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Study on the Safety of the Foundation Rock Masses in the Tangkou Bank of the Taipinghu Bridge

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Abstract: The Taipinghu Bridge is an important project, and the safety of rock masses of its foundation is very crucial. This article analyzes the potential causes of the deformation of the rock masses of the bridge foundation, and uses the Fast Lagrangian Analysis of Continua to analyze the geologic model. The simulating process shows that no mater in the excavating process or in the loading process the rock masses are suit for the engineering. The modeling and analyzing process can be used for reference.

Key words: FLAC^{3D}; Numerical simulation; Engineering; Bridge foundation

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The Taiping lake bridge is located in Taipinghu town, which is in Huangshan city of Anhui province. The span of the bridge is over 330m and the bridge's abutments are situated in the Tongling bank and the Tangkou bank. Because of the huge span of the bridge, the diversity of the rock masses in the abutments and the abundant structural planes, it is very important to study comprehensively on the engineering geological condition of the bridge and to estimate the engineer security of the rock masses in the abutments.

This article uses the FLAC^{3D} to analyze the deformation of the rock masses in the excavating process and in the loading process, and estimates the engineer security.

1 The geological setting

The strata in Tangkou bank are mostly made up of the pelitic siltstone and the sandy shale, and the principal factor of rock masses is that the incompetent beds interbedded with the competent beds. In this area the NW direction's structural planes are abundant, and incise the rock masses into sheet structures. Because there are many pelitic bands, it's easy to see some layers of earth that are changed from the pelitic bands by the weathering. Wiped off the layer of earth, the bedrock that is made up of the strong or the whole dimorphism siltstone is shown.

The landform is gentleness. Because the rock masses contain many argillaceous elements, the weathering is strong relatively. In the Tangkou bank, the strong aerated layer's depth is 10~20m, the average depth is 15m; the moderate aerated layers' depth is 10~20m, the average thickness is 13m; the weak aerated layer's depth is about 25m. As a rule, the rocks containing more argillaceous elements or in the low grounds are weathered seriously, otherwise the weathering function is weak relatively.

The slope gradient in the skewback is under 10°, therefore the free faces are ambiguous. Because the relieving cleft's dip angle is small, the depth of the

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stress-releasing strap is thin. The depth of the strong stress-releasing strap is about 5m, and the weak stress-releasing strap is about 10m.

Though the competent beds interbedded with the incompetent ones and the structural planes (specially the horizontal direction) are abundant, the deformation of the rock masses is not serious because there is no free face in the abutment.

2 Computing model

The FLAC is the abbreviation of the Fast Lagrangian Analysis of Continua. The FLAC is a famous mechanics technique. Its name comes from the hydrokinematics, which studies the liquid particle's movement along with the time's change. The Fast Lagrangian Analysis of Continua divided the computing areas into some mesh regions, and the mesh regions' deformation can be changed along with the materials' change. This algorithm is the Lagrangian algorithm. The algorithm can simulate the materials' deformation, plastic flow, intenerate and vast deformation. This algorithm has special dominance in materials' elastic and plastic analysis, vast deformation analysis and simulating the construct process. Therefore using the FLAC algorithm to analyze the geologic process in this area is appropriate.

2.1 The scope of the model

To make certain the three dimension models' scope should follow two principles: firstly, in order to give prominence to the researching area, the scope of the model should not be too wide; secondly, the models' scope is large enough to eliminate the boundary effect.

According to the two principles, the model of the Tangkou bank is wide 250.6 m along the paralleling direction of the lake (Z-axis direction); the width is 222 m along vertical direction of the lake (X-axis direction); the maximal height of the model is 156 m (Y-axis direction). The bottom's height above sea level is 50 m (fig. 1).

2.2 The parameters of the rock masses

After the model has been created, to make certain the determination of the parameters of the rock should follow the physical differences of the rock masses and

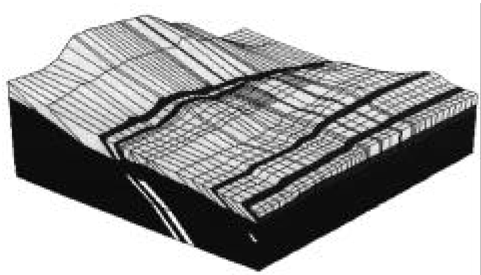

Fig. 1 The model of the rock mass in Tangkou bank

geological framework. According to this principle, the rock masses in Tangkou bank are divided into pelitic siltstone, sandy shale and fault zone. The pelitic siltstone is divided into the strong weathered pelitic siltstone①, the moderate weathered pelitic siltstone② and the weak weathered pelitic siltstone③ according to the weathering condition. The sandy shale is also divided into the moderate one④ and the weak weathered one⑤. The fault zone has the lowest parameter values because of its weak geological condition. The data are showed in Table1.

2.3 Boundary condition

In the evolvement of the slope, it is believed that there was no horizontal movement. Therefore the X-axis and the Z-axis are constrained. Other boundaries are free, and the only load is the weight of the rock masses.

3 The engineering feasibility analysis

3.1 The deformation character of the wall and the underside in the excavating process

In order to analyze the deformation of the wall and the underside, the excavating process is divided into 3 steps:

Firstly: excavating the strong weathered zone in the abutment;

Secondly: excavating some moderate weathered zone in the abutment;

Finally: excavating the moderate weathered zone in the abutment to the supporting course.

The results show that deformations in the Tangkou bank have some regularity.

Table 1 the parameters of the rock masses in Tangkou bank

Group	E (MPa)	μ	C (MPa)	f (°)	γ (MN/m³)	T (MPa)	K (MPa)	G (MPa)
①	7000	0.30	0.1	35	0.025	0.2	2692	5833
②	10000	0.26	0.6	40	0.026	0.7	3968	6944
③	16000	0.23	1.3	43	0.026	1.5	6504	9876
④	6500	0.29	0.05	37	0.055	0.05	2519	5158
⑤	6000	0.31	0.02	34	0.025	0.02	1908	4325
⑥	3000	0.33	0.01	31	0.022	0.01	1129	2941

(1) The rock masses' deformation near the foundation bed mostly is the rebounding of the unloading (Fig.2). After the new excavating process, the new deformation appears near the new excavating areas.

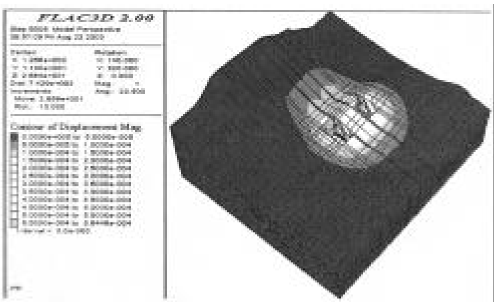

Fig.2 The deformation of the rock masses after excavating

(2) During the excavating process, the deformation of the Y-axis is largest, and its direction is verticality; the X-axis deformation is moderate; the Z-axis deformation is minimal.

(3) After the excavating process, the X-axis' deformation's numerical value of is 0.35 mm. The Z-axis' deformation occurs in the middle and top wall, and its maximal value is 0.2 mm. The Y-axis' deformation appeared in the bottom of the abutment and the under part of the wall, and its maximal value is 0.5 mm. Therefore the most unambiguous deformation is the rebounding of the unloading in the bottom, and the deformation of the wall is in the next place.

(4) The range of the deformation locates on the excavation area nearby. In relation to the whole area, the influence of the excavation is not obvious.

In order to know the values of the deformation accurately, we traced some rock masses in some important places.

The data in the table 2 are the deformation values of some places on the wall in different altitudes. As a whole, if excavation's depth is larger, the value of the deformation is bigger. But the total value is very small.

Table 2 the movement value of some points

Location	X-axis movement (mm)	Y-axis movement (mm)	Z-axis movement (mm)
Bottom of the abutment	0.1	0.43	0.05
Lower part of the wall (93m)	0.2	0.2	0.04
Middle part of the wall (96.5m)	0.1	0.15	0.07

3.2 The deformation character of the wall and the underside after loading

From the engineering point of view, the most important question is that after the building of the bridge the rock masses are whether safe or not and the deformation of the rock masses is small enough to bear the loading. Therefore we use the FLAC^{3D} to analyze the deformation character of the wall and the underside after loading.

The loads load on the bottom of the underside and wall directly to simulate the weight of bridge piers and the force that are passed by the piers. The data of loads are shown on table 3.

Table 3 loads on rock masses

Place	Attitude (m)	Load on X-axis (MPa)	Load on Y-axis (MPa)	Load on Z-axis (MPa)
Bottom	92	0	1	0
Wall	92~93	-0.49	0	0.326
	93~96.5	-0.48	0	0.316
	96.5~102	-0.44	0	0.276
	102~104	-0.39	0	0.226
	104~106	-0.37	0	0.206

After loading, the deformation of Y-axis in the siltstone is less than 0.5mm. The maximal deformation appears in the middle of the abutment, which stratum is made up of the sandy shale, and is a compression deformation. The maximal value of the deformation is about 3mm. Because the sandy shale has a poor bearing capacity, the same load can make more deformation than the load makes on the pelitic siltstone.

The fig. 3 shows the total deformations of the rock masses after loading. The loading process influences only the rock masses near the excavating area.

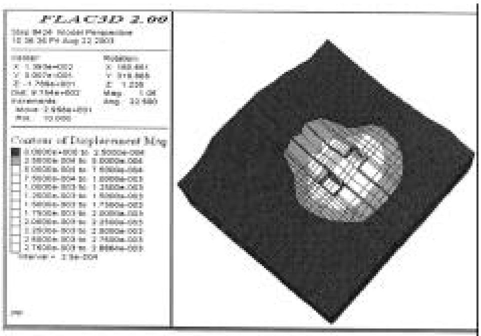

Fig.3 The total deformation after loading

4 Conclusion

In the excavating process, the deformations of the rock masses are the rebounding because of the unloading, and the range of the deformation is near the new working face. As a whole, the Y-axis' deformation is most unambiguous. After loading, the range of the deformation is near the loading area, and the deformation is a compression deformation. The influence of the loading is not obvious. The maximal deformation appeared in the incompetent beds of the bottom of the abutment. The deformation in Z-axis is not obvious. Tracing some points' movement, we find that the system of rock masses is safe even after loading.

Therefore, in Tangkou bank, the moderate weathered rock masses' bearing capacity can take the weight of the bridge and the loading that is passed by the bridge, and the rock masses have the condition to fit the project.

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