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Structural behaviour of T-Perfobond shear connectors in composite girders: An experimental approach

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Abstract

This paper presents the results from eighteen push-out tests made at the Civil Engineering Department of the University of Coimbra, Portugal, on T-Perfobond shear connectors. The investigated variables were: concrete slab thickness, concrete compressive strength, connector geometry, relative position of the connector to the direction of loading, shear connector hole number and disposition, among others. The results are presented and discussed, focusing on the T-Perfobond structural response in terms of shear transfer capacity, ductility and collapse modes. Finally, a comparison of the experimental results with existing analytical formulae was also made to develop guidelines for designing the T-Perfobond connectors.

Keywords: T-Perfobond connector; Experimental analysis; Composite structural systems; Composite construction; Structural behaviour; Shear transfer

1. Introduction

The shear connector is the component that assures shear transfer between the steel profile and the reinforced concrete slab, enabling the development of the composite action in composite beams. Several different types of connectors have been studied, proposed, and used in the past. Reference is made to headed or Nelson studs (Fig. 1a), Perfobond (Fig. 1b) and Crestbond (Fig. 1c) shear connectors.

Among these connectors, the most widely used, due to a high degree of automation in workshop or site, is the Nelson stud (Fig. 1a), designed to work as an arc welding electrode and, at the same time, after the welding, as the resisting shear connector. It has a shank and a head that contributes to the shear transfer and prevents the uplift. However, it has some limitations in structures submitted to fatigue, and its use requires specific welding equipment and a high power generator at the construction site. Additionally, in applications where a discrete distribution of the connectors is needed, for example in precast concrete decks or in strengthening, repairing or even retrofitting existing structures taking advantage of the steel and concrete composite action, the stud may be substituted with advantages by stronger shear connectors.

The Perfobond type connector has some common properties with the specific connector studied in this paper. It is formed by a rectangular steel plate with holes welded to the beam flange (Fig. 1b). The Perfobond or Perfobond rib shear connector was developed in the eighties, as referred by Zellner [23], motivated by the need of a system that, under service loads, only involved elastic deformations, with specific bond behaviour and also was associated to higher fatigue strength.

Several authors have recently studied the behaviour of the Perfobond connector, mostly from push-out tests. Among these, reference is made to the studies of Al-Darzi et al. [1], Iwasaki et al. [11], Machacek & Studnika [12], Medberry & Shahrooz [13], Neves & Lima [14], Oguejiofor & Hosain [15], [16], Ushijima et al. [17], and Valente & Cruz [18,19]. These authors concluded that their structural response was influenced by several geometrical properties such as the number

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List of Symbols

A_{cc}	longitudinal concrete shear area per connector (mm^2)
D	connector hole diameter
h	slab height (in the test specimen) from the base up to the the connector (mm)
H_c	slab height
h_{sc}	Perfobond connector height
l	connector length
n_1	number of transverse reinforcement bars used at each slab
P_{Rk}	test characteristic load
$qu_{,\text{test}}$	maximum experimental load
t	connector thickness, for the T-Perfobond the web thickness
t_c	slab thickness
δ_u	connector slip capacity
δ_{uk}	connector characteristic slip
ϕ	reinforcement bars diameter
γ_c	concrete safety factor

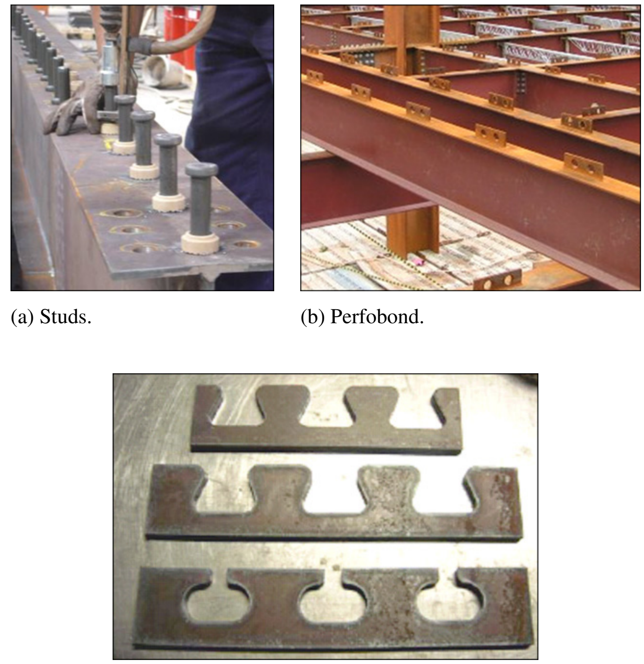
of holes, the plate height, length and thickness, the concrete compressive strength, and the percentage of transverse reinforcement provided in the concrete slab.

Ferreira [6] has adapted the Perfobond geometry for thinner slabs, usually used in residential buildings, and isolated the contributions to the overall shear connector strength from the reinforcement bars in shear and from the concrete cylinders formed through the shear connector holes.

The motivation of developing new products for the shear transfer in composite structures is related to issues involving particular technological, economical or structural needs of specific projects. In this context, some other alternative shear connectors have been proposed for composite structures. Reference can be made to the studies of Fink and Petraschek [7], Gündel and Hauke [8], Hechler et al. [9], Hegger and Rauscher [10], Machacek and Studnika [12], Vellasco et al. [20], Veríssimo et al. [21], and Zellner [23].

Also, an alternative connector, named as T-Perfobond (Fig. 2), was presented by Vianna et al. [22], in the scope of a study on Perfobond connectors, where a comparison of the behaviour of these connectors and a limited number of T-Perfobond connectors was made. This connector derives from the Perfobond connector by adding a flange to the plate, acting as a block. The motivation for developing this T-Perfobond connector is to combine the large strength of a block type connector with some ductility and uplift resistance arising from the holes at the Perfobond connector web.

The present work focuses on T-Perfobond connectors and involved eighteen push-out tests performed at the Civil Engineering Department of the University of Coimbra, Portugal. Specimens were fabricated from an IPN 340 section cut at the symmetry axis parallel to the flanges, and were produced without holes, and with, respectively, two or four holes, located in one or two rows in the load transfer direction, with slabs of 120 mm (Fig. 3a) and 200 mm thicknesses, (Fig. 3b). Six tests were made from the nominal C25/35 concrete compressive strength class, and twelve tests from the nominal C35/45 class according to EN-1992-1-1 (Eurocode 2 [2]).



(a) Studs. (b) Perfobond.

(c) Crestbond.

Fig. 1. Typical shear connector examples.

Fig. 2. T-Perfobond shear connector.

2. Models for the strength prediction of relevant connectors

The T-Perfobond connectors were conceived as a combination of a T-connector or block type connector (Fig. 4) with the perforated Perfobond connector (Fig. 1b). Therefore, any tentative model to predict its resistance should initially be based on existing models for the strength prediction of these two types of connectors.

An evaluation of the shear resistance of Perfobond connectors was proposed by Oguejiofor & Hosain [15,16], adding three contributions for the overall resistance: the bearing concrete resistance at the connector face, the steel