Research on load test of reinforced retaining wall suffered freezeing and thawing cycle

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ABSTRACT: Through modeling the true field temperature process, the freezing and thawing test of reinforced retaining wall under open freezing conditions was made. After freeze-thaw cycle, the load test of reinforced retaining wall was made. The FEM Analysis was made based on the theoretics of equivalent additional stress method. The contrast analysis of vertical deformation and panel level displacement which obtioned from calculation and measurement was made.

1 INTRODUCTION

In seasonal frozen soil regions, in the process of temperature reduction, pore water of the soil and the water from the external water sources is freezing. The volume of the soil body increased causes frozen heaving. The ice in soil body thaws into water in spring, but the soil body is not completed drained and solidified, so the buildings on the soil body may collapse. Such extra deformation or damage arising from the soil body freezing-thawing is the frozen damages in projects. The experiment research discovers that, the reinforcement can reduce the horizontal frozen heaving force and the frozen damages in projects(Wang Enliang 2008).

The plastic geogrid is high molecular polymer slab and mesh structure made of high-strength polypropylene or high-density PVC. It is the ideal reinforcement material for reinforcement retaining wall and high slope treatment and its excellent reinforcement performance is highly appraised by the civil engineering field.

The loading test of reinforcement retaining wall after freezing-thawing cycle under open conditions was carried out. Through comparing the results of loading test and finite element, some beneficial conclusions is obtained.

2 TESTING CONTENTS AND METHODS

The reinforcement retaining wall is the composite structure of the reinforcement, wall body and faceplate, and can bear the freezing and thawing cycles for many years in the seasonal frozen soil regions. The stress and deformation is monitored in the process of the load on the top of the retaining wall after freezing and thawing cycle twice. The structure schematic diagram of the retaining wall in the simulating test as shown in the figure 1.

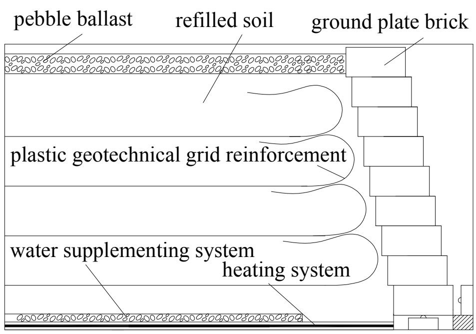

Fig.1 Structural sketch of reinforced wall

2.1 *Preparation of the specimen*

The clay specimen is tested in accordance with requirements in Specification of Soil Test (SL237-1999). Main physical and mechanical indexes are shown in the table 1. The reinforcement employs the uniaxial tension plastic geogrid of model TGDG35.

2.2 *Testing instrument and proposal*

2.2.1 *Testing instrument*

The testing instrument is comprised of model box (L×W×H: 250cm×150cm×150cm), temperature control system, deformation monitoring system, load control system, water supplementing system and refrigeration system.

Table 1 Physical and mechanical indexes of silty-clay specimen

Soil granule specific gravity	2.69	Internal friction angle/ °	18.1
Liquid limit /%	32.2	Vertical permeability coefficient /cm/s	1.32E-06
Plastic limit /%	18.3	Maximum dry density/g/cm^3	1.68
Plastic index	13.9	Optimum water content/%	16.1
Liquidity index	< 0	Unit weight of the refilled soil /kN/m^3	17.3
Cohesive force /kPa	31	Soil category	Low-liquid clay(CL)

2.2.2 *Testing proposal*

The control dry density is 90% of the maximum dry density. The compactness thickness of each layer is 5-10cm.

The freezing and thawing process simulates the actual measurement materials from 2006 to 2007 at *Wanjia frozen soil experiment station in Haerbin, Heilongjiagn Provice*. To ensure bi-directional freezing of the retaining wall in temperature fall, insulation treatment is carried out for the wall except the brick and the top.of the wall. A heater is buried below the bottom plate with temperature controllable to make the underground water of the lower layer of the wall body not frozen and realize bi-directional thawing when the temperature is rising to ensure that the freezing curve is consistent with the field observation and measurement results.

The loading test is carried out after the freezing and thawing cycle twice for the reinforcement retaining wall. The testing device is shown in the figure 2.

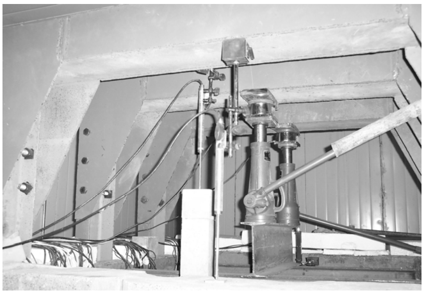

Fig.2 Test apparatus for loading

The loading test is started from the load 0kPa. The 1st level load is 20kPa; after stabilizing for 48 hours, the 2nd level load 60kPa is applied; after stabilizing for 24 hours, the 3rd level load 100kPa is applied. A load of 10kPa is increased for each 24 hours hereinafter until the full load 200kPa.

When the test is loaded to 150kPa, the face-plate makes sound for being pressed and crack occurs at the connection of the face-plate and the model box. When the test is loaded to 200kPa, the counter-force steel beam makes a louder sound. Stop increasing the load and keep the load at 200kPa for continuous 120 hours, then unload and complete the whole loading test.

3 TESTING RESULTS ANALYSIS

3.1 *Loading damage of the reinforcement retaining wall*

The maximum deformation on the top of the wall is 120.81mm. However, seen from the appearance, there is no communicated arc slid surface in the soil body.After completion of the loading, the location of the loading plate produces sinks.The side wall of the model platform and rear edge of the face-plate produce wider cracks caused by the shearing force.

3.2 *Load-deformation curve*

According to the testing results, the load-settlement was drawn as shown in the figure 3.

The distribution of the horizontal displacement along the wall height when loaded at 200kPa and 200kPa was shown in the figure 4.

3.3 *Finite element analysis*

3.3.1 *Finite element analysis model of the plastic geogrid reinforcement soil*

Basic though of the equivalent additional stress method is to equalize function of the reinforcement materials in the reinforcement soil as the additional stress on the geotechnical frame along the direction of the reinforcement, and the soil body in the reinforcement soil shall be taken for calculation. In detail, only the soil unit is in the finite element calculation, function of reinforcement is taken as the external force (equivalent additional stress) is added on the soil unit(Jie Yuxin 1998，1999，2007&Li Guangxin 1999，2007&Wang Naidong 2007) .

3.3.2 *Constitutive relations and element type of the reinforced retaining wall*

In the analysis procedure, the soil body comprised of granule materials with smaller tensile strength is deemed as elastoplastic body. The constitutive relation model employ Drucker-Prager（D-P）ideal elastic-plastic constitutive model.

In the finite element analysis, the entire structure is treated as a plane. Such treatment is the same with the actual project. The wall body is divided by four-node element.

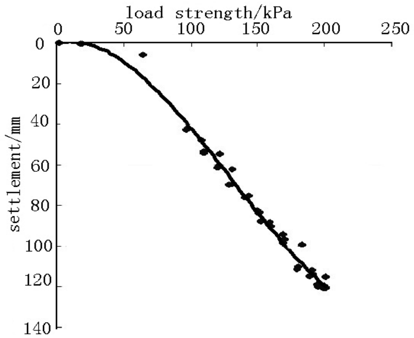

Fig.3 Curve of loading and settlement of model reinfored retaining wall

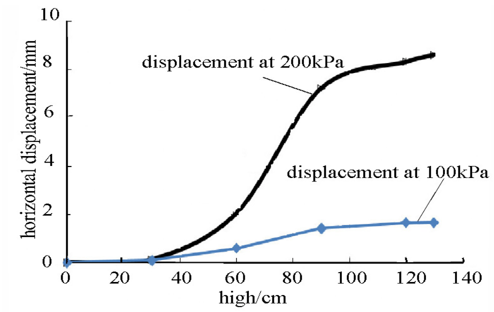

Fig.4 Horizontal diaplacement of retaining wall under load

3.3.3 *Handling of the plastic geogrid reinforcement materials*

In accordance with the thought of the equivalent additional stress, the element strain $\{\varepsilon\}$ shall be:

$$\{\varepsilon\}=[C]\{\sigma\}=[C](\{\tilde{\sigma}\}+\{\sigma_e\})$$

Where $[C]$= the flexibility matrix of the soil.

$$\{\sigma\}=\{\tilde{\sigma}\}+\{\sigma_e\}$$

Where $\{\tilde{\sigma}\}$= the stress on the soil unit without considering function of the reinforced materials and

$\{\sigma_e\}$=the equivalent additional stress of the reinforcement material and

$$\{\sigma_e\}=-[E]\{\varepsilon\}$$

3.3.4 *Calculation meshes and calculation parameters*

The calculation meshes is shown in the figure 5.In combination with the lab testing and analyzing the testing materials, the calculation model and calculation parameters are determined: γ_d=17.3kN/m^3, E=3MPa, μ=0.3, c=31.0kPa and φ=18.1°. Thickness of element of the reinforcement is $\Delta H=0.05$ m, α=1, so E_t=12MPa is concluded. The face-plate concrete brick is calculated based on linear and elastic model, namely E=2×10^{3}MPa and the Poisson ratio is 0.2（μ=0.2）.

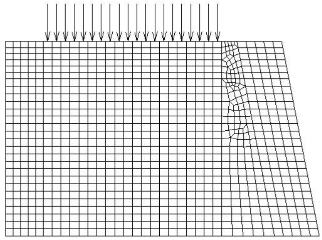

Fig.5 Mesh of finite element

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3.3.5 *Contrast analysis of the finite element calculation results and the testing results*

The finite element calculation employs the NM software system by Tsinghua University. See figures 6 to 10 on the calculation results. The horizontal and vertical displacement equivalence lines are given in figures 6 to 8 for loads 20kPa, 100kPa and 200kPa.

Seen from figures 6 to 8, when the load is 20kPa, the horizontal displacement only occurs at the retaining wall top; when the load is increased to 100kPa, horizontal displacement of the retaining wall top is increased, about 4 times of the maximum displacement values; when the load is increased to 200kPa, horizontal displacement of the retaining wall top continues to increase, maximum displacement about 5mm.

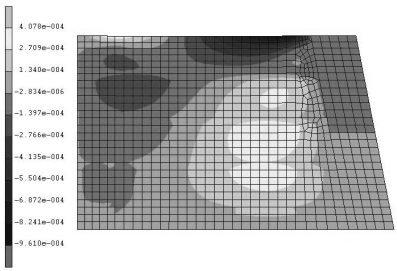

Fig.6 Displacemntof soil mess under 20kPa load (unit: m)

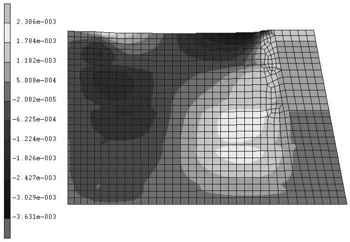

Fig.7 Displacemntof soil mess under 100kPa load (unit: m)

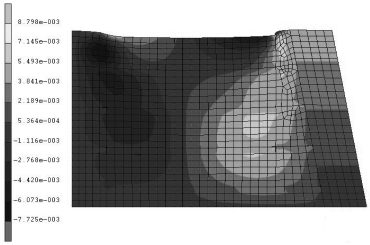

Fig.8 Displacemntof soil mess under 200kPa load (unit: m)

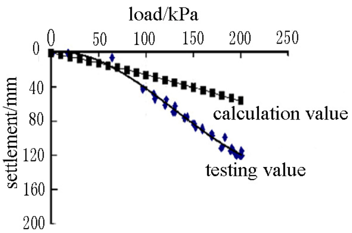

Fig.9 Comparison curve of load and settlement

Seen from figure 9, when the load value is less than 60kPa, the collapse quantity testing value is less than the calculation value; when the load is increased to above 60kPa, the collapse testing value is larger than the calculation value; when the load is increased to 200kPa, the collapse testing value is 120mm in maximum, which is twice of the calculation value.

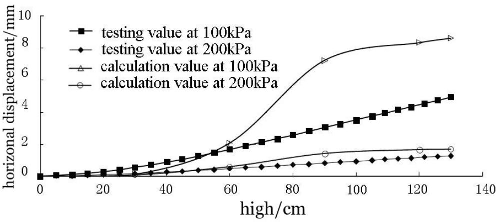

Fig.10 Horizontal diaplacement of retaining wall under load

Seen from figure 10, under the load of less than 100kPa, testing value of horizontal displacement of the retaining face-plate is very close to the calculation value; the maximum testing value is 1.65mm and maximum calculation value is.32mm. When the load is increased to 200kPa, maximum value of the horizontal displacement is 8.48mm, and the maximum calculation value is 4.93mm, with a difference of 70%.

4 CONCLUSION

The loading testing after 2 freezing and thawing cycles for the reinforcement retaining wall under open conditions is carried out in this thesis. After comparing the finite element value analysis results and the actually measured results, the conclusions are obtained as follows:

(1) For this test employs the method of restricting the fixed bottom, without sliding cracking surface, with increase of the load, the deformation increment in the middle of the wall body is maximum. After the freezing and thawing cycle of the reinforcement retaining wall twice with load destruction, the collapse deformation damage is dominant.

(2) The equivalent additional stress method only offers the soil unit in the unit mesh and the constitutive model of the plain soil can be directly utilized. This handling greatly reduces meshes of the unit division and removes hindrances of testing and calculation of different properties of the compound materials. The calculated displacement changes are in line with general rules.

(3) The finite element calculation employs the parameters of the soil body without freezing and thawing cycles in the model test. After freezing and thawing cycles of the reinforcement retaining wall, elastic module of the soil body is reduced, which is the main cause for the actually measure value more than the calculation value in the model test.

ACKNOWLED GEMENTS

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