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Numerical Simulation of Fiberglass Tunnel Model Based on FLAC3D

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Abstract: In order to verify the performance of fiberglass material and to ensure the strength, stiffness and stability of fiberglass tunnel model meet the needs of large-scale model test, numerical simulation is carried out with FLAC3D software, offering reference to installation location of monitoring components in the following bearing capacity monitoring test of the 1m fiberglass tunnel model. Through contrast to the results of bearing capacity monitoring test, it is found that the prediction of deformation of the model through results of numerical simulation is relatively accurate, while there are still large differences in numerical values, which may be caused by the improper selection of constitutive model and material parameter. Continuous improvement is still in need to offer reference and help to further optimization design of fiberglass tunnel model.
Keywords: fiberglass, field test, FLAC3D

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1. BACKGROUND INTRODUCTION

In order to reveal the geophysical response characteristics of typically poor geology and to validate the effectiveness of various advanced prediction methods, Geo&Stru Engineering Research Center of Shandong University developed a large-scale physical model test system for advanced geological prediction of tunnels, as shown in Fig. 1. The size of the device in the large-scale physical model test is 17m long ×8.4m wide ×6.7m high, with the reinforced concrete wall of 0.4m thick in the exterior and material similar to surrounding rock filled in the interior, which can meet the needs of advanced prediction test through various methods such as induced polarization, seismic wave and transient electromagnetic. In order to simulate the real tunnel environment, a tunnel model which is 2.1m high × 1.7m wide is inbuilt for researchers to conduct tests in. Through research analysis, fiberglass material has the advantages of light weight, high strength and good designability, suitable to be used to make tunnel model. In order to verify the performance of fiberglass material and to ensure the strength, stiffness and stability of fiberglass tunnel model meet the needs of large-scale model test, numerical simulation is conducted with the commonly used FLAC3D software to get the stress and deformation situation of fiberglass tunnel model under the pressure of overlaying soil, and then corresponding optimization design is carried out [1-3].

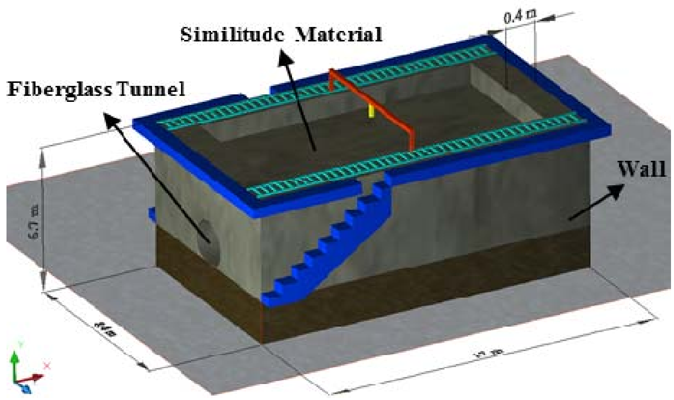


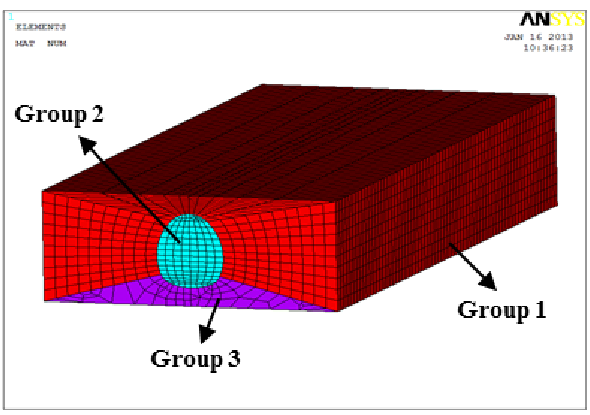
Fig. 1 Sketch map of large-scale model test

2. NUMERICAL SIMULATION AND CALCULATION

Developed by Itasca Consulting Goup lnc in America, FLAC-3D (Three Dimensional Fast Lagrangian Analysis of Continua) is a three-dimensional fast Lagrangian analysis program, which can simulate mechanical behaviors of damage or plastic flow happening when the geological material reaches ultimate strength or yield limit, especially suitable to analyze progressive failure and unstability, and to simulate large deformation [4].

2.1 Ansys modeling and meshing

As modeling and meshing with FLAC3D software is rather complex and difficult, Ansys software is used instead. Numerical calculation model is built according to the real proportion of the overground part of large-scale physical model test. As shown in Fig. 2, the model is 17m long × 8.4m wide × 3m high, consisting of three main parts: Group1 standing for soil surrounding the tunnel and overlaying soil; Group 2 for fiberglass tunnel model; Group 3 for subsoil layer of tunnel. The unit type is Solid 45 and hexahedral element is adopted for meshing, which is done through mapping.



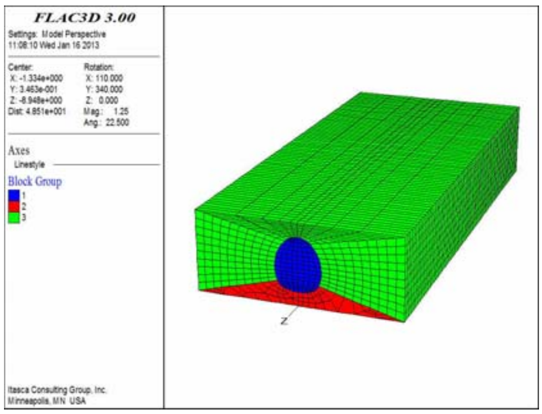


Fig. 2 Ansys modeling and meshing   Fig. 3 Numerical simulation imported into FLAC3D

2.2 FLAC3D parameter setting and calculation

Import the model built with Ansys into FLAC3D (shown in Fig. 3). Parameter assignment and calculation are conducted by invoking command file and the parameters and calculation thought are shown as follows:

(1) Establish model structure and assign material parameters:

Invoke geometrical model in FLAC3D and excavate a one-meter-long soil mass from Group 1. Set it to be shell structure unit, which is used to simulate fiberglass tunnel model. Fiberglass parameters can be got through uniaxial compression test of fiberglass test block: elastic modulus is 2.46 GPa, Poisson ratio 0.35, thickness 15 mm and density 1522.38 Kg/m3. Mohr - Coulomb models are adopted for other Groups and assign them according to parameters of soil: elastic modulus is 15 MPa, Poisson ratio 0.38, internal friction angle 16 and cohesion 3.6 × 104.

(2) Apply boundary conditions:

Since the tunnel model is buried in the soil during the test, displacement constraints should be imposed around and at the bottom of the model when conducting the modeling analysis.

(3) Remove the overlaying soil and balance gravity:

Remove Group 1 and Group 3, only calculate the displacement and stress of fiberglass tunnel model and the subsoil layer under the effect of its own gravity.

(4) Reset speed field and restore the overlaying soil:

Reset the velocity and displacement field generated by the fiberglass tunnel model and the subsoil layer under their own gravity and restore the overlaying soil Group 1 and Group 3.

(5) Apply load and calculate:

Considering that other load effects above the soil mass may exist during construction and the actual use of device for large-scale physical model test, uniform load should be applied to the upper surface of the soil mass before calculation.

3. RESULT ANALYSIS

After calculation, the results of stress and displacement are analyzed respectively:

3.1 Analysis of stress result

As shown in Fig. 4, the stresses in the Y direction at the arch crown and arch foot are big, with the maximum value of 4.20 MPa, which occurs at the arch foot of the model. As shown in Fig. 5, the stress in the X direction at the bottom is big, with the maximum value of 2.58 MPa, which occurs at the bottom of the model. According to the results of uniaxial compression test of fiberglass test piece, the compressive strength of fiberglass material is about 55 MPa, with stronger tensile strength, which is higher than the maximum stress in numerical analysis. Therefore, the strength of fiberglass material should meet the test requirements.

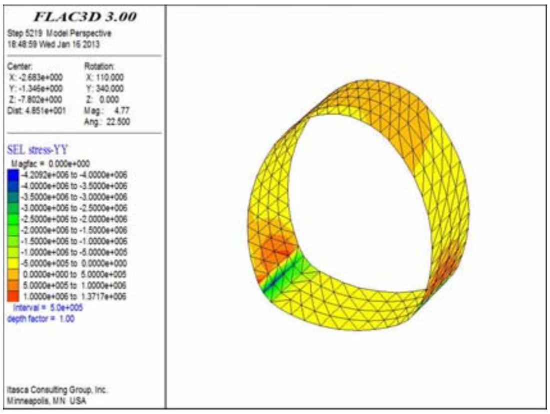


Fig. 4 Stress in the Y direction

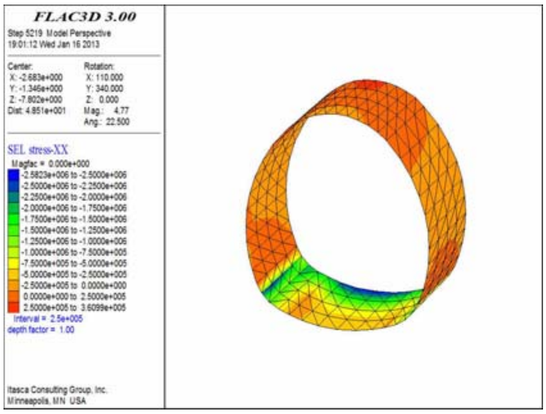


Fig. 5 Stress in the X direction

3.2 Analysis of displacement result

As shown in Fig. 6, displacements at the arch crown and arch bottom of the model are big, with the maximum value of 5.53 mm. Fig. 7 shows that displacement in the X-direction at the haunch of the model is big, with the maximum value of 3.69 mm. The deformation of the tunnel model after 100-fold magnification is shown in Fig. 8. Combining with the deformation direction shown in Fig.9, it is found that the model under load begins to become concave at the shoulder, expand in the middle and shrink at the right and left bottom.

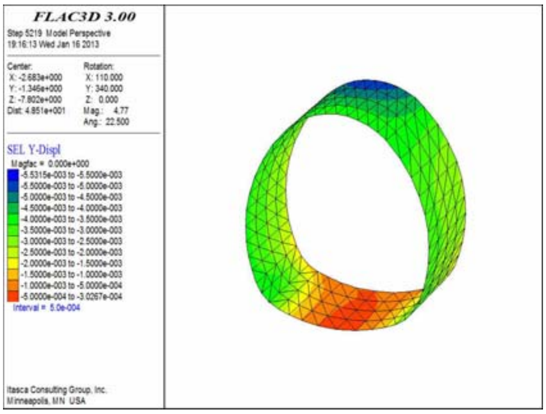


Fig. 6 Displacement in the Y direction

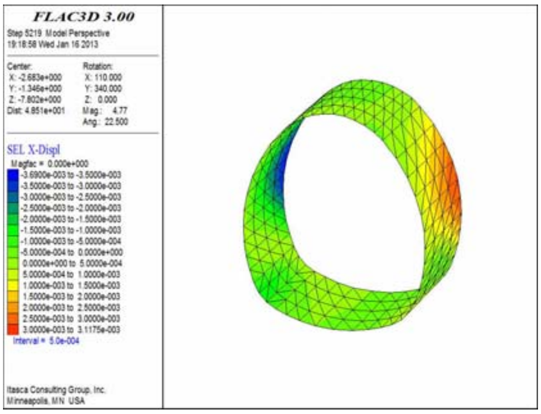


Fig. 7 Displacement in the X direction

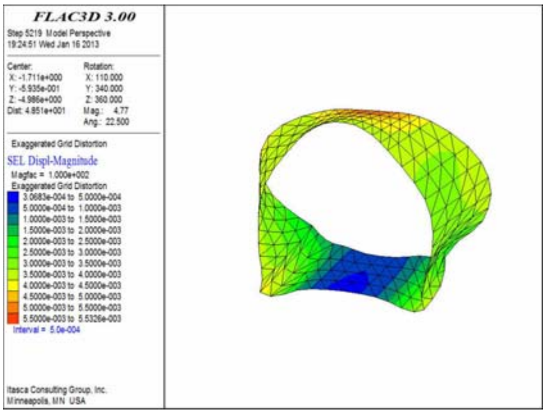


Fig. 8 Tunnel deformation after 100-fold magnification

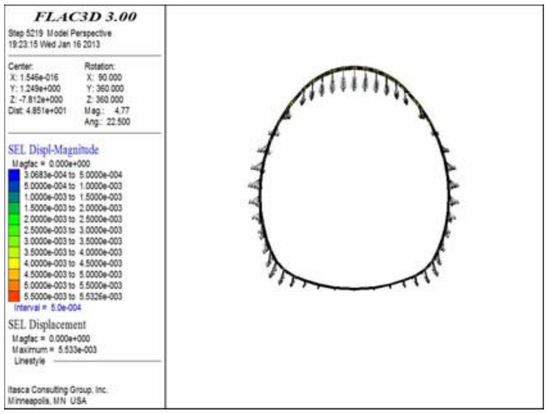


Fig. 9 Tunnel deformation direction

4. CONTRAST IN FIELD TEST

A one-meter-long fiberglass tunnel model is designed in order to further study the deformation of the fiberglass tunnel model under load. Corresponding bearing capacity monitoring test is designed and conducted. The field test data show that the deformation of the 1m fiberglass tunnel model mainly consists descending of the arch crown rise of the arch bottom and expansion of haunch, among which, the relative displacement between the crown and haunch is 4 cm and the relative displacement between the left and right haunch is 2.5 cm. Through the contrast between photos in Fig. 10, it is obvious that the shape of the model changes from the original duck egg to roundness due to stress. It is easy to find that the actual deformation of the model is consistent with the deformation trend obtained by numerical simulation.

(a) Photo Taken before the Test (b) Photo Taken after the Test

Fig. 10 Vector diagram of deformation direction of tunnel

5. CONCLUSION

Numerical simulation study is conducted on fiberglass tunnel model in large-scale physical model test system through FLAC3D software and deformation and stress of model in the test are analyzed, offering reference to installation location of monitoring components in the following bearing capacity monitoring test of the 1m fiberglass tunnel model. Through contrast to the results of bearing capacity monitoring test, it is found that the prediction of deformation of the model through results of numerical simulation is relatively accurate, while there are still large differences in numerical values, which may be caused by the improper selection of constitutive model and material parameter. Continuous improvement is still in need to offer reference and help to further optimization design of fiberglass tunnel model.

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