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Test method research on weakening interface strength of steel-concrete under cyclic loading

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Abstract: The mechanical properties of steel-concrete interface under cyclic loading are the key factors affecting the rule of horizontal load transfer, the calculation of bearing capacity and cumulative horizontal deformation. Cyclic shear test is an effective method to study the strength reduction of steel-concrete interface. A test system composed of large repeated direct shear test instrument, hydraulic servo system, data acquisition system, test control software system and so on is independently designed, and a set of test method, including the specimen preparation, the instrument preparation, the loading method and so on, is put forward. By listing a set of test results, the validity of the test method is verified. The test system and the test method based on it provide a reference for the experimental study on mechanical properties of steel-concrete interface.

1. Introduction
When the concrete-filled steel tube rock-socked piles are subjected to the horizontal cyclic load such as ship collision force and mooring force, the horizontal cyclic load acts on the outer surface of the steel tube first and then transmits part of the load to the core concrete through the steel-concrete interface. At last, the load is transferred from the concrete and steel pipe to the entire foundation. During loading and unloading of cyclic loads, the mechanical response of the steel-concrete interface will have an impact on the structure. The microscopic damage of the interface gradually accumulates, the material properties continue to decline, the macro-cracks begin to appear, and finally the structural damage occurs. Therefore, accurate understanding of the mechanical properties of the steel-concrete interface under horizontal cyclic loading is an important work to ensure the normal operation of the concrete-filled steel tube rock-socked piles structure and to improve the reliability and service life of the concrete-filled steel tube rock-socked piles.

At present, domestic and foreign scholars usually use the method of push-out test to study the mechanical properties of steel-concrete interface. Shakir KH¹² found that when the slenderness ratio is small, the interfacial bond strength of concrete-filled steel tube components is not affected by the slenderness ratio; the stiffener welded on the steel pipe wall will make the interface bond strength get a greater degree of improvement. Xue Lihong³⁴ found that the interfacial bond strength of concrete-filled steel tube increases with the increase of concrete strength, the average bond strength of concrete-filled steel tube under the condition of natural environment conservation is higher than that of...
wax-sealed closed, and the length of interface has no effect on the size of the interfacial bond strength.

Due to the limitation of the experimental method and the theoretical analysis method, the researches on the mechanical properties of the steel - concrete interface under cyclic loading are not many. Xiushu Qu, etc.\cite{6} through the repeated push-out test of rectangular concrete-filled steel tube concrete to obtain the distribution of interfacial bond stress. They explained the mechanism of the development of cohesive force, and put forward the concept of critical shear transfer length. Su Xianxiang, etc.\cite{7} studied the load-displacement hysteresis curve of rectangular concrete-filled steel tubular columns under cyclic load, and they found that the axial compression ratio had an important effect on the hysteretic behavior of rectangular concrete-filled steel tubular columns. Gu Zhangchuan\cite{8} proposed that the damage variable of bonding interface increases with the increase of the number of fatigue load cycles through the push-out test of the concrete-filled steel tube under fatigue load.

In order to further study the mechanical properties of steel - concrete interface under cyclic loading, the research and development of test system with higher precision, convenient data collection and multiple loading modes are especially important. To this end, a test system and a set of test methods are independently designed, which provides reference for future research.

2. Test system

The test system of steel - concrete interface strength weakening under cyclic loading is constituted with large repeated direct shear test instrument, hydraulic servo system, data acquisition system, test control software system, etc.. Based on electro-hydraulic servo loading principle, the system can carry out static test, fatigue test and cyclic load test through the closed-loop control of force and displacement. In the loading process, the loading control mode, the displacement control mode and the two coupling control mode can be used. What’s more, the control mode of mutual conversion also can be used. Input load signal through the computer when loading. The load signal is converted into electrical signal and passed to the electro-hydraulic servo valve through analog controller. Then, the electrical signal is converted into hydraulic signal by the electro-hydraulic servo valve. Controlling the hydraulic pressure source through above progress, let it provide the power to make the electro-hydraulic servo actuator work. Throughout the test loading process, the measuring sensor continuously feeds back the force and displacement signals to the analog controller. The analog controller regulates the actuator loading after the feedback signal is processed and finally completes the closed loop control of loading.
Figure 1. Large-scale cyclic straight shear testing instrument

1. Vertical loading actuator; 2. Load frame beams; 3. Pressure plate; 4. Upper cut box; 5. Lower cut box; 6. Support base; 7. Fixed connector; 8. Upper sliding plate; 9. Lower sliding plate; 10. Guide plate; 11. Roller row; 12. Horizontal actuator mount; 13. Horizontal loading actuator; 14. Instrument base; 15. Base plate

Figure 1 shows the self-designed large-scale direct shear test instrument, which is the main part of the self-designed test system. The instrument is mainly constituted with the instrument frame, horizontal and vertical actuators, and other components. The square cut box of the direct shear test instrument has an overall size of 200 mm × 200 mm × 100 mm. Square cut box composes the upper shear box and the lower shear box. The upper shear box is connected to the mounting seat by the connecting rod and remains fixed during the experiment. The lower shear box is connected to the horizontal actuator through the connecting seat. The bottom of the shear box is equipped with a base bearing plate, the backing plate is installed on the base of the instrument base, and the guide wheel is arranged between the bearing plate and the backing plate to reduce the frictional resistance in the cyclic shear test.

3. Test method

3.1 Specimen preparation

According to the shear box overall size of the large-scale repeated shear test instrument, the specimen cross-sectional size should be 200mm × 200mm. If the surface of steel plate was welded with steel to simulate different roughness of the interface, 5 mm gap was reserved between the ends of the steel bar along the shear direction and the edge of the steel plate in order to ensure that the test instrument will not shear the steel bar during the test, as shown in figure 2 and figure 3.
3.2 Instrument preparation
The main steps are as follows:

(1) Put the upper and lower shearing box apart before placing the specimen, then lowering the shearing specimen to the lower shearing box, observing and adjusting the position of the shearing specimen, and keeping the steel-concrete interface of the specimen flush with the top of the lower shear box. Installing the upper shear box, covering the pressure plate, and then connecting the upper shear box with the support through the connecting rod.

(2) Turn on the oil source and the computer control unit, and lowering the normal actuator so as to be in contact with the pressure plate of the upper shearing box. Bringing horizontal actuator front contact into contact with lower shearing box seat. Screwing on the nut to connect the horizontal actuator with the lower shear box.

(3) Enter the corresponding test parameters in the computer control unit, prepare for the cycle test.

3.3 Loading method
The test system supports load control mode, displacement control mode and two coupled control modes to load the test pieces, and can realize the conversion of the control modes during the loading process. For the experimental study on steel-concrete interface of concrete-filled steel tube rock-socked piles under cyclic loading, the cyclic loading test can be carried out first, then carrying out the shear failure test. In the cyclic loading test stage, the load is repeatedly applied to the steel-concrete interface to the specified number of cycles without breaking the interface, and then the interface shear failure test is performed on each group of specimens by displacement control mod.

3.4 Test process and results
Test process is shown in Figure 4. During the test, the control of Large-scale cyclic straight shear testing instrument is completed on the computer. Some basic parameters can be reflected on the display in real time. After the test, the data will be automatically saved in the computer.
Figure 4. Steel - concrete interface shear process schematic diagram

Figure 5. Shear Force - Shear Displacement Curve under 25kN normal load

Figure 5 shows the shear force-shear displacement curve which is obtained through applying the load to the steel - concrete interface to the specified number of cycles by the force control mode first and then applying the 25kN normal load to each group by displacement control mode. It can be seen from Figure 5 that the specimen begins to slide obviously at the beginning of the experiment. The slopes of the points in the curve are nearly the same and increase linearly. When approaching the shear failure load, the curve shows a significant peak point. After the limit load is reached, the shear load decreases significantly with the increase of shear displacement, and the load decreases slowly and then stabilizes. The curve shows a steady downward trend. The ultimate shear loading decreases with the increase of shear cycles.

4. Conclusion
(1) Self-designed test system consists of large repeated direct shear test instrument, hydraulic servo system, data acquisition system, test control software system and so on. The system can support the functions like vertical loading, horizontal cyclic loading, physical quantity measurement, automatic test data collection and so on. In the process of loading, load test mode, displacement control mode and the two coupled control modes can be used, and the control modes can be converted during the loading process. The test system provides a reference for the further research on steel - concrete
interface mechanical properties.

(2) The proposed test methods include specimen preparation, instrument preparation, loading method and so on. Through a set of experiments, the shear stress-shear displacement curve can be obtained, meanwhile, the morphology of the interface shear deformation and destruction also can be obtained.

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References
[1] Shakir K H. 1993 Pushout strength of concrete-filled steel hollow sections J. The Structural Engineer, 71(13): 230-233.
[2] Shakir K H. 1993 Resistance of concrete-filled steel hollow tubes to push-out forces J. The Structural Engineer, 71(13): 234-243.
[3] Xue Lihong, Cai Shaohuai 1996 Bond strength of steel - concrete in concrete filled steel tube columns (Part 1) J. Building Science 3:22-28.
[4] Xue Lihong, Cai Shaohuai 1996 Bond strength of steel - concrete in concrete filled steel tubular columns (Part 2) J. Building Science 3:22-28.
[5] Xue Lihong, Cai Shaohuai 1997 Influence of load eccentricity on bond strength of composite interface of concrete filled steel tubeular column J. Building Science (02): 22-25.
[6] Qu Xiushu, Chen Zhihua, David A.Nethercot et al 2013 Load-reversed push-out tests on rectangular CFST columns J. Journal of Constructional Steel Research 81:35-43.
[7] Su Xiangxiang, Yan Yuemei, Li Chaohua 2009 Research on the hysteretic behavior of CFRT columns under cyclic loading J. World Earthquake Engineering 25, No.1.
[8] Gu Zhangchuan 2012 Experimental reaserch on bond interface damage properties of concrete filled steel tube columns D. East China Jiaotong University.