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Experimental analysis of new interfaces for connections by adhesion, interlocking and friction

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ABSTRACT

This paper presents the results of an experimental program developed to investigate the behavior of an innovative technology for connections by adhesion, interlocking and friction in composite structures. Connections have a strategic importance for precast concrete and steel–concrete composite structures, since they determine the global structural behavior and affect the whole production process, from execution to assemblage and other services on site. Currently, however, steel–concrete composite connections are not completely adapted for their use in prefabricated slabs. In this way, the development of new types of connections is clearly necessary, where connections by adherence (or connections by adhesion, interlocking and friction) seem quite promising. To improve the knowledge in the field of connections by adherence, this paper proposes a new geometry of embossments in the steel and in the concrete surfaces associated with the use of a high performance mortar. Monotonic push-out tests are performed, and their results are presented and discussed. A satisfactory behavior of the proposed connection in terms of strength is observed, justifying further studies on the subject.

1. Context and motivation

Due to the irreversible process of industrialization of construction demanded by the post Second World War in Europe and, nowadays, by the growing demand for infrastructure in countries with emerging markets, the search for building systems with a high level of prefabrication is a reality. In this context, steel and concrete composite structures can provide very competitive solutions, once they are adaptable to a process of prefabrication, in which whole or part of the structural elements may be produced in an industrial environment, and not on site.

Composite structural systems made of steel and concrete aim to extract maximum performance of each material. Therefore, it is necessary to ensure the best possible interaction between the steel element and the concrete component. A composite action can be obtained by limiting the relative displacement at the interface between steel and concrete through the use of shear connectors.

Currently, steel and concrete composite connections are not yet completely adapted to be used in prefabricated slabs. For example, to achieve composite action, the commonly used connection consists in a group of headed studs that are welded to the upper flange of the steel beam and then connected to the slab, when the pockets in the slab are concreted on site. This solution presents several disadvantages [1]: numerous small quantities of concrete need to be poured on site to fill the pockets which slows down the construction progress and cracks may develop in the corners of the pockets, increasing the risk of degradation by corrosion for both the slab reinforcement and the connection itself.

In this context, the development of new types of connections is clearly necessary aiming to reduce the construction time and to improve the building durability, without increasing the cost of the solution.

Thus looking for a practical, economical and fast solution for connections in steel and concrete composite structures, connections by adhesion, interlocking, and friction, first presented and studied by Thomann [2], seem quite promising.

Basically, the innovative connection (Fig. 1(a)) is constituted by two embossed steel plates (Fig. 1(b)), welded "*back-to-back*" to each other, and welded longitudinally to the upper flange of the steel girder.

A "*bonding layer*" is created on the external face of the upper flange by disposing an adhesive film with sand. The deck consists of precast reinforced concrete segments which are fabricated with an inner rib at the lower part. The surface of this inner rib is roughened by using a retarding agent during casting followed by hydro-jetting or sandblasting.

The slab segments are positioned over the steel connector and the void is filled with injected high strength cement grout. Once the cement grout is cured, the connection is activated and the structural element becomes composite.

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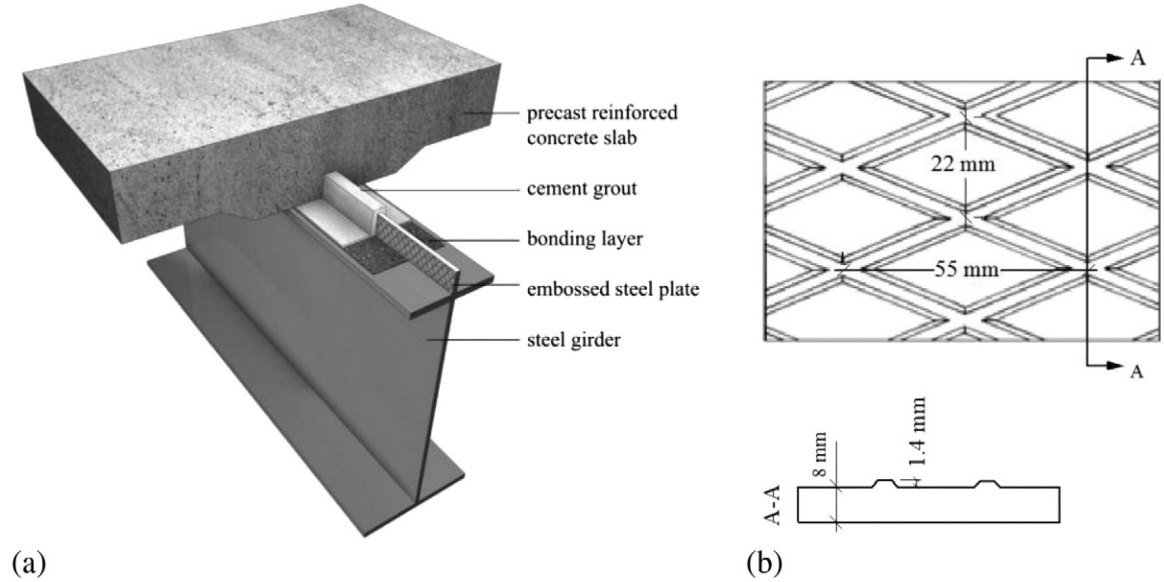

Fig. 1. (a) Connection by adhesion, interlocking and friction [3]; (b) employed embossed steel plate (BRI 8/10) [4].

The resistance of the connection is sourcing from the shear stress developed in three types of interfaces: the embossed steel-cement grout interface, the cement grout-rough concrete interface and finally the interface between cement grout and the bonding layer (Fig. 1).

According to Papastergiou and Lebet [1] and Thomann and Lebet [2], the main advantages of connections by adhesion, interlocking and friction, are due to the fact that they present a high resistance to shear, which provides a high level of connection (related to the proportion of displacements between the interfaces) on the composite section and they present also a very stiff behavior which provides a high level of interaction. This indicates that the initial premise for a composite action, a small relative displacement between the interfaces is valid, and therefore the connection is possible. Furthermore, the presence of continuous embossed steel plates welded along the upper flange, contributes to:

a. a higher strength of the steel beam;
b. does not create concentration of stress in the connection region, thus minimizing problems of durability caused by cracking when compared to headed studs.

However, it is important to note that the cost of these advantages is reflected in the behavior of the connection in relation to ductility, once connections by shear presents brittle behavior usually.

Thus aiming to explore the field of connections by adhesion, interlocking and friction, this paper proposes a new geometry of embossment for the interfaces involved in the connection associated with the use of a high performance mortar (HPM) to connect these materials.

These new solutions for the connections aim to provide an easier way to produce adequate interfaces. Basically, the proposal consists in producing a regular embossment in the surface of concrete slab and more deep ribs in the shear connector surface, besides establishing the angle of 45° to the direction of the ribs in the connector surface.

Fig. 2 highlights the principal alterations introduced in the actual solution for the interfaces, in comparison to the previous solution adopted in [1] and [2].

1.1. Brief review

Several shear connectors have been proposed, and many types are currently used in composite structures. However, many of them have significant restrictions in terms of industrial production, installation and structural behavior. In building structures, the most usually employed shear connectors are *stud* and *U-laminated*. In bridge structures are also employed other special connectors as for example Shim, Lee, and Chang [5], Studnicka et al. [6], Baran and Topkaya [7], Kim et al. [8], Schmitt et al. [9], and Vellasco et al. [10].

Nowadays, the most widespread connector is the *headed stud* developed by Nelson Stud Welding, in the 40s. For composite floors, the connection between the concrete slab and the steel framework made with studs is used worldwide. Although they are “easy” to install, it is usually necessary to have a high amount because its isolated shear strength is relatively small.

Regarding the U-laminated connectors, they are still used in Brazil but in disuse in other industrialized countries. It consists basically on a piece of laminated U profile with one of the flanges welded to the steel profile. Although they have a lower productivity in terms of welding process than stud during installation, they have a similar structural behavior. It is noteworthy that the isolated resistance is higher in U-connectors than in studs.

As an alternative to pin-type connectors, as studs and U-laminated connectors, at the end of the 80s the German engineering company Leonhardt, Andrä and Partners presented the Perfobond connector,

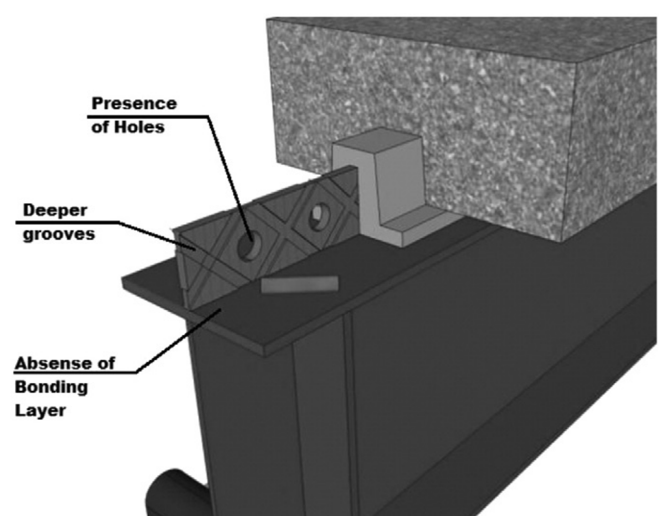

Fig. 2. New proposal for the connection.