Experimental Study on Shear strength of Rock-Concrete Interface at Different Ages

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Abstract. Aiming at the power grid engineering construction, the shear strength or friction resistance of rock-socketed digging pile foundations and rock bolt foundations are different. The basic dimensions designed by each unit are quite different, in the shear strength test device of rock concrete interface, tests on the shear strength of the rock-concrete interface of different rock types (limestone, marble, and granite) and ages (3-day and 21-day) have been carried out. The results show that, the bond strength of the rock-concrete interface of different ages is quite different. Within 21 days of age. The bond strength of the rock-concrete interface has a linear relationship with age.

Keywords: Shear strength, Friction resistance, Rock-concrete interface

1. Introduction
With the large-scale construction of the power grid, the survey, design, construction and management of rock-socketed digging piles, rock bolts and other types of foundations are facing some technical problems [1-2]. Among them, the determination of the shear strength or frictional resistance of the bedrock-concrete interface and how to design such foundations are particularly prominent and urgent. The mechanical properties of the interface have a significant influence on the internal force and deformation characteristics of rock and concrete structures [3]. It has been suggested that the structural surface is an important factor affecting the mechanical properties of the interface [4-7]. However, the mechanical properties of the interface between different rocks and different curing ages of concrete are quite different. Due to the lack of related technology, the same conditions are caused, and the basic dimensions designed by each unit are quite different.

In order to solve the technical problems faced in engineering applications such as rock bolts and rock-socketed digging piles, carry out relevant research on the shear strength test of the rock-concrete interface [8].

2. Shear Strength Test

2.1. Test Device
In this test, the 300 mm diameter alloy steel pipe sleeve is used as the foundation boundary. The wall thickness of the pipe sleeve is 15 mm, and the thickness of the upper and lower bottom plates is 20 mm. The bolt assembly and fixation can be used to make the effective and safe test foundation boundary, as shown in figure 1. The shear strength test of core samples with different diameters and lengths can be carried out by using different sizes of roof plates.
2.2. Core Sampling
The portable hand-held water drill rig is used for core sampling, and 2-3 people on the sampling site can complete the operation of the drilling rig and sampling process. According to the needs, drill pipes of different diameters are selected to drill in rock mass from small to large (convenient for complete sampling) to obtain annular core samples. In order to avoid burning the bit, water supply should be ensured at all times during drilling, as shown in figure 2.

2.3. Foundation Pouring
Select, cut, and polish a suitable ring core sample and place it in the pipe sleeve, after positioning and locking the annular core sample, from the inner circle to the outer circle (to prevent the uneven force of the annular core sample from shifting), pour the same concrete, vibrate, and finish after curing, as shown in figure 3.
2.4. Shear Strength Test Assembly
When the concrete curing period is reached, the shear strength test of rock concrete interface is assembled, and the roof with a thickness of more than 2cm is placed at the edge of the annular core sample to ensure that the inner edge of the roof is between the inner edge and the outer edge of the ring core sample, so as to ensure that the shear strength failure of the rock concrete interface occurs during the test [9], rather than the shear failure between the rock outer diameter and the concrete, as shown in figure 4.

![Figure 4. Test assembly.](image)

The test can be stopped after the shear strength failure of the rock-concrete interface occurs.

2.5. Test Equipment
After the curing period is reached, the basic shear strength test assembly is carried out, in the test, the RS-JYC static load test analyzer is connected to the oil pressure pump and the jack to control the oil pressure. Obtain real-time load and displacement information through data testing, display and acquisition devices, adjust and control the load according to the preset loading plan and measured load value, realize the precise combination of data testing and loading control. The test is mainly to test the load and displacement of the test foundation.

1) Load test
The vertical uplift load of the foundation measures the oil pressure through the strain gauge oil pressure sensor, then it is converted by the RS-JYC pile foundation static load test analyzer and automatically collects and records the data.

2) Displacement test
In the test, the pull-up displacement is measured by a displacement sensor. The RS-JYC pile foundation static load test analyzer's repeater and bus are transmitted to the host for collection and recording. Frequency displacement sensor measures displacement, the accuracy can reach 0.01mm, the response is sensitive, the measurement is accurate, the installation is convenient, the use is simple, and it can quickly collect data through the static load instrument.

3. Test Data and Analysis
3.1. Core Category
In this test, three types of ring core samples were used to carry out the 3-day and 21-day shear strength tests of different ages, the three ring core samples are limestone, marble, and granite. The limestone was sampled from Wanzhou District, Chongqing City, the marble was sampled from Fangshan District, Beijing, and the granite was sampled from Yunhe County, Lishui City, Zhejiang Province. The parameters of the annular core samples are shown in table 1.
Table 1. Parameter table of three kinds of annular core samples.

| Serial number | Category | Length /cm | Internal diameter /cm | Degree of weathering | Integrity       |
|---------------|----------|------------|-----------------------|----------------------|-----------------|
| 1             | Limestone| 15         | 12                    | Micro- Medium        | Complete        |
| 2             | Limestone| 19         | 8.5                   | Micro- Medium        | Complete        |
| 3             | Limestone| 20         | 8.5                   | Micro- Medium        | Complete        |
| 4             | Limestone| 25         | 8.4                   | Micro- Medium        | Complete        |
| 5             | Limestone| 15         | 12                    | Micro- Medium        | Have a crack    |
| 6             | Limestone| 20         | 8.5                   | Micro- Medium        | A crack at the top |
| 7             | Limestone| 25         | 8.4                   | Micro- Medium        | Complete        |
| 8             | Marble   | 29         | 12                    | Micro- Medium        | Complete        |
| 9             | Marble   | 25         | 8.4                   | Micro- Medium        | Complete        |
| 10            | Marble   | 21.5       | 16                    | Micro- Medium        | Complete        |
| 11            | Marble   | 10         | 8.4                   | Micro- Medium        | Complete        |
| 12            | Granite  | 25         | 8.4                   | Micro- Medium        | Through crack   |
| 13            | Granite  | 21.5       | 16                    | Micro- Medium        | Through crack   |
| 14            | Granite  | 29         | 12                    | Micro- Medium        | Through crack   |
| 15            | Granite  | 29         | 12                    | Micro- Medium        | Through crack   |

3.2. Test Data

The results of shear strength tests carried out at different ages are shown in the tables 2-4:

Table 2. Limestone test statistics.

| Age /Day | Load /kN | Displacement /mm | Bond strength /MPa |
|----------|----------|------------------|-------------------|
| 3        | 130      | 11.02            | 2.55              |
|          | 120      | 1.18             | 2.25              |
|          | 240      | 4.75             | 3.18              |
|          | 190      | 6.69             | 3.33              |
| 21       | 180      | 2.78             | 3.40              |
|          | 180      | 10.72            | 2.96              |
|          | 200      | 2.91             | 3.51              |

When the displacement of limestone concrete shear test with concrete curing period of 3 days reaches the ultimate displacement, the failure loads are 130kN, 120kN and 240kN respectively, and the corresponding bond strengths are 2.55MPa, 2.25MPa and 3.18MPa respectively. The average bond strength is 2.66 MPa. When the ultimate displacement of limestone concrete shear test with concrete curing period of 21 days is reached, the failure loads are 190kN, 180kN, 180kN and 200kN respectively, and the corresponding bond strength are 3.33MPa, 3.40MPa, 2.96MPa and 3.51MPa respectively. The average bond strength is 3.30 MPa. The average bond strength of limestone concrete with concrete curing period of 21 days is 24% higher than that of limestone concrete with concrete curing period of 3 days.

Table 3. Marble test statistics.

| Age /Day | Load /kN | Displacement /mm | Bond strength /MPa |
|----------|----------|------------------|-------------------|
| 3        | 210      | 0.15             | 1.92              |
|          | 165      | 1.47             | 2.09              |
|          | 280      | 0.16             | 2.56              |
| 21       | 180      | 2.34             | 2.27              |
When the concrete curing period is 3 days, the ultimate displacement of marble concrete shear test is reached, the failure load is 210kN and 165kN respectively, and the corresponding bond strength is 1.92MPa and 2.09MPa, The average bond strength is 2.01 MPa. When the concrete curing period is 21 days, the ultimate displacement of marble concrete shear test is reached, the failure load is 280kN and 180kN respectively, and the corresponding bond strength is 2.56MPa and 2.27MPa, The average bond strength is 2.42 MPa. The average bond strength of marble concrete with concrete curing period of 21 days is 20% higher than that of marble concrete with concrete curing period of 3 days.

Table 4. Granite test statistics.

| Age /Day | Load /kN | Displacement /mm | Bond strength /MPa |
|----------|----------|------------------|-------------------|
| 3        | 340      | 2.02             | 2.99              |
|          | 260      | 8.21             | 2.76              |
| 21       | 360      | 9.05             | 3.22              |
|          | 340      | 11.04            | 3.61              |

When the displacement of granite concrete shear test with concrete curing period of 3 days reaches the ultimate displacement, the failure load is 340kN and 260kN respectively, and the corresponding bond strength is 2.99MPa and 2.76MPa respectively, The average bond strength is 2.88 MPa. When the displacement of granite concrete shear test with concrete curing period of 21 days reaches the ultimate displacement, the failure load is 360kN and 340kN respectively, and the corresponding bond strength is 3.22MPa and 3.61MPa respectively, The average bond strength is 3.42 MPa. The average bond strength of granite concrete with concrete curing period of 21 days is 19% higher than that of granite concrete with concrete curing period of 3 days.

4. Conclusion

The shear strength tests of different ages of limestone, marble and granite have mainly drawn the following conclusions:

(1) Concrete of different ages has a greater impact on the results of the shear strength of the rock-concrete interface, within 21 days of age, the bond strength of the rock-concrete interface has a linear relationship with age;

(2) The different weathering degree of the annular core sample has a great influence on the results of the shear strength of the rock-concrete interface, differences in the degree of weathering and integrity can cause discrete bond strength values;

(3) The sampling process ensures that the wall thickness of the annular core sample is the same, the uneven thickness caused by the eccentricity of the drilling process has a greater impact on the test; During the whole process of the shear strength test of the assembled rock-concrete interface, it is necessary to ensure that the inner edge of the roof is just clamped between the inner and outer edges of the annular core sample, in order to ensure the failure of the test at the rock concrete interface.

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