Experimental study on mechanical behavior of steel-concrete composite beams with friction connections in different structural zones

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Abstract: in order to study the mechanical properties of steel-concrete composite beams with asymmetric friction connections and considering the structural factors, three simple steel-concrete composite beams with friction connections were fabricated, and the uniaxial low cycle cyclic loading sine wave tests were carried out on the steel-concrete composite beams with friction connections. The test results show that the composite beam can get stable two-stage hysteretic curve in structure 1 and structure 3, and has reliable hysteretic energy dissipation capacity. The hysteretic curve of structure 1 is more full and stable, and the strength increases first and then decreases with the loading.

1. Introduction

Steel concrete composite structure can give full play to the advantages of steel and concrete, so it is widely used in engineering[1]. Stud is one of the most widely used shear connectors in steel-concrete composite beams because of its high shear bearing capacity, good uplift resistance and convenient construction. There are basically perfect calculation theories for stud connectors of common concrete and steel composite structures[2]. However, in the construction, the stud is directly welded with the steel beam, which requires high welding quality. At the same time, the stud welded is not easy to remove and replace, which can not meet the requirements of sustainable development of infrastructure[3]. The bolt is the most common connector in steel structure. High strength bolt has the advantages of tight connection, easy disassembly and fatigue resistance, and is widely used in the installation and connection of steel structure and the structure often disassembled. High strength bolts can be used not only in the reinforcement of steel-concrete composite floors, but also in steel-concrete composite beams[4-6].

In addition, friction damper can provide larger additional damping and stiffness, stable performance, large energy dissipation capacity, and its hysteretic performance shows good Coulomb characteristics. Moreover, the load size, loading frequency and loading cycle times have little influence on its energy dissipation performance, with obvious energy consumption and good damping effect. In addition, because of its simple structure, easy to obtain materials, low cost, convenient installation and maintenance, strong applicability and wide range of application, it has been widely used in practical engineering. Most of the energy dissipaters tested in China are symmetrical friction connections, but the related applications of asymmetric friction connections are few. Asymmetric friction connections have two yield platforms, which can meet the two-stage fortification requirements through reasonable design, and the connection can provide high stiffness and reduce damage while...
increasing energy consumption capacity, the damage concentrated on bolts after earthquake can be easily repaired by replacing bolts. Therefore, the asymmetric friction connection is applied to the steel-concrete composite structure.

In order to study the mechanical properties of steel-concrete composite beams with asymmetric friction connections in different structural zones, three simple specimens of steel-concrete composite beams with friction connections were made in this paper. Considering the structural factors, the sinusoidal wave tests were carried out on the steel-concrete composite beams with friction connections under uniaxial low cyclic loading.

2. test overview

2.1. Specimen design

The steel-concrete composite beam with friction connection is composed of Figure 1. Structure 1 consists of cover plate, gasket, slotted steel plate and concrete slab from top to bottom, in which cover plate and gasket are firmly bonded by special glue; structure 2 is cover plate, gasket, slotted steel plate, gasket and concrete slab from top to bottom, in which cover plate and gasket are firmly bonded by special glue, and there is no treatment between concrete slab and gasket; Structure 3 consists of cover plate, gasket, slotted steel plate, gasket and concrete slab from top to bottom. The cover plate and gasket are firmly bonded by special glue, and the concrete slab and gasket are firmly bonded by structural adhesive. The three structures are connected by two groups of $\Phi 16$ high-strength friction bolts under positive pressure. In order to reduce the friction loss of the high-strength beam in series, the pre stress of the bolt is reduced in series.

In order to compare the influence of structure on the performance of composite beams, three specimens (Table 1) were made. The concrete slab is made of ordinary C35 concrete with the size of $330mm \times 180mm \times 100mm$. The HRB400 steel bar with 8mm diameter is used in the concrete slab. All the steel bars are spot welded. Q345 steel is used for steel plate and grade 8.8 large hexagon high strength bolt is used for bolt.

![Figure 1 Schematic diagram of composite beam](image1)

![Figure 2 dimension drawing of test piece](image2)

**Table 1 Parameters of specimens**

| Experimental group | Loading rate (Hz) | Number of loading cycles | Displacement amplitude (mm) | Number of test pieces |
|--------------------|-------------------|--------------------------|----------------------------|-----------------------|
| Construction 1     | 0.05              | 30                       | $\pm 10$                   | 1                     |
| Structure 2        | 0.05              | 30                       | $\pm 10$                   | 1                     |
| Structure 3        | 0.05              | 30                       | $\pm 10$                   | 1                     |
2.2. test device and loading system
The test device is shown in Fig. 3. A jhbt-h force sensor is connected in series on the disc spring to monitor the change of positive pressure on the interface. Displacement is recorded by displacement meter and actuator.

The displacement controlled loading method was used to load and unload the specimens in forward and reverse directions respectively. The sine wave loading is shown in Fig. 3, and the loading rate is 0.05Hz (Fig. 4). The maximum static tension force is 100kN and the maximum loading behavior is 200 mm.

3. Analysis of test results

3.1. test phenomenon
After 5 cycles of loading, there are obvious friction marks on both sides of the grooved steel plate.

3.2. Test results and analysis
Figure 5 shows the hysteretic curves of the test under three working conditions. It can be seen from the figure that the hysteretic curve has no obvious staged energy consumption behavior under construction condition 2, and obvious staged energy consumption behavior can be found in structure 1 and structure 3, which has reliable hysteretic energy consumption capacity. The hysteresis curve of structure 1 is fuller and achieves the expected asymmetric friction performance. In order to avoid the adverse effect of abnormal points, 2-5 cycles are taken as the design value of hysteresis curve.

![Hysteretic curves of energy dissipator](image)

**Structure 1**

**Structure 2**

**Structure 3**

*Fig. 5 hysteretic curve of energy dissipator*

4. **Conclusion**

The mechanical properties of the composite beams with low cyclic friction under uniaxial loading are investigated

1. The steel-concrete composite beams with friction connection in structure 1 and structure 2 can well describe the double step energy consumption of hysteretic curve, and maintain good sliding
friction force (strength) under cyclic loading, which is conducive to achieve the two-step seismic
fortification goal, and the hysteretic curve of structure 1 is more plump and stable.

(2) The results show that the sliding friction of the composite beam increases first and then
decreases, the sliding friction strength decreases little, and the hysteresis curve is stable and full.

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