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Static behavior of multi-stud shear connectors for steel-concrete composite bridge

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ABSTRACT

Push-out tests were conducted to investigate the different behavior between single-stud and multi-stud connectors. The results show that the single-stud and multi-stud connectors have the similar stiffness, and the spacing of studs has little influence in the stiffness of multi-stud connectors. The ultimate strength of single-stud connector is about 10% larger than multi-stud connectors. When the load reaches its peak, the relative slip of single-stud connector is about 19% larger than that of multi-stud connectors. The multi-stud effect on static behavior of shear connector is negligible. Based on the push-out test results, a new expression of stud load-slip relationship was proposed. Compared to existing relationships, the new expression has a better match with the experimental values. The static behavior was studied and compared to design equations. The results show that the estimation based on Eurocode-4 agrees well with the multi-stud test results and the estimations based on AASHTO LRFD and Chinese code agree well with the single-stud test results.

1. Introduction

Headed stud shear connectors are the most common type of shear connectors used in the steel-concrete composite construction to transfer the longitudinal shear forces at the interface between steel and concrete. The behavior of headed stud shear connectors is explored by push-out tests. According to previous researchers, the behavior of headed studs in composite construction depends on many factors, including shank diameter, height and tensile strength of studs, compressive strength and elastic modulus of concrete, direction of concrete casting, reinforcement detailing and stud welding quality. Present design methods in codes for the calculation of the shear strength of studs are based on push-out tests results.

The push test was first devised in Switzerland in 1930s to determine the load transfer capacity of shear connectors [7]. Since the 1950s a large number of experimental tests have been done on headed stud shear connectors.

Viest IM [1] performed 12 push-out tests with varying ratio of effective depth-to-stud diameter. Three types of failure modes were observed from the test. The first mode of failure was that the stud connector fully yielded and no concrete failure was observed. The second mode of failure was concrete cone failure where no shearing off of headed stud was observed. And the third mode of failure was the combined failure of stud and concrete. Furthermore, one of the first formulas to assess the shear strength of the headed studs of composite structures was proposed.

Chinn J [2] and Isabel B. Valente [3] carried out push-out tests to evaluate the behavior of shear connection between steel and lightweight concrete. The connection behavior was analysed in term of its load-slip relation and the failure modes were identified. Also, the load capacity, maximum slip, elastic slip and plastic slip were quantified.

Li An [4] presented push-out tests of studs in normal and high strength concrete. It was found that the concrete compressive strength significantly affects the strength of the stud connections. The increase of the transverse reinforcement had a negligible effect when high strength concrete was used and some effects when normal concrete was used. A design formula taking into account the interaction between the studs and the surrounding concrete was proposed.

Pil-Goo Lee and Chang-Su Shim [5,6] investigated the static and fatigue behavior of large stud shear connectors up to 30 mm diameter, which were beyond the limitation of current design codes. The ultimate strength of the shear connection showed that the design shear strength in Eurocode-4 and AASHTO LRFD gives conservative values for large studs. The fatigue endurance obtained from the tests was slightly lower than the current design values of Eurocode-4.

Dennis Lam [7] studied the capacities of the headed stud connectors in precast hollowcore slabs. 72 full-scale push tests were performed and the results of the experimental study were analysed and findings on the effect of all the parameters on connectors' strength and ductility were presented. Newly proposed design equations for calculating the shear connectors' capacity for this form of composite construction were developed.

Youn-Ju Jeong [8] studied partial-interaction behavior by using push-out tests and a commercial structural analysis program. The results showed that the partial-interaction behavior of steel-concrete composite members can be efficiently and accurately predicted by the analysis method presented in the paper.

Huu Thanh Nguyen [9] and Ehab Ellobody [10] developed an accurate nonlinear finite element model of push-out specimens to investigate the behavior of headed stud shear connectors. The results

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