Journal of Constructional Steel Research 95 (2014) 22–31

Contents lists available at ScienceDirect

Journal of Constructional Steel Research

Experimental research on bearing mechanism of perfobond rib shear connectors

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ARTICLE INFO

Article history:
Received 28 April 2013
Accepted 23 November 2013
Available online 27 December 2013

Keywords:
Composite structure
Perfobond rib shear connector
Ultimate bearing capacity
Push-out test

ABSTRACT

Push-out test is widely used to study the bearing capacity of perfobond rib shear connectors. Due to the discrepancies in both the specimen size and the test procedure adopted by different researchers, the obtained results did not coincide well with each other. On the basis of the push-out test methods by previous researches, a novel push-out test technique for perfobond rib connector was proposed. 7 different groups, totally 21 push-out test specimens, were fabricated and tested. By means of the proposed test method, load–slip relationships of the specimens were obtained and their failure modes were observed. Satisfied reproducibility of load–slip curves in each group proved the rationality of the test method proposed in this paper. According to the failure phenomenon in ultimate loading state, failure mechanism of perfobond rib shear connectors was analyzed and the analysis results indicated that brittle failure always occurs in perfobond rib connectors. Based on the test results, influence of the connector configuration on the load bearing capacity was discussed.

1. Introduction

Nowadays steel–concrete composite structure, with its remarkable technological and economical benefits, has been widely used in civil engineering. In steel–concrete composite structures, it is the shear connectors between concrete slab and steel girder that ensure the two parts work collaboratively to bear external loads [1–4]. In steel and concrete composite bridges, headed stud is the most widely used one among all kinds of shear connectors [5–8]. Notwithstanding headed stud could bring about inconvenience of construction in site to a great extent, some evidences indicate that the headed studs subjected to repeated loading may suffer from fatigue failure [9,10].

In order to overcome the drawbacks of headed studs, Fritz Leonhardt developed a new kind of shear connector, named as perfobond rib connector [9,11]. Perfobond rib connector refers to a piece of steel plate, on which a certain number of holes are punched. After pouring of the concrete slabs, concrete dowels could be formed in these holes. The concrete dowels could resist the shear force and also the up-lifting force between the concrete slab and the steel girder. It is very convenient to install the perfobond rib connectors on the steel components and no special welding equipment is required. Besides, shear bearing capacity of perfobond rib connector is larger than that of headed studs, i.e. bearing capacity of the perfobond rib connector with one hole is several times that of single stud shear connector. No evident fatigue problem of perfobond rib connector in engineering practices was reported so far. If transverse reinforcement is provided in the holes, the shear bearing capacity could increase significantly. Due to these merits, perfobond rib connector is a promising connector in steel–concrete composite structure.

Much attention has been paid on the structural behavior of perfobond rib connectors recently and various calculation methods for the shear bearing capacity were proposed [12–17]. Nonetheless, some studies show that calculated results of these methods do no not agree well with experimental results and the results diverge with each other in a large degree. This is mainly caused by the discrepancy in specimen size and test methods [18–20].

To this end, in this paper, a novel push-out test method for perfobond rib connector was proposed. 7 different groups of perfobond rib connectors, totally 21 push-out test specimens, were conducted to obtain the load–slip relationships of the specimens and to verify the rationality of the proposed test method. Based on the test results, influence of the parameters of the shear connectors on the bearing capacity was discussed.

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http://dx.doi.org/10.1016/j.jcsr.2013.11.020

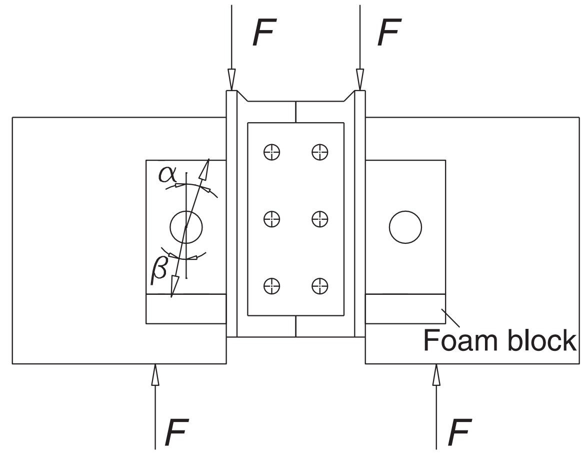

Fig. 1. Conventional push-out test layout.

Table 1
Dimensions of test specimens.

Specimen	Hole		Rib height (mm)	Diameter of transverse reinforcement (mm)
	Diameter (mm)	Number		
SCP-50	50	1	150	–
SCP-60	60	1	150	–
SCP-75	75	1	150	–
SBP-24	24	1	150	22
SBP-60	60	1	150	22
SBP-60 × 2	60	2	150	22
SCP-60 × 2	60	2	150	–

2. Test method

2.1. Conventional test methods

Nowadays, both push-out test and full-scale composite beam test are usually adopted to investigate the shear bearing capacity of shear connectors [21–25]. Full-scale beam test method is feasible for small composite beams used in building structure, and it is difficult to test the shear bearing capacity of perfobond rib connectors in composite bridge using this method because the sizes of the connector and the girder are very large. Therefore, push-out test results are usually adopted to estimate the bearing capacity of shear connectors in composite bridges conservatively.

Push-out test of shear connectors can be of different procedures. A test method is recommended in Eurocode 4 [26], in which specimen size, loading procedure and data processing of the test results are specified. This method is mainly applicable to the headed studs. Providing the basic layout specified in Eurocode 4, different researchers have tried to use specimens of different sizes for push-out test, varying the thickness of concrete slab from 150 mm to 200 mm, 300 mm or 400 mm. Fabrication procedure of the specimens is as follows. Firstly, perfobond rib connectors are welded onto the outer sides of an H-shaped steel component and then concrete is cast to form a prism on each side. In the loading stage, vertical compressive force is applied on the top of the H-shaped steel component. This test method brings about a deviation angle between the direction of resultant shear force of connector and the direction of applied force, as shown in Fig. 1. Additionally, bonding and friction on the steel–concrete interface due to the horizontal component of the interaction force between the steel and the concrete also have a significant influence on the test result of perfobond rib connector during the push-out test. Lubricating oil could be greased on the steel flanges to eliminate the bonding effects and friction force [13], however a large portion of the bonding and friction effects still exist. All these reasons mentioned above lead to large discrepancy of the test results by different researchers.

In view of the drawbacks of conventional push-out test methods, some measures have been proposed by some researchers, such as adoption of a single piece of penetrated steel plate and adoption of a single plate pull-out test instead of push-out test. Due to different test methods, different sizes of specimens and different numbers of holes in shear connectors, failure modes of the perfobond rib connectors in these tests also differ from each other.

2.2. Proposed test method

Calculation formulae available for bearing capacity of perfobond rib shear connector mainly take into account the shear resistance of concrete in the holes and that of the transverse reinforcements [14], and the effects of bonding and friction on the steel–concrete interface are not considered. Moreover, some formulae also take into account the local bearing effect between the end of perfobond rib connector and the concrete slab [16,17]. The local bearing effect does play a great role in the independent layout of the perfobond rib connectors in composite beam of building structures, while in continuous layout of

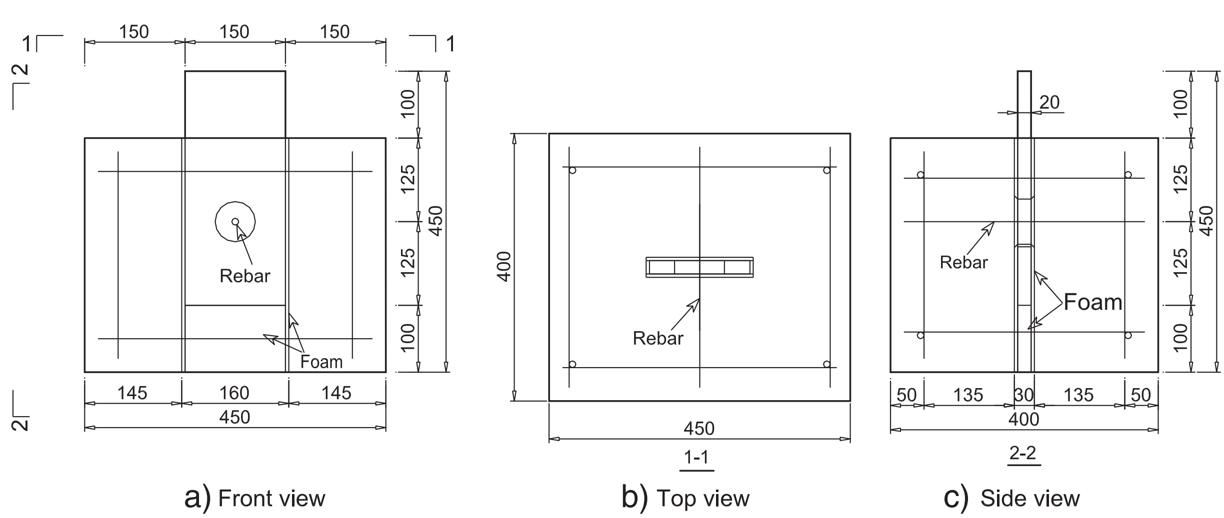

Fig. 2. Specimen dimensions (unit: mm).