content. The effect of water content on frozen soil strength is shown in the degree of binding between soil particles by ice and the content and strength of ice itself. When the water content in the soil is lower than the saturated water content, the compressive strength of frozen soil increases with the increase of water content. When the water content reaches saturation, the frozen soil strength also reaches the maximum. However, when the water content continues to increase, the compressive strength of frozen soil decreases, while the water content continues to increase, and the sample is close to the characteristics of pure ice.

The dry density of soil also has great influence on the uniaxial compressive strength of artificial frozen soil. Under the condition of a certain water content, with the increase of dry density, the soil sample becomes denser and the content of soil particles in the soil increases. The larger the effective area that the soil skeleton can bear the load, the stronger the ability to bear the load, and the greater the uniaxial compressive strength of frozen soil.

The freezing temperature of soil is directly related to the amount of salt in the soil. When the frozen soil test temperature is constant, the uniaxial compressive strength decreases with the increase of salt content. The strength decreases by 0.1~0.5MPa for every 1000mg increase in salt content. It is known that the freezing temperature of brine is lower than that of pure water. The higher the concentration of salt solution, the more difficult it is to freeze and the lower the freezing temperature. The greater the salt content in the native land, the lower the temperature is required to reach the same compressive strength. However, at the same temperature, the soil sample with higher salt content has lower strength after freezing.

In general, with the decrease of freezing temperature, the elastic modulus of frozen soil gradually increases. Every time the freezing temperature decreases by 1℃, the elastic modulus increases by 4.84 MPa to 9.4 MPa. Among them, silt clay and marine silty clay frozen soil have small elastic modulus and relatively large freezing deformation. During design, check calculation of deformation shall be paid attention to to prevent freezing pipe from breaking due to excessive deflection. The temperature strength of other soils can reach 85-107MPa at-10 C.

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