MECHANICAL INVESTIGATION ON STUD SHEAR CONNECTOR IN STEEL FIBER REINFORCED CONCRETE (SFRC)

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1. INTRODUCTION

Steel fiber reinforced concrete (SFRC) is characterized by its considerable hardening capability and ductility. There have been some applications of it in steel concrete composite bridges for improving the mechanical behavior. Shear connector is an important member in composite bridges, whereas mechanical research on it in SFRC is rare. Therefore, we carried out a study on mechanical behavior of the typically used stud shear connector in SFRC by doing static and cyclic push-out tests. The stud shank diameter and height in these tests were 19 and 150mm. 1.5% volume percentage of steel fibers were mixed with normal concrete with designed 40MPa compressive strength to compose SFRC.

2. Test setup

2.1 Specimens

There were two types of push-out specimens, including normal concrete specimens (N series) and steel fiber reinforced concrete specimens (S series). N-series included 2 specimens respectively for static (N1) and cyclic (N2) tests. And in S-series specimens, one (S1) was for static test and the other two (S2 & S3) were for cyclic test. The specimen layout shown in Figure 1 was designed according to Standard of Japanese Society of Steel Construction (JSSC 1996). The stud horizontal spacing was 100mm, and the stud height and shank diameter were 150mm and 19mm, respectively. The length of the steel fiber was 30mm, and its diameter was 0.62mm. The aspect ratio (ratio of length to diameter) was 48. The steel fiber's ultimate tensile strength was approximately 1080MPa. In addition, the steel concrete interlayer bonding and friction was artificially reduced by grease.

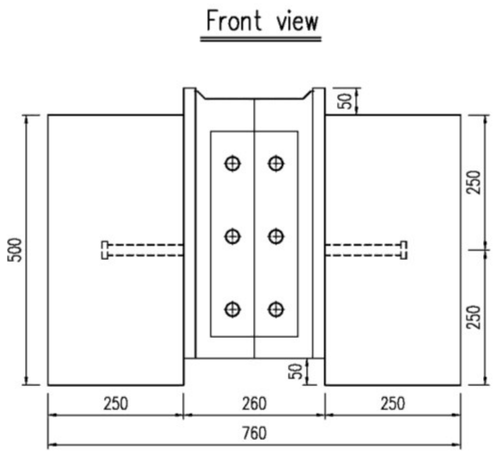

Fig. 1 Specimen layout(mm)


Fig. 2 load setup


Fig. 3 SFRC crushes

2.1 Material test

The tested strength of the 28-day normal and steel fiber reinforced concrete were 39.8 and 28.5MPa. The lower strength of SFRC was largely due to the unskillful casting operation of steel fiber reinforced concrete. Nevertheless, the modulus and tensile strength were still rational and the ductility was considerable. The tested yield and ultimate stress of stud were 380.4 and 455.5 MPa, respectively.

Keywords: Stud shear connector, Steel fiber reinforced concrete, stiffness, strength, fatigue strength.
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2.1 Load setup

Fig. 2 presents the load instrumentation and the relevant monitoring sensors at the site, including the load cells and displacement transducers. It was based on the Standard of Japanese Society of Steel Construction (JSSC 1996). Fig. 3 presents the corresponding loading procedure. There were two types of cyclic load ranges introduced in tests, which were 241.0 and 203.6 kN. The cyclic mean load was 30% of the strength. Particularly, N2 and S2 specimens were applied by the cyclic load action with a load range of 241.0kN, S3 specimen were applied by the cyclic load action with a load range of 203.6kN.

3. Test results

Fig. 4 shows the static load-slip curves. The curves are close to each other until the ultimate hardening and unloading stage. If being defined as the ratio of one third of the maximum average shear force to the corresponding average slip, the stud shear stiffness of N1 and S1 were 370.0 and 316.4kN/mm, respectively. The lower stud stiffness of S1 was believed due to the lower concrete strength. However, the maximum average shear force in N1 and S1 were 168 and 172kN, respectively. Generally, compressive strength and modulus of concrete are the main factors that influence the stud mechanical performance. Even though the compressive strength and modulus of steel fiber reinforced concrete was tested lower than that of normal concrete, the reduction of stud stiffness and strength was not significant. In this sense, steel fibers contributed favorable effect on stud mechanical performance. It is in common that the tested push-out failure mainly appears as shear fracture at stud root and crushes of surrounding concrete.

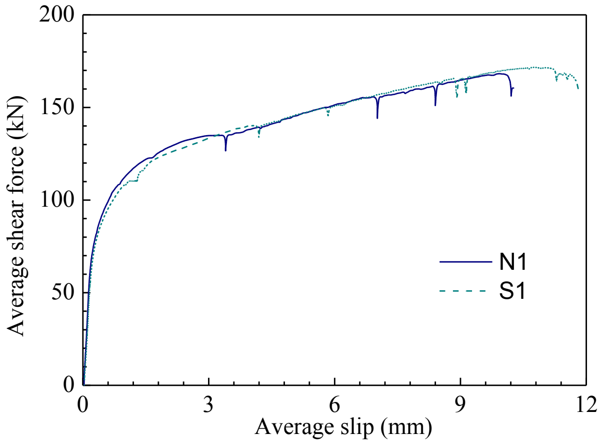

Fig. 4 Static load-slip curves

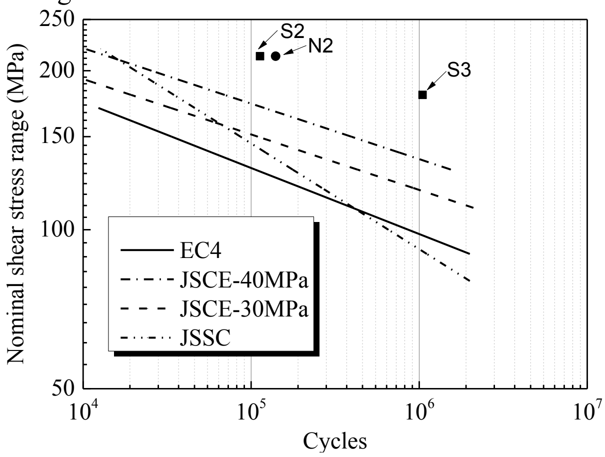

Fig. 5 Stud fatigue strength comparison

On the other hand, fatigue test results were compared with evaluations in civil codes, including Euro code 4(2005), Standard Specification for Hybrid Structure (JSCE 2009) and JSSC fatigue design recommendations for steel structures (JSSC 2012) (Fig. 5). It shows that all of the fatigue strength curves based on specifications are left-below the test result points. The evaluation results kept obvious safety redundancy for studs in both normal and steel fiber reinforced concrete. Moreover, it should be noticed the tested similar fatigue strength between N2 and S2 were from the fact that the compressive strength of steel fiber reinforced concrete was lower than the normal concrete. There was a tendency that fatigue strength of steel fiber reinforced concrete can improve the fatigue strength of stud shear connector. It may be explained by that the embedded steel fibers ameliorated the mechanical status of concrete surrounding the stud root. Therefore, the current specification evaluations with little direct consideration of effect of steel fibers in concrete may lead to underestimation of fatigue strength of stud in steel fiber reinforced concrete.

8. CONCLUSIONS

1. Based on the static test results, steel fiber reinforced concrete tended to improve the stud shear strength. Moreover, the slip hardening and ductility of stud in steel fiber reinforced concrete performed better than that in normal concrete in tests.

2. Fatigue strength of stud in steel fiber reinforced concrete was found close to that of stud in normal concrete in tests. Since the tested compressive strength of steel fiber reinforced concrete was lower than that of normal concrete, steel fibers in concrete was believed favorable to stud fatigue behavior. For design practice, the current specification evaluations with little direct consideration of effect of steel fibers in concrete may lead to underestimation of fatigue strength of stud in steel fiber reinforced concrete.

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