The Influence of Groundwater Level Rise on Bearing Capacity of Sand Foundation

Ma Lizhu, Zhao zhonghua, Tian Yue

Department of civil engineering, Shenyang Urban Construction University, Shenyang, Liaoning, 110167, China

Corresponding author’s e-mail: 463511327@qq.com

Abstract. Along with the development of city construction, the underground space is exploited widely. This paper simulated the natural basement in sandy foundation by the way of laboratory test. Then through the SLT test we will get the change laws of bearing capacity, porewater pressure, effective stress and settlement in sandy foundation after analyzing change of underground water level. These may provide reference for the engineering application.

1. Introduction

Groundwater is an extremely important natural resource in the crust and an important component of the three-phase rock and soil. Groundwater seepage in pore or fissure of rock and soil has great influence on engineering mechanical properties of rock and soil. For example, the seepage of groundwater will cause the seepage deformation of rock and soil, which will directly affect the stability and safety of buildings and their foundations; the change of groundwater level will change the effective stress field in the foundation soil, which will cause the rebound or settlement of the foundation soil; the change of groundwater level will also cause the change of soil moisture content, which will also change the mechanical properties of the soil and cause the change of bearing capacity of foundation soil[1]. The decrease of groundwater level caused by pumping will cause the consolidation of foundation soil and the uneven settlement of buildings, etc. It can be seen that the change of groundwater level usually has many adverse effects on buildings. Especially in recent years, with the rapid development of urban construction in China, the underground space has been used more and more widely. In the construction of underground space, the problem of groundwater will inevitably be involved. Quality accidents often occur in the process of construction such as uneven settlement of buildings and foundation floating caused by the change of groundwater and water level, which cause great losses to the project. It can be seen that the influence of groundwater and its water level changes on the bearing capacity of foundation is a problem that we must pay attention to in geotechnical engineering investigation and foundation design.

At present, for the determination of bearing capacity of foundation in geotechnical engineering design, many engineers only calculate the bearing capacity of foundation soil according to the calculation index provided by the survey unit, but do not consider the influence of the rise of groundwater level on the bearing capacity of foundation soil. In fact, the rise of groundwater level is bound to have an impact on the bearing capacity of foundation soil. Therefore, the study of the influence of the rise of groundwater level on the bearing capacity of foundation will have an important guiding significance for practical engineering.

At present in our country, Beijing, Shanghai and other places had researched deeply about
underground water level change on the influence of the bearing capacity of foundation soil, but due to the reason for the formation of rock and soil is very complex, the influence factors of its mechanical properties are also very much, and its engineering properties on the spatial distribution of significant inhomogeneity and regional features. The mature engineering experience of other provinces and cities only has certain reference value for Liaoshen region, and can’t be directly used. Therefore, it is very urgent and necessary to study the influence of the change of groundwater level on the bearing capacity of foundation soil by combining the engineering geological conditions and construction characteristics of Liaoshen region. This paper mainly analyzes the influence of the rise of groundwater level on the bearing capacity of sandy soil foundation.

2. Laboratory test

2.1. Test principle
According to the predetermined control index of backfill sand sample, layered backfill sand sample is filled in the test tank, and then the direct shear test is carried out under different water content. When the water level in the test tank changes, the relationship between load and settlement of sand soil foundation is measured. The influence of groundwater level rising on the bearing capacity and settlement of sandy soil foundation is mainly studied.

2.2. Test overview
The test tank adopts reinforced concrete structure, and its length, width and height are 4.0m, 1.0m and 4.5m respectively. The wall thickness of the test tank is 0.2m. Two simulation foundations are buried inside, and the No.1 and No.2 are used respectively. The numbering and simulation bases all adopt a square planar shape with a base side length of 0.5m. A soil pressure sensor and a water pressure sensor are buried at the base and 0.5m below the base to test the variation of soil stress during the rise of the groundwater level.

3. Analysis of test results

3.1. Influence of water level change on foundation bearing capacity
The dry density of the foundation soil of the two simulated foundations buried in the test tank is 1.75 g/cm³. The difference is that the moisture content of the foundation soil under Number.1 foundation is 5.72%, which belongs to unsaturated soil. The moisture content of the foundation soil under Number.2 foundation is saturated (the moisture content is 23%). The results of static load test are shown in figure 1 and table 1.

![Fig. 1. The P-S curve of static load test of the No.1 and No.2 foundation](image-url)
Table 1. The eigenvalue of foundation bearing capacity fa’s comparison of the No.1 with No.2 foundation.

| Settlement/mm | No.1 foundation | No.2 foundation | Reduction range |
|---------------|-----------------|-----------------|-----------------|
| 0.010b        | 550             | 400             | 27.27%          |
| 0.012b        | 600             | 450             | 25.00%          |
| 0.015b        | 680             | 500             | 26.47%          |

Note: b is the base width

As can be seen from the results of the static load test, the P-S curve changes gently under both saturated and unsaturated conditions without obvious steep drop. The corresponding load when the settlement is 0.01, 0.012 and 0.015 times the width of the foundation is taken as the characteristic value of the bearing capacity of the foundation according to the code fa[2-3]. It can also be seen from table 1 that the bearing capacity of sandy soil foundation under the condition of water saturation is lower than that under the condition of unsaturated soil, with a reduction range of 25%-27.27% and an average value of 26.25%.

From unsaturated to saturated condition, the bearing capacity of sandy soil foundation decreases, the main reason is that with the increase of water content of sandy soil, the internal friction Angle decreases, and the shear strength of soil also decreases.

3.2. Influence of water level change on effective stress in sand soil

Based on the No.2 simulation foundation with saturated soil moisture content, 100kPa load was applied in advance to simulate the load of existing buildings, and then we add water to the tank and control the water level in the depth of basement under 2.8m, 2.5m, 2.0m, 1.5m, 1.0m, 0.5m, 0m, at the same time monitoring total stress and pore water pressure in soil, according to the principle of effective stress again: As a point of effective stress in saturated soil is always equal to the total stress minus pore water pressure, so as to calculate the size of the effective stress of the unearthed.

The stress transmitted through the pores of soil is called pore stress, also known as pore pressure, including pore water pressure and pores gas pressure. For saturated soil, only pore water pressure exists. The measured value of pore water pressure in table 2 is directly measured by the embedded pore water pressure sensor, while the calculated value of water pressure in the table is calculated based on the head difference between the water level in the tank measured by the water level pipe installed outside the test tank and the embedded position of the pore water pressure sensor, in which the water weight is 9.8 kN/m$^3$.

Table 2. Comparison of test results of pore water pressure sensor.

| Calculated value of water pressure/kPa | Measured value of water pressure/kPa |
|---------------------------------------|--------------------------------------|
| 4.9                                   | 4.43                                 |
| 9.1                                   | 9.09                                 |
| 14.7                                  | 14.19                                |
| 19.6                                  | 19.29                                |
| 24.5                                  | 23.73                                |
| 29.4                                  | 30.38                                |
| 32.3                                  | 33.26                                |

As can be seen from table 2, the pore water pressure measured by the pore water pressure sensor in the sand is basically the same as that due to the head difference measured by the water level pipesandy, it indicates that pore water pressure in the sand is generated by hydrostatic pressure. When calculating the effective stress of the sand, the weight of the underwater part of the sand should be taken as the weight of buoyancy[4-5].

Table 3. Calculation table of effective stress under 0m of foundation.

| Water head/m | Pore water pressure/ kPa | Total stress/kPa | Effective stress/kPa |
|--------------|--------------------------|------------------|----------------------|
| 0.5          | 4.9                      | 167.5            | 162.6                |
| 1            | 9.8                      | 167.5            | 157.7                |
| 1.3          | 12.7                     | 167.5            | 154.8                |

As can be seen from table 3, with the increase of water level in the sand foundation, pore water pressure increases, while the effective stress in the soil decreases.
3.3 Effect of Water Level Rising on Settlement of Sandy Soil Foundation

According to the knowledge of soil mechanics, we know that with the decrease of groundwater level, the pore water pressure in the foundation soil will decrease, and the effective stress will increase, which will lead to the settlement of the foundation. Then we will study the influence of rising groundwater level on foundation settlement through experiments. After adding 100kPa load on the basis of the No. 2 foundation, the water level in the test tank rises gradually from 0m at the bottom of the foundation. During this process, the measured settlement value of the foundation changes, as shown in Figure 2. It is not difficult to see from the figure that with the increase of the water level in the test tank, the foundation has a certain settlement. When the water level rises by 4.3m, the cumulative settlement is 0.565mm. This is because although the water level rises, the pore water pressure will increase and the effective stress will decrease, but for the normal consolidation or overconsolidation strata, the deformation will rebound, but sand is a typical elastoplastic body, the elastic rebound caused by unloading is very small compared with the overall compression, which can be neglected[6-7]. For the settlement of foundation in test, it can be considered that the shear strength of soil decreases and the bearing capacity of foundation decreases when the saturated state of foundation soil changes to unsaturated state.

![Figure 2. Measured values of foundation settlement during water level rise](image)

4. Conclusion

Due to human development and other factors, the personnel engaged in geotechnical engineering design will inevitably face a rising trend of groundwater level. However, the rise of the groundwater level will inevitably lead to the decline of the bearing capacity of the sandy soil foundation. The bearing capacity of the sandy soil foundation under the condition of water saturation is lower than that under the condition of unsaturated soil, and the average reduction range is 26.25%. When the load of 100kPa is applied in advance on the foundation, the bearing capacity of the foundation decreases with the rise of the groundwater level, resulting in additional settlement of the foundation. When the water level rises by 4.3m, the cumulative settlement is 0.565mm. Therefore, people must pay enough attention to it and take corresponding measures to control the rise of groundwater level and ensure the safety of the project.

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