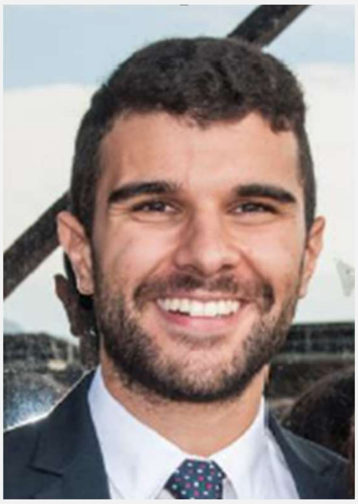
Fire behaviour of GFRP sandwich panels for the rehabilitation of building floors



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Period

2018-2022

Funding

Programma Operativo Regionale Calabria FSE/FESR 2014 – 2020 (CCI 2014IT16M2OP006)

Summary

This work centres on the fire resistance behaviour of sandwich panels composed of GFRP face sheets and longitudinal webs, and two different core materials, namely polyurethane (PUR) foam and polyethylene terephthalate (PET) foam, produced by vacuum infusion. The investigations developed in this thesis aimed at evaluating three main aspects of the fire behaviour of these composite sandwich panels: (i) the characterisation of the mechanical and thermo-physical properties at elevated temperature of their constituent materials; (ii) the influence of different core materials and GFRP configurations on their fire resistance, and (iii) the effectiveness of different passive fire protection systems in enabling their structural use in buildings. In a first stage, experimental, analytical and numerical studies were performed to evaluate the thermophysical and mechanical properties of the constituent materials of GFRP panels (namely GFRP and polymeric foams, PET and PUR) as a function of temperature. The research about the mechanical behaviour at elevated temperature of the GFRP laminates and polymeric foams comprised small-scale mechanical tests (tension, compression and shear) at elevated temperatures (up to 300 °C). These tests allowed determining the variation with temperature of the mechanical properties (strength and stiffness) of the materials. With respect to the thermophysical properties, an inverse numerical analysis was developed using a one-dimensional (1D) heat transfer model together with experimental thermal data. These temperature-dependent thermophysical properties were then used as input data in finite element (FE) models to simulate the thermal response of foam-filled GFRP sandwich panels under fire. The results obtained confirmed that the mechanical properties of both polymeric foams and GFRP materials undergo significant reductions with temperature, which generally take place when the T_g of the polymeric material is approached and exceeded. Finally, the results obtained from the inverse numerical analysis highlighted that the specific heat and thermal conductivity of GFRP laminated and polymeric foams (PET and PUR) are strongly affected by elevated temperatures. In a second stage, fire resistance tests were performed on loaded GFRP sandwich panels, either unprotected or protected with different passive systems. In this context, simply supported GFRP panels were simultaneously subjected to a service load and the fire curve established in the ISO 834 standard. The influence of using different core materials and the presence of longitudinal webs was investigated. Additionally, the efficacy of different passive fire protection systems was evaluated, including (i) calcium silicate (CS) boards directly applied on the bottom face sheet of the GFRP panels or (ii) suspended from the bottom face sheet, forming an air cavity. The temperature profiles, the evolution of strains and deflections, the fire resistance and failure modes of the GFRP panels were assessed. Finally, two-dimensional (2D) and three-dimensional (3D) numerical models were also developed aiming at understanding in further depth the fire behaviour of GFRP sandwich panels. In particular, FE models were used to provide a better understanding about relevant kinematic and static issues, including the evolution of deflections and the variation of the stress distributions with increasing temperature/time. The results obtained confirmed that the type of core material, as well as the passive fire protection systems and cross-sectional configurations, significantly affect the thermal and mechanical response of the sandwich panels in fire. In general, the calcium silicate boards proved to be effective in delaying the temperature increase in the panels, thus improving their fire endurance.

Keywords

Sandwich panels, glass fibre reinforced polymers (GFRP), polymeric foams, elevated temperature, fire behaviour, fire protection systems; experimental tests; numerical studies.

General views of a fire resistance tests on a foam-filled sandwich panels.