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Flexural performance of innovative hybrid sandwich panels with special focus on the shear connection behavior

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ABSTRACT

The present study intends to evaluate the flexural performance of hybrid sandwich panels through the execution of four point bending tests. The proposed hybrid sandwich panel uses Deflection Hardening Cementitious Composites (DHCC) on the top layer, a GFRP bottom layer and perforated shear connectors in the GFRP ribs to transfer shear stresses between top and bottom layers.

The tested hybrid slabs use two types of shear connectors, which include indented and perforated shapes. The tests were performed to study the behavior of a novel shear connection between the GFRP ribs and the DHCC layer that is here proposed. A comparison on the obtained experimental results was executed to clarify the influence of the shear connectors' geometries on the flexural performance of the developed hybrid slabs.

The results show that the shear connection mechanical behavior strongly influences the peak load, the deflection at peak load, the post-peak load carrying capacity and the degree of composite action of the hybrid slabs.

1. Introduction

Sandwich panels are an interesting solution for building floors due to their high strength to weight ratio and adequate levels of acoustic and thermal insulation. Low self-weight, and high stiffness and durability have increased the demand for this type of composite structures, and several studies have been dedicated to improve the structural performance of sandwich panels. Typical sandwich panels are composed of three different layers that include two thin, stiff and resistant composite material skins, such as fiber reinforced polymer (FRP) materials, separated by a layer of a low density material that is usually made with polyvinyl chloride (PVC), Basalt, polystyrene (PS), polyurethane (PU), polymethacrylamide, polyetherimide (PEI) or styreneacrylonitrile (SAN). The proper combination of different core and skin materials may promote the merge of the most advantageous properties of each constituent material, and even eliminate some negative characteristics. The combination of skins with appropriate cores leads to a structural response characterized by high stiffness-to-weight and high strength-to-weight ratios. The development of new production techniques has made sandwich panels more cost-competitive, with especial precautions for attributing to these panels requisites for an easy and fast mounting [1].

The main deficiencies that have been reported to this type of sandwich panels are: its low load carrying capacity when compared to the one of structural elements constituted by traditional materials, like concrete and steel; low resistance to high temperatures; susceptibility to the occurrence of local and global failure modes. These concerns create extra difficulties for the designers, with a detrimental consequence on the acceptance of sandwich panels by the construction industry [1]. Therefore, several studies have been carried out to overcome the indicated disadvantages, not only by using new composite materials, but also disposing the materials according to new structural configurations that optimize the potential of each constituent.

Norton [2] proposed a deck solution that consists of two skins (E-glass fabric) and trussed GFRP webs to act as flexural members supported by the girders. Each skin includes two orthogonal woven fabrics stitched together by fibers in the perpendicular directions (0° and 90°) to form a 3D GFRP material for the entire cross section. Balsa cores are adopted to maintain the configuration of the cross section during the vacuum infusion process with epoxy resin. As indicated in Fig. 1a, the top skin is a concrete layer, thereby a hybrid sandwich panel was proposed. As shown in Fig. 1e and f,

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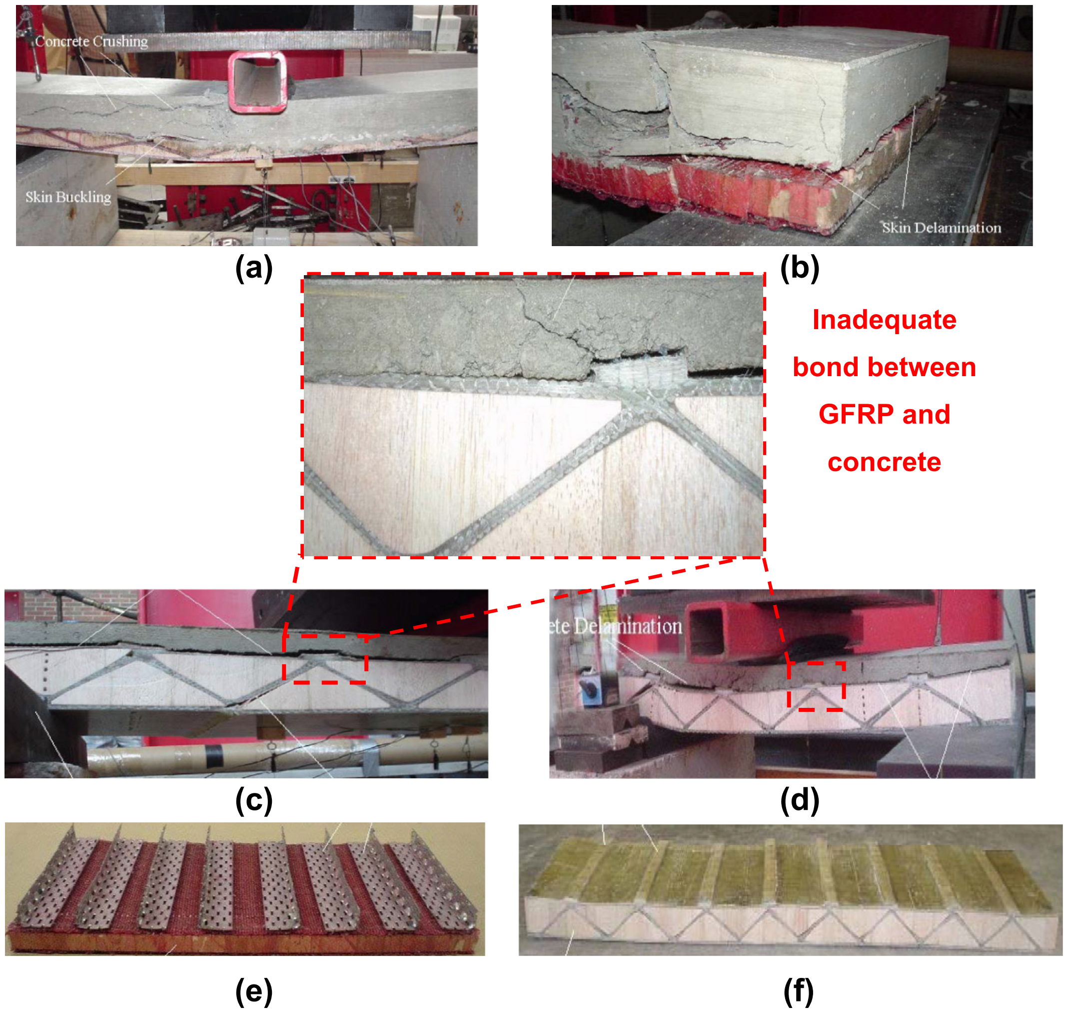

Fig. 1. a) Concrete crushing and shearing; b) concrete shearing; c) concrete delamination; d) concrete delamination and shear; e) steel shear connectors; f) composite shear connectors [2].

both steel and composite shear connectors are used in an attempt of ensuring the composite action between the GFRP cross section and the top concrete layer [2].

The metallic shear connectors showed good performance, but were difficult to work with beneath the vacuum bag, during the infusion process. This difficulty derived from puncture of the vacuum bag caused by the metallic shear connectors. As shown in Figs 1b–d, the composite shear connectors were simpler to infuse and maintain their bond with the composite deck. However, the bond between the concrete and the top GFRP skin of the hybrid panels was inadequate for high loading levels, and debonding was the common failure mode. This study illustrated that the shear connection between the concrete layer and the composite surface is the limiting factor for the ultimate load carrying capacity of the tested elements.

In 2013, Mastali et al. [3] used FEM-based analysis to perform a parametric study on hybrid sandwich panels with GFRP bottom skin and ribs, while the top skin was made of deflection hardening fiber-reinforced cementitious composite (DHCCs). This FEM based study was executed to optimize the slab dimensions and reveal the contribution of each structural component to the global behavior of the hybrid sandwich slabs. The authors found out that hybrid sandwich slabs present high load carrying capacity, high span-to-weight ratio and high stiffness [3]. Previous experimental studies on hybrid sandwich panels, presented in Refs. [2,4], showed that there are some difficulties in transferring shear stresses from top skin to bottom skin through shear connectors.

In the present study, efforts are made to assess the flexural performance of hybrid sandwich panels with the execution of four point bending tests. These bending tests aim to analyze the behavior of shear connectors that are part of the GFRP ribs, and stay embedded in the DHCC layer after curing. Two types of shear connectors are used in the tested hybrid slabs: indented and perforated shear connectors.

Therefore, two hybrid slabs with indented shear connectors are manufactured and tested under Four Point Bending (FPB) test. In Ref. [5], two other hybrid slabs with perforated shear connectors were previously tested under FPB test configuration, and the corresponding experimental results are herein used to execute a comparative analysis.

2. Experimental program

2.1. Dimensions of slab's components

Two optimized hybrid sandwich slabs with total thickness of 140 mm and 172 mm were proposed in Ref. [3], which are depicted in Fig. 2a. The dimensions of slab's components were obtained with a parametric FEM-based analysis, described elsewhere [3]. Table 1 lists the geometry of the components of the two types of