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COMPOSITE SANDWICH PANELS FOR BUILDING FLOORS: RECENT DEVELOPMENTS AND MAIN CHALLENGES

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1. INTRODUCTION

Sandwich structures have a long history of successful use in various applications, namely in automotive, aerospace and naval industries [1]. For civil engineering applications, sandwich structures also present very high potential, due to their high strength- and stiffness-to-weight ratios, lightness and potential multi-functionality, *i.e.* their ability to fulfil multiple functions in a single element [2]. In addition, when made of fibre reinforced polymer (FRP) skins, this type of construction also offers durability and low maintenance requirements.

The above-mentioned features are particularly useful for the rehabilitation of existing buildings, namely those made of masonry walls with degraded timber floors. In these cases, replacing timber floors with FRP sandwich panels does not represent significant weight increase, which can be a very important advantage, especially in seismic regions [3]. However, for building applications, composite sandwich panels need to meet specific requirements, namely (i) those concerned with the connection technology; (ii) the ability to present limited deformations during service life, (iii) the acoustic comfort afforded by partition elements; and (iv) the behaviour when exposed to elevated temperatures or fire. These different requirements constitute a main challenge towards the use of FRP sandwich panels in buildings. This presentation summarizes some of the research made in recent years at Instituto Superior Técnico - University of Lisbon (IST-UTL) regarding the prospects of composite sandwich floors in addressing such challenges.

2. CONNECTION TECHNOLOGY

Recent investigations at IST focused on the connection technology for sandwich panel floors at two levels: (i) panel-to-supports; and (ii) panel-to-panel.

At the panel-to-supports level, connection systems were designed, tested and simulated, aiming at joining sandwich floor panels to masonry walls of old buildings in the scope of rehabilitation projects [4]. These systems involve bolting and/or bolding the panels to the load-bearing walls through metallic angle section members along the contour of the walls (Fig. 1). This follows the same intervention principle used when replacing timber floors, where angle profiles are also used to brace the walls, thus improving their resistance to out-of-plane loads.

At the panel-to-panel level, connection systems have been developed and investigated with the following main requirements: (i) easy and fast panel installation in confined spaces, by means of vertical movements (instead of horizontal/sliding movements); (ii) adequate structural performance; and (iii) possibility of integration in the production process. Two main types of connection systems were designed, tested and simulated: adhesively bonded (Fig. 2) [5] and snap-fit or interlock. While the former system provides higher stiffness, the latter offers quicker installation times and the possibility of disassembly.

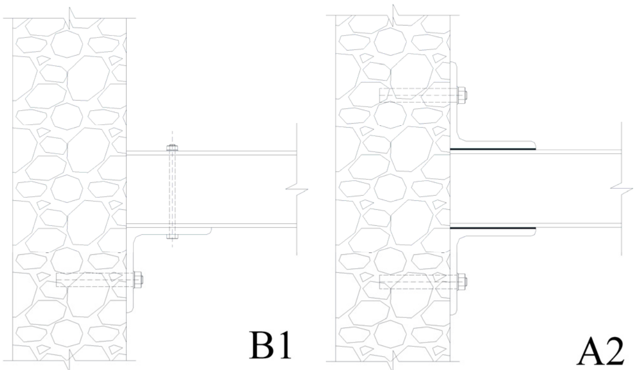

Fig. 1: Detail of two of the panel-to-wall connection systems tested (B1 – bolted, single profile; A2 – adhesive, two profiles) [4].

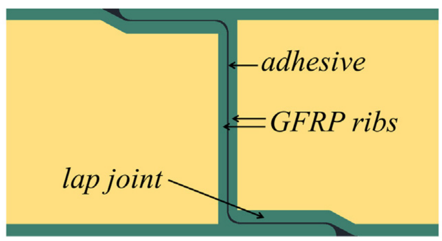

Fig. 2: Detail of a Z-shaped adhesively bonded panel-to-panel connection [5].

3. LONG-TERM STRUCTURAL BEHAVIOUR

Sandwich panels used in building floors need to be designed to fulfil service limit states requirements during service life, which is generally set as 50 years. This period is much longer than that considered in other more typical applications of sandwich panels. This explains the very limited information available in the literature and in existing design guidance about the creep behaviour of sandwich panels and their constituent materials.

Previous research at IST in this domain focused on the characterization of the creep response of (i) different core materials – polyurethane (PUR) and polyethylene terephthalate (PET) foams and balsa wood – in shear [6]; (ii) GFRP skins in bending [7]; and (iii) full-scale sandwich panels in bending [8,9]. In each case, the influence of the load level and of the service temperature on the creep behaviour were investigated. Results of experiments were used to derive design-oriented creep coefficients and simple analytical models to predict the long-term structural response of sandwich panels [6-9].

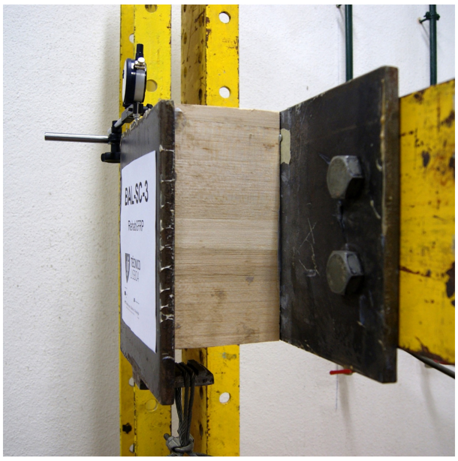

Fig. 3: Shear creep test in balsa wood.

Fig. 4: Flexural creep tests of web-core FRP sandwich panel.

4. ACOUSTIC BEHAVIOUR

For building applications, a very relevant requirement for user's comfort is the acoustic performance of partition members, such as walls and floors. In this respect, due to their inherent lightness, there are concerns about the acoustic insulation provided by FRP sandwich panels.

In this domain, recent and on-going research at IST has two main goals: (i) to understand and characterize the acoustic performance of FRP sandwich panels and, whenever needed, (ii) to define and assess constructive strategies towards the fulfilment of acoustic-related building regulation requirements, either adjusting the characteristics of the panels or adopting complementary constructive measures. To that end, full-scale experimental tests were recently conducted to assess the acoustic insulation of FRP sandwich panels for both airborne and impact sounds (Fig. 5). These experiments were complemented with finite element (FE) models that were used to simulate the response measured in those tests (Fig. 6) and to assess the effectiveness of different improvement measures.

Fig. 5: Full-scale acoustic tests in FRP sandwich panels.

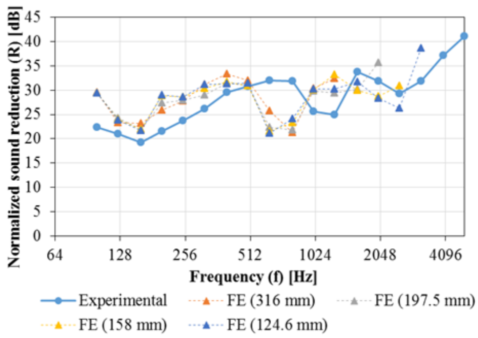

Fig. 6: Numerical FE simulation of airborne sound insulation of FRP sandwich panel for different mesh sizes.

5. BEHAVIOUR AT ELEVATED TEMPERATURE AND UNDER FIRE EXPOSURE

The behaviour of FRP sandwich panels at elevated temperature and under fire exposure is one of the most serious challenges regarding their use in buildings, where elements must fulfil relatively strict requirements in terms of both fire resistance and fire reaction. Indeed, when exposed to moderately elevated temperature, the mechanical properties of both FRP skins and most core materials are significantly decreased. Accordingly, under fire exposure, the integrity of structural members can be compromised in relatively short periods. Moreover, most materials ignite under such temperatures, releasing heat, smoke and potentially toxic gases.

In this domain, research at IST has focused on three main issues: (i) the mechanical behaviour at elevated temperature of the constituent materials of sandwich panels - FRP skins, and polymeric foam and balsa wood cores [10,11]; (ii) the fire resistance behaviour of tubular and multicellular structural elements in bending [12,13]; and (iii) the fire reaction behaviour of FRP panels. For the last two issues, the influence of different passive fire protection systems was experimentally and numerically assessed, indicating the conditions under which fire-related building regulation requirements may be met.

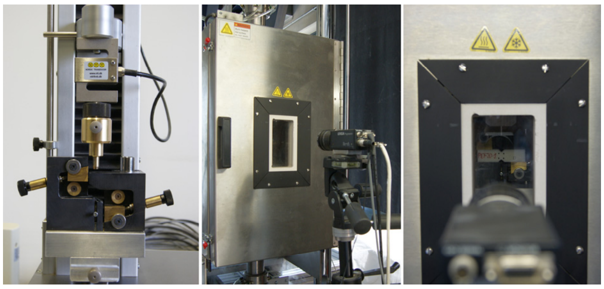

Fig. 7: Shear (Iosipescu) test in PUR foam at elevated temperature [10].

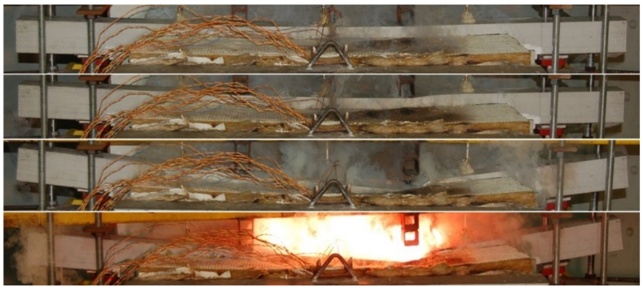

Fig. 8: Fire resistance test in tubular FRP profile [13].

6. CONCLUDING REMARKS

Sandwich construction is a very interesting solution for civil engineering structural applications, for both new constructions and the rehabilitation of existing ones. Composite sandwich panels in particular offer many advantages for this specific application, namely for the replacement of degraded timber floors of old buildings. This presentation describes the results of recent research activities conducted at Instituto Superior Técnico in order to address a number of challenges towards the use of composite sandwich panels in building floors: the connection technology, the creep behaviour, the acoustic performance and the fire behaviour. The results obtained confirm the potential of composite sandwich panels for this application, but also point out the need to take those aspects into account in their design.

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