Study on bond mechanics of antifloating anchor in red sandstone

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Abstract. In order to study the mechanical properties of anti-floating anchor rod in medium-strong weathered red sandstone and its application in engineering examples, this paper takes the virtual university town project of Hengyang High-tech Zone of Hunan Province as the engineering background. This paper had done destructive test of anti-floating anchor rod. The effects of different parameters on the adhesion of anti-floating anchor rod were studied by test and from three aspects: drilling depth of anti-floating anchor rod, highly and intermediary weathered sandstone. At the same time, the adhesion of anti-floating anchor rod in the same type of rock but with different drilling depths is compared and analyzed. The results show that under the condition of the same drilling depth, the adhesion of anti-floating anchor rod of different lithology is different, and under the condition of the same type of rock formation, the adhesion of anti-floating anchor rod of different drilling depth is not the same. The recommended bearing capacity characteristic value of the weathering layer is 1500 KPA, which can be used as the foundation bearing layer of the proposed building.

1. Introduction
With the progress of our society and the acceleration of urbanization, the utilization rate of underground space has also started to increase steadily. In recent years, damage to existing buildings caused by buoyancy above groundwater has been common. Setting up vertical anti-floating bolt can reduce the damage caused by insufficient soil covering capacity of foundation[1]. In addition to balancing the buoyancy of groundwater, anti-floating bolt can also play a role in strengthening the foundation, thus reducing the foundation deformation and uneven settlement. Therefore, it is necessary to study the bonding ability of anti-floating bolt and the application of anti-floating bolt in practical engineering. In recent years, the research on mechanics of anti-floating bolt has become a hot topic. For example Wang Jianyu[2] based on Mindlin solution by deformation compatibility condition anchor internal force calculation, the calculation results reflect the anchor solid - interface in geotechnical engineering pile side friction distribution inhomogeneity, Fujita[3] etc. Through the analysis of 30 cases of field test results summary, it is considered that after the anchoring length exceeded the critical anchoring length, the ultimate pull-out force of anchor increased very little. Based on the virtual university town project of Hengyang High-tech Zone of Hunan Province, this paper provides relevant basis and reference for the construction of anti-floating anchor in medium-strongly weathered red sandstone in eastern Hunan Province.
2. Project Summary

Hengyang high-tech zone virtual university city project in Hengyang city Hengzhou avenue and Caixia street junction. According to the geotechnical investigation report of the site, the main strata in the excavation depth range are:(1) miscellaneous fill: this layer is mainly distributed in the south and east of the site, with a small distribution in other sections;(2) strongly weathered silty mudstone: this layer is distributed throughout the whole field, with an average thickness of 4.16m and low compressibility. However, the rock core with uniform properties is semi-rock and semi-soil, with few fragments and a small number of short columns. The rock is extremely soft, and fragments can be broken.(3) moderately weathered silty mudstone: this layer has a full-field distribution. According to the results of indoor rock test, the uniaxial saturated compressive strength range is 5.60-11.60mpa, with high bearing capacity. It is recommended that the characteristic bearing capacity of this layer is 1500kPa, which can be used as the foundation bearing layer of the proposed building. The tests were all located in the strong weathering zone and the middle differentiation zone. The underground water level at the site of the project reaches 63.13-68.32m, and the anti-floating water level is 71.50m, with abundant groundwater. Secondly, the geological type of this project is not ordinary rock strata but red sandstone.

2.1 Test Design

Refer to relevant test method specifications [4]. The destructive test of anti-floating bolt is carried out. The failure condition is that the reinforcement bar is pulled out or the anchor bar is pulled out and the foundation deforms and damages. Reinforcement bolts are adopted, and 3 bars with diameter D of 25mm are placed for each anchor. The thickness of the protective layer of reinforcement is 25mm, the strength of cement mortar is M30, and the diameter of drilling hole is 150mm. The curing period is 28 days. Figure1 are shown below.

![Figure 1: After rock bolt grouting.](image)

The distribution of rock strata in the hole position and the drilling depth are as follows:(1) the drilling holes in the strong weathering layer are in the first group with 3 in each group and the drilling depth is 3.50m;(2) the drilling holes in the strong weathering layer are in the second group, with 3 holes in each group, and the drilling depth is 6.50m;(3) the Moderate weathering boreholes are in the third group, 3 in each group, with a drilling depth of 3.50m;(4) the Moderate weathering boreholes are in the fourth group, with 3 in each group, and the borehole depth is 6.50m. The number and size of bolts for each group are shown in table 1.

| Rock bolt number | Anchorage length (m) | Diameter of reinforcement (mm) | Anchor length (m) |
|------------------|----------------------|-------------------------------|-------------------|
| Q_T1,Q_T2,Q_T3,Z_T1,Z_T2,Z_T3 | 3 | 25 | 3.5 |
| Q_T4,Q_T5,Q_T6,Z_T4,Z_T5,Z_T6 | 6 | 25 | 6.5 |

2.2 Test Loading Mode
First of all, in addition to the strong weathering layer $Q_{t1}$ and $Q_{t4}$, two bolts are loaded in grades, the rest of the bolts are loaded in grades, to stop loading when reaching the conditions of loading termination.

In order to more image simulation of the groundwater in the circulating water buoyancy effect, strong weathering bolt adopt hierarchical load, two former triple load according to 20% of the test load applied, after applying, by 10% per level to load after 10 min, and within 10 min load time, the displacement of the anchor bolt should be less than 1.0 mm, and record data, load step by step to stop loading [5] when the termination conditions.

### 2.3 Test Loading Device

The test equipment mainly includes manual piercing hydraulic jack, dial gauge, high pressure oil pump, pad and other equipment and equipment, among which the loading equipment and dial gauge equipment need to be adjusted in advance to ensure the accuracy of test reading. The test device is shown in figure 2.

**Figure 2. Test Loading Device.**

### 2.4 Test Process

Firstly, GPS was used to locate the location of the required drilling hole, and then the drilling machine was used to drill the hole. The drilling depth was 0.5m deeper than the designed depth of the anchorage section. When the depth of the test drilling hole was reached, the drilling would not be stopped immediately, but 1-2min. Then, the prefabricated anchor rod that meets the requirements of the test design is placed vertically on the ground downward into the hole, and then the cement mortar with the strength of 30MPa is injected. The cement mortar is mixed in the concrete mixing plant and transported by tank truck. After curing for 28 days, install test drawing device.

Before the test, the three exposed bar reinforcement bars were welded to the three combined bars with diameters of 25mm that were exactly the same as the bar reinforcement bars for test loading, and more than the exposed sections were cut off to prevent the steel plate from being supported during the test. Then level the ground around the test area to remove soft soil and remove stagnant water. The jacks are raised by steel plate to reduce the influence of soil deformation on the test results. The test process is shown in figure 3.
3. Test Results

3.1 Anti-floating bolt failure form
The test results showed that the failure forms of anti-floating bolt were pulled out, the welding position was damaged, the foundation was damaged and the consolidated steel bar was pulled out, as shown in figure 4 below.

![Figure 3. Test Process.](image-url)
3.2 Ultimate Bearing Capacity of Anti-floating Bolt

The ultimate bearing capacity of the strong weathering layer and the middle weathering layer under grade loading is shown in table 2 and table 3 below.

Table 2. Strong weathering layer.

| Anchor number | Anchorage length 3m | Anchorage length 6m |
|---------------|---------------------|---------------------|
| QT-2/5        | 806.64              | 798.09              |
| QT-3/6        | 843.74              | 871.57              |

Table 3. Middle weathering layer.

| Anchor number | Anchorage length 3m | Anchorage length 6m |
|---------------|---------------------|---------------------|
| ZT-1/4        | 370.72              | 305.79              |
| ZT-2/5        | 398.54              | 398.54              |
| ZT-3/6        | 370.72              | 398.54              |

When the building foundation underside is located below the underground water level, the groundwater will generate hydrostatic pressure on the foundation underside, that is, the buoyancy force [6]. In order to simulate groundwater circulation, anchor rods QT-1 and QT-4 were loaded in stages [7].

The ultimate bearing capacity of anchor rods QT-1 and QT-4 under staged loading is shown in table 4 and table 5 below. The ultimate load in turn 336.96KN and 407.82KN.
4. Sliding friction between solid particles

Sliding friction on a solid surface [8] is the real friction generated by sliding along the surface of a solid plane, it is generally the main part of the friction strength of the soil. Can be expressed as

$$\mu = \frac{T}{N} = \tan \varphi_{\mu}$$

(1)

Where, $N$ is the positive pressure; $T$ is the surface friction; $\mu$ is the friction coefficient, is a material constant; $\varphi_{\mu}$ is the sliding friction Angle.

Friction coefficient is

$$\mu = \frac{\tau_m}{\sigma_y}$$

(2)

Where, $\tau_m$ is the shear strength , $\sigma_y$ is the yield strength of the material.

5. Conclusion

The variation law of anchor anchorage stress in the middle weathering layer and the strong weathering layer under the same anchorage length is obtained by drawing test of anti-floating anchor rod. When the anchorage length is 3m, the anchorage stress in the strong weathering layer is basically 1.5 times that in the middle weathering layer. When the anchorage length is 6m, the anchorage stress of the strong regolith is basically 1.8 times that of the middle regolith.

According to the test, it can also be seen that the anchorage stress of rock bolts in the middle weathering layer and the strong weathering layer changes in the case of different anchorage lengths. When the rock type is the middle differentiated layer, the anchorage stress at the anchorage length of 6m is 1.2 times that at the anchorage length of 3m. When the rock type is strongly weathered, the anchorage stress at 6m is 1.5 times that at 3m.

When the anchorage length of the anti-floating anchor in the red sandstone of the middle and strong weathered strata increases exponentially, the anchorage stress does not increase exponentially with the anchorage length.

In the test, when the anti-floating bolt is pulled out and the pulling length reaches 5cm, the bolt has lost its anchoring ability.
References

[1] Soil mechanics foundation/edited by Chen xizhe.-4 Ed.- Beijing: tsinghua university press, 2004 (selected civil engineering textbooks)

[2] Wang jianyu. Calculation of internal force of cohesive anchor head in ground anchor engineering based on common deformation principle [A]. New technology of geotechnical anchorage engineering [III]. Beijing: people's communications press, 1998.52-63.

[3] Fujita K.et al .A method to predict the load-displacement relationship of ground anchors[A]. Proceedings of the 9th International Conference on Soil Mechanics and Foundation Engineering[C]. Tokyo:The Japanese Society of Soil Mechanics and Foundation Engineering, 1977.58-62

[4] Code for design of building foundation. China building industry press,GB 50007-2011

[5] technical code for rock and soil bolts (cables) CECS 22:2005

[6] engineering geology/shi zhenming, kong xianli. 2nd Ed.- Beijing: China building industry press, 2011.1

[7] Liu guoming. Research on bearing capacity of full-length bonded anti-floating anchor in strongly weathered sandstone.

[8] Higher soil mechanics/li guangxin. 2nd Ed.- Beijing: tsinghua university press, 2016 (reprint 2019.1) pp.140-141.