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THERMALLY EFFICIENT SANDWICH PANELS COMPRISING FIBER REINFORCED SELF-COMPACTING CONCRETE AND NON-METALLIC CONNECTORS

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KEYWORDS
Precast concrete, sandwich panels, fiber reinforced self-compacting concrete (FRSCC), non-metallic connectors

ABSTRACT

A durable, flexible, resistant and thermally efficient precast sandwich structural cladding panel composed of two exterior FRSCC thin layers and a lightweight core material will be developed. The stress transfer between the two FRSCC layers will be assured by non-metallic connectors, in order to avoid the thermal bridging effect that would occur in case metallic connectors were used. To explore the use of embedded and glued non-metallic connectors, pullout tests will be performed and the sandwich behaviour of elements composed by these connections will be evaluated and compared. A thermo-hygro-mechanical model will be implemented into a finite element method (FEM) based computer program, and its use, together with an extensive experimental program, will be able to predict the actual behaviour of the proposed structural solutions along time. Finally, tests with prototypes will be performed and guidelines will be developed for the design of this proposed structural system.

INTRODUCTION

Precast concrete sandwich panels are extensively used as exterior walls in multi-unit residential, commercial and warehouse buildings due their thermal and structural efficiency (EINEA et al., 1991). They also incorporate the inherent benefits of precast concrete construction such as high speed of construction, increased accuracy and quality ensured by factory production, among others.
These panels tipically comprise two exterior precast reinforced concrete layers (usually termed as wythes) separated by a lightweight thermally insulating material, and joined with steel connectors that pass through the insulation layer. Due to the high thermal conducticity of the steel connectors as compared to the insulating material, thermal bridging occurs, thus diminishing the performance of the panel (LEE and PESSIKI, 2008).
Furthermore, the use of conventional reinforced concrete for the wythes, and the associated necessity of reinforcement cover, leads to the necessity of using relatively thick concrete layers. As a consequence, the resulting panels are heavy and difficult to handle and place at the construction site.

OBJECTIVES

This research aims to propose and assess the behavior of a new competitive thermally efficient precast sandwich panel (with both structural and cladding functions) comprising thin-walled FRSCC as facing material, lightweight thermally insulating core material, and non-metallic shear connectors. The idea is to develop a structural cladding system that incorporates all the installations (electrical, water pipes, etc.) and finishes, which is manufactured in a plant and later transported to the construction site where only positioning and panel-to-panel connection needs to be done. The wall system here proposed will perform as part of loadbearing structure and support slabs. This is considered an added value to these panels, as usual systems are just devised for cladding. It is thus possible to reduce stages in the construction and, consequently, costs.
The development of panels will be guided by the objectives of decreasing the self-weight, improving the durability, enhancing the thermal insulation level and overally obtaining a efficient and optimized utilization of material resources. The use of technologies as the self-compacting concrete (SCC) and fiber reinforced concrete (FRC), here proposed, offers the advantages of reducing non-value adding activities (vibration and reinforcement placement), reducing individual work steps and the related labour costs. The elimination of reinforcing bars of concrete layers, replaced by the use of discrete fibers, also permits the adoption of thinner and, consequently, lighter elements.

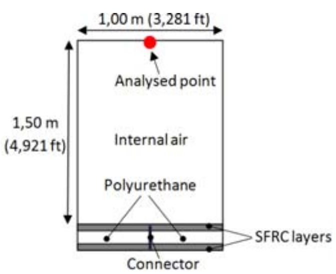
ACTIVITIES

This research is part of a larger project aimed at improving the design of such panels. This part of research will be divided in two main parts: a thermal study and a structural study of proposed sandwich panels. In the thermal part of research the effect of insulation type and thickness on the thermal performance of panels will be studied and these

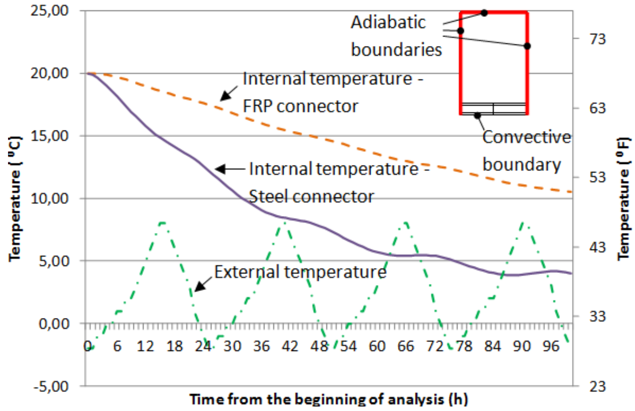
parameters will be optimized. The effect of geometric properties of panels and effect of connectors' type and arrangement will be also considered. Regarding the structural part of this study, three main topics will be studied: (i) the use of different durable fibers to produce the most adequate composite material to be used as facing material (thin-walled FRSCC elements); (ii) the use of different non-metallic connectors; and (iii) the interaction between these connectors and the FRSCC.
As these sandwich panels form the outer skin of buildings, special attention will be given to stresses and deflections caused by thermal and moisture-induced bowing and warping of panels. Hence, the following areas will also be studied: the behaviour of the panel when subjected to uniform and differential temperature field and the moisture driven stresses.
To predict the cracking risk and the post-cracking behaviour of the panels during their full service life, taking into account all relevant time-dependent phenomena, a thermo-hygro-mechanical model will be implemented into a FEM-based computer program. The predictive performance of the constitutive models will be assessed from the results in tests with specimens and reduced scale structures, while the modelling performance of the program will be appraised from data obtained from tests with panel prototypes.

PRELIMINARY RESULTS

FEM heat-transfer analyses were performed to quantify the impact of key parameters in the thermal insulation efficiency of the proposed sandwich panel. The idea was to employ the model to evaluate panel characteristics that lead them to comply with current design codes. Using this model it was possible to define some desirable geometrical parameters, as the necessary thickness of insulation material when is adopted different types of connectors. All the FEM heat-transfer analyses were executed using the DIANA software.
Figure 1 shows the impact of using different materials (steel and fiber reinforced polymer – FRP) for the shear connectors. The internal temperature of a room built with these sandwich panels is compared for both situations. The room is initially at 20ºC and the façade is subject to an outer temperature that varies between 8ºC and -2ºC. The obtained results evidence the gains obtained in terms of overall insulation when non-metallic connectors are used.



(a)



(b)

Figure 1 - a) details of implemented heat-transfer analyses; b) comparison of evolution of internal temperature of a room comprised of sandwich panels made with steel and FRP connectors.

Figure 2 compares the temperature field in the panels with both type of connectors 12 hours after the beginning of analyses. Results show that when steel connectors are adopted the insulation is interrupted, causing thermal bridges. On the other hand, the panel comprising FRP`s connectors does not present any significant discontinuity of insulation.

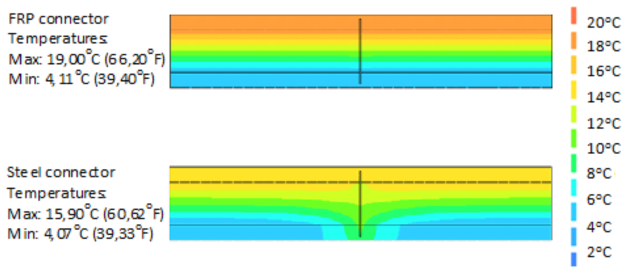


Figure 2 - Temperature field in the panels after 12 hours from the beginning of analyses.

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