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Experimental study of the short-term and long-term behavior of perfobond connectors

Jing Zhang [a], Xiamin Hu [a,*], Liya Kou [b], Bing Zhang [a], Yuchen Jiang [c], Huihui Yu [a]

[a] Department of Civil Engineering, Nanjing Tech University, Nanjing 211816, China
[b] Department of Civil Engineering, Jiangsu Open University, Nanjing 210036, China
[c] Department of Civil Engineering, Taihu University of Wuxi, Wuxi 214000, China

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ABSTRACT

Recently, perfobond connectors for steel-concrete composite structures have received extensive research attention due to their excellent bonding and fatigue performance, and the construction convenience. However, the research on the long-term behavior of perfobond connectors was seldom reported. This paper presents the results of laboratory tests on perfobond connectors, including twenty short-term specimens and six long-term specimens. Parametric study was conducted to investigate the influence of the hole diameter in the connector, the number of the holes, the thickness of the connector, the concrete strength as well as the diameter of the transverse rebar on the shear performance of perfobond connectors. For the short-term test series, the failure modes of the connector, the load-slip response, the ultimate shear bearing capacity and the load-strain curves of transverse rebar were studied. For the long-term test series, the transverse rebar strain, the relative slip between the steel beam and the concrete slab and the stress around the holes with duration of loading were discussed. The shear performance of perfobond connectors after long-term loading was also investigated. Finally, based on the test data from both this paper and open literature, a model was proposed to predict the shear bearing capacity of perfobond connectors.

1. Introduction

Steel-concrete composite beams have been widely adopted in building and bridge engineering due to their excellent structural performance, ease for construction, and economic reliability [1,2]. The composite action of composite beams between the steel beam and the concrete slab relies heavily on the mechanical behaviour of shear connectors, which transfers the shear force between the steel beam and concrete slab. In steel-concrete composite structures, headed stud is the most widely used one among all kinds of shear connectors [3,4]. However, the headed stud connector has certain limitations for its comparably high flexibility, which is unfavourable when fatigue loads exist. In addition, the installation of headed studs requires a special welding device and high-power generator that may not be available on site [5]. In order to overcome the drawbacks of headed studs, Leonhardt et al. and Partners Engineering Consultants proposed a new type of Perfobond Leiste (PBL) connector in 1987, namely perfobond connector [6]. Perfobond connector refers to a steel plate with certain number of round holes. 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 beam [7]. Compared with headed stud connectors, perfobond connectors have great advantages in fatigue resistance performance, shear bearing capacity and processing production [8]. This kind of connector was adopted in the Kurt-schurmacher Bridge (Germany), Normandy Bridge (French) and Third Nanjing Yangtze Bridge (China) et al. [9].

Many researchers have studied the behavior of the perfobond connector and various equations for predicting the shear capacity were proposed in the recent past [10–17]. Nonetheless, there has been no fully comprehensive research on the shear performance of perfobond connectors [18–20]. The existing studies on perfobond connectors are only focused on the short-term behaviour, while studies on the long-term behaviour of perfobond connectors researches have not been reported. In practical engineering, perfobond connectors are susceptible to shrinkage and creep of concrete and internal stress redistribution around the hole under long-term loading, which may affect the shear capacity of the perfobond connectors. Therefore, it is necessary to study the long-term performance of perfobond connectors.

This paper presents the results of short-term and long-term loading tests on perfobond connectors. The varying parameters in the tests were the connector holes diameter, connector thickness, number of holes, concrete strength and transverse rebar diameter. Ten different groups

* Corresponding author.
E-mail address: huxm_njtech@163.com (X. Hu).

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Table 1
Parameters of specimens.

Specimens	Concrete slab				Perfobond connector			Transverse rebar
	f_{ck} (MPa)	l_c (mm)	b_c (mm)	t_c (mm)	t_{sc} (mm)	D (mm)	n	d_s (mm)
P-SA-1,2	50	650	600	150	16	50	4	2B16
P-SB-1,2	50				16	40	4	2B 16
P-SC-1,2	50				16	60	4	2B 16
P-SD-1,2	50				5	50	4	2B 16
P-SE-1,2	50				10	50	4	2B 16
P-SF-1,2	50				16	50	6	2B 16
P-SG-1,2	30				16	50	4	2B 16
P-SH-1,2	40				16	50	4	2B 16
P-SI-1,2	50				16	50	4	2B 20
P-SJ-1,2	50				16	50	4	2B 25
PL1	50				16	50	4	2B 16
PL2	50				16	40	4	2B 16
PL3	50				16	60	4	2B 16
PL4	50				5	50	4	2B 16
PL5	50				10	50	4	2B 16
PL6	50				16	50	6	2B 16

of short-term specimens and six long-term specimens were conducted to obtain the failure modes, transverse rebar strains and load-slip relationships of the specimens. Moreover, the influence of the parameters on perfobond connectors and the change of bearing capacity after long-term loading were discussed. Based on the test data from both this paper and open literature, the equation for the shear bearing capacity of perfobond connector was proposed by multiple linear regression analysis. Research results in the present paper could provide a reference to the design and application of perfobond connectors.

2. Experimental program

2.1. Specimen details

A total of twenty perfobond connectors were designed for the short-term tests (ten different test groups with 2 specimens in each group). Specimens in this test in accordance with the clauses Annex B in Eurocode 4. The varying parameters included the connector holes diameter, the connector thickness, the number of connector holes, the compressive strength of concrete slab and the diameter of the transverse rebar. Six push-out specimens were designed for long-term loading, with the varying parameters which included the connector holes diameter, connector thickness and number of connector holes. The parameters of all the specimens are shown in Table 1, where f_{ck} is the nominal compressive strength of concrete (MPa); l_c is the concrete slab length (mm); b_c is the concrete slab width (mm); t_c is the concrete slab thickness (mm); D is the connector holes diameter (mm); t_{sc} is the connector thickness (mm); n is the number of connector holes; d_s is the transverse rebar diameter (mm). The diameter of the ordinary rebar in the concrete slab is 10 mm. Dimensions and configuration of test specimens are illustrated in Figs. 1 and 2.

2.2. Material properties

The mechanical properties of concrete, perfobond connector and rebar are summarized in Tables 2-4 respectively. The cubic compressive strength of concrete was obtained from the tests on 150 mm concrete cubes at the age of 28 and 182 days, respectively. The axial compression strength and tensile strength of concrete can be calculated in accordance with the GB 50010-2010 [21].

2.3. Short-term test

The short-term push-out tests were loaded in two stages according to Eurocode 4 [22]. At the first stage, the load was applied at the rate of 1kN/s until 40% of the expected failure load was reached. At the subsequent stage, the specimen was loaded to failure at the rate of 0.5 kN/s. The test should ensure that the loading process for each specimen is no less than 15 min.

The gauging point arrangement of specimens is illustrated in Fig. 3. D1 to D4 are displacement transducers (LVDTs) to measure the vertical relative slip between the concrete slab and the steel beam, as shown in Fig. 3a. SG1 to SG8 are strain gauges on transverse rebar for both the

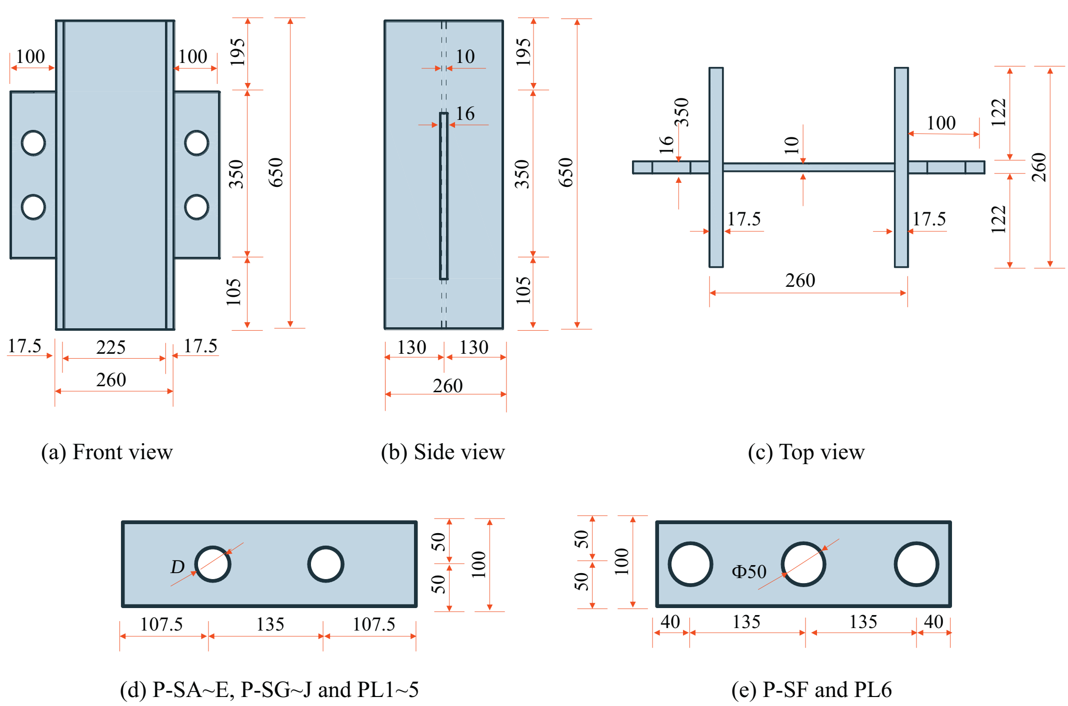

Fig. 1. Dimensions of perfobond connectors (measures in mm).