LEGOUSE - Development of cost competitive pre-fabricated modular buildings

Financing Institution(s): QREN - Project nº 5387

Promoting Institution(s): MEBEP

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Partner Institutions: CiviTest, University of Minho, PIEP

Period: September 2009 to September 2012

Relevant facilities: FEMIX V4.0 Finite Element package; Servo close-loop equipments for experimental programs

Objectives:
The present project aims to take advantage of the appropriate use of fibre reinforced concrete (FRC) and fibre reinforced polymers (FRP), and computational tools in the conception, design and construction of cost competitive modular houses. The concept "modular system" refers to the complete structure that is built-up by assembling pre-fabricated elements, which are pre-fabricated sandwich structures, with FRC outer layers that are connected by lightweight and cost-effective materials with sufficient mechanical properties to fulfil the structural requirements of each structural element, resulting in a panel with adequate structural, acoustic and thermal insulation properties. This concept is especially appropriated for countries with strong needs of houses, such is the case of the Portuguese-speaking countries (PALOP), but it has also the aim to extend its application to other countries on the African continent, India, and Latin-America. This project involves the development and characterisation of physical and mechanical properties of the materials composing the structural elements, the building and testing of the structural elements of the modular system, the full-scale construction and testing two real scale prototypes, the development of the technical specifications and design rules, and the dissemination of the project results.

Main achievements:

Development of SFRSCC and characterization
Steel fibre reinforced self-compacting concrete (SFRSCC) was developed with the required properties. The initial and the long term behaviour of SFRSCC are being characterized. From the results obtained in the flexural and in the direct tensile tests the applicability of the inverse analysis is being checked. Fibre pullout creep tests are being carried out for the development of a model that predicts the creep deflection of cracked SFRSCC laminar structures. The influence of crack width and environmental aggressiveness conditions on the corrosion of cracked SFRSCC is being assessed.

Structural optimization of the sandwich panel
The sandwich panel is composed by SFRSCC outer layers bonded with FRP systems. The thickness of the SFRSCC layers is optimized performing material nonlinear analysis with FEMIX computer program. Relevant results are presented in Figs. 1 and 2.

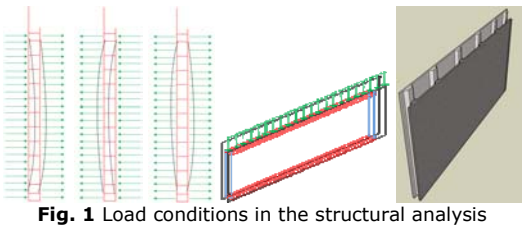

Fig. 1 Load conditions in the structural analysis

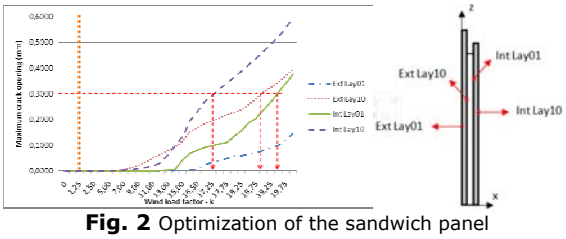

Fig. 2 Optimization of the sandwich panel

A typical crack pattern is represented in Fig. 3.

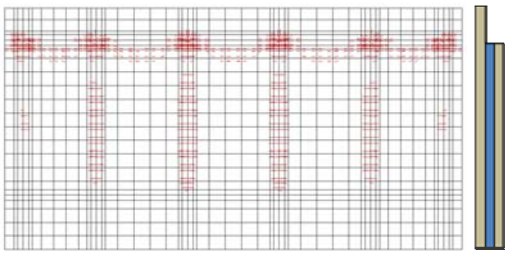

Fig 3 Crack pattern in layer 10

Thermal analysis of the sandwich panel
The thermal analysis was carried out to assess the effectiveness of using FRP connectors. Relevant results are presented in Figs. 4 and 5.

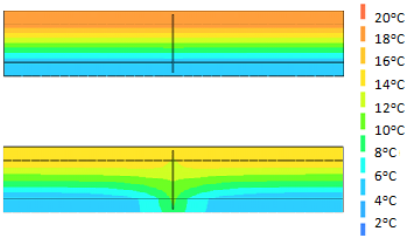

Fig. 4 Heat field with connectors type: FRP (top); Steel (bot)

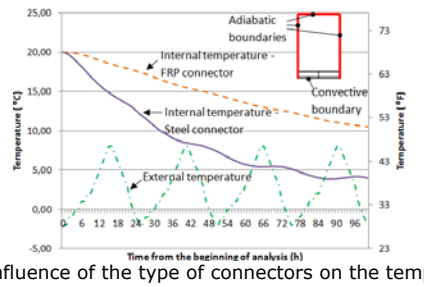

Fig. 5 Influence of the type of connectors on the temperature

Direct pullout tests with connectors

The type of FRP connectors tested is indicated in Figs. 6 and 7.

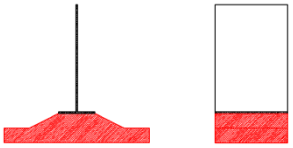

Fig. 6 Adhesively bonded connectors

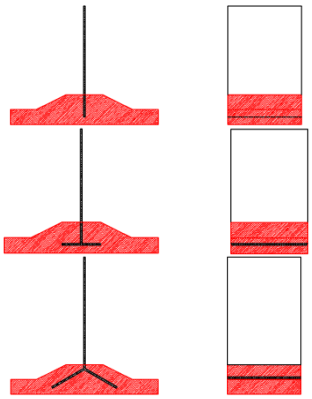

Fig. 7 Embedded connectors

The test setup is represented in Fig. 8.

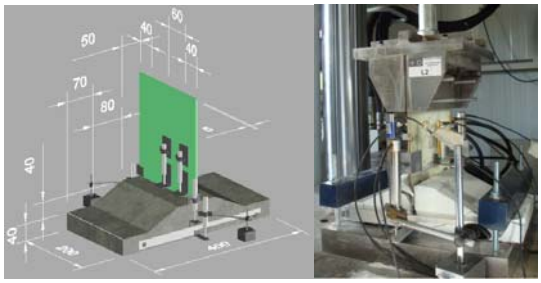

Fig. 8 Test setup

The typical failure modes are shown in Fig. 9.

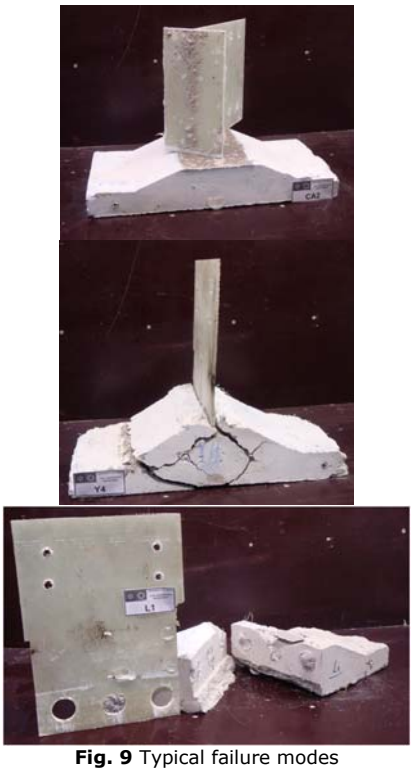

Fig. 9 Typical failure modes

The highest load carrying capacity and ductility was registered in the inverted Y embedded connector. Its force-sliding relationship is represented in Fig. 10.

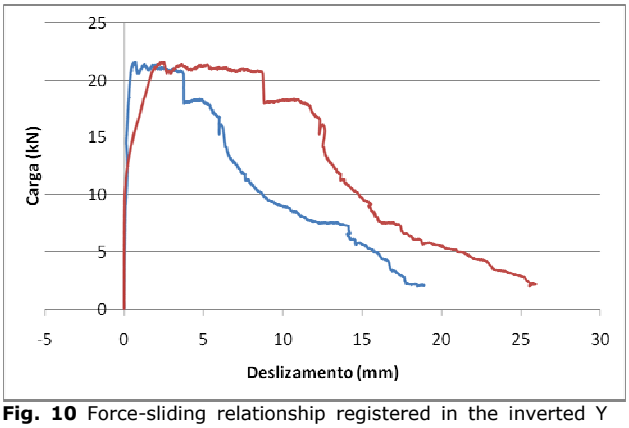

Fig. 10 Force-sliding relationship registered in the inverted Y connector

Flexural behaviour of strips of sandwich panel prototype

Fig. 11 shows the force-deflection registered in four-point beam bending tests with strips of the sandwich panel prototype.

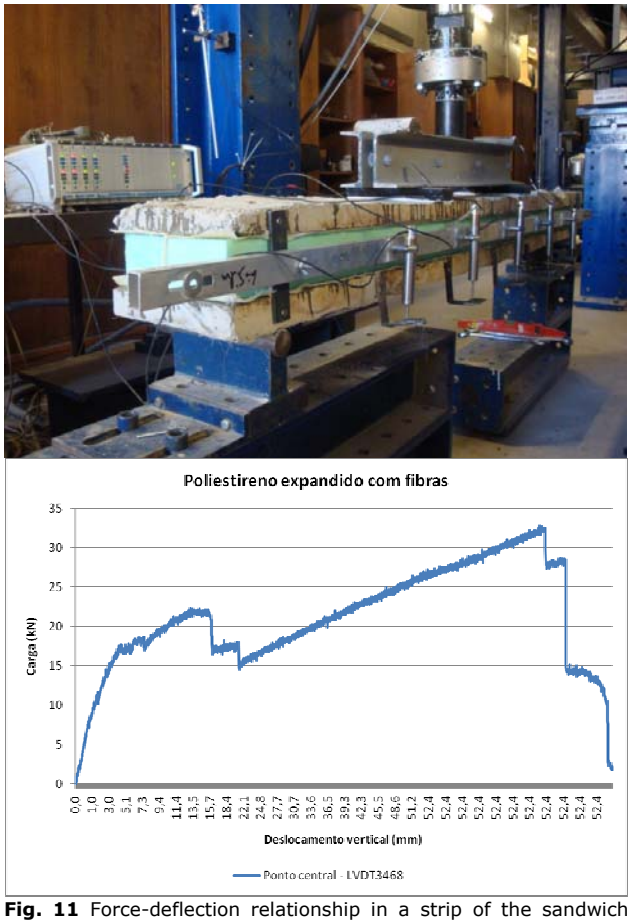

Fig. 11 Force-deflection relationship in a strip of the sandwich panel prototype

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