CERIS Civil Engineering Research and Innovation for Sustainability

Thermo-mechanical structural modelling of GFRP profiles subject to fire

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Summary

Glass fiber reinforced polymer (GFRP) is a type of composite material consisting of a polymeric matrix reinforced with glass fibers. These materials are used in a wide variety of engineering fields, with well-established applications in naval and aerospace industry. Their success can be mainly attributed to their compelling material properties, i.e, low density, high stiffness-to-weight ratio and excellent corrosion resistance. One major drawback regarding the use of GFRP (and other FRPs) is related to its poor fire performance. When exposed to high temperatures, its polymeric matrix quickly softens and decomposes, compromising its structural capability. It is agreed that the poor fire performance is one of the main issues preventing the application of these materials in numerous engineering fields, with special emphasis in construction, where fire events are a critical problem.

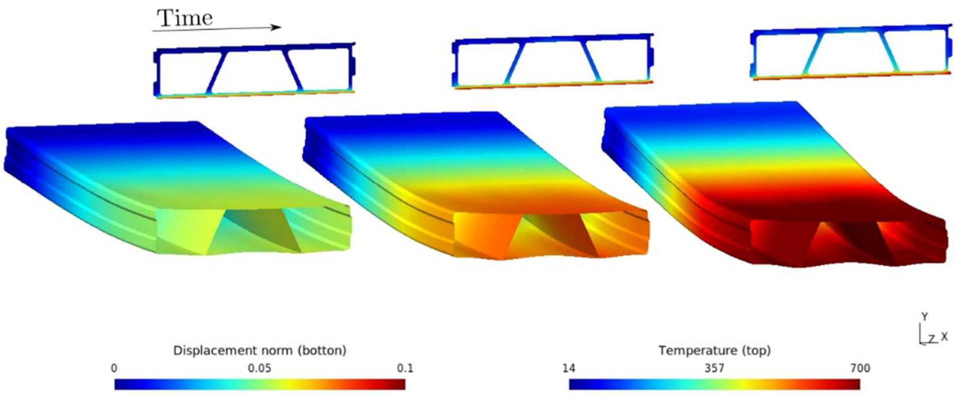
This thesis presents the development and implementation of a model capable of predicting the thermo-structural behaviour of GFRP profiles subjected to high temperatures. The model is applied to beams/panels under standard fire tests and validated using in-house experiments. Finally, the model results are used to aid in the creation of fire design guidelines for GFRP structural members that take into account fire safety issues. Aiming to reduce the overall computational cost of the problem, the modelling process is divided into two main parts. First, we independently solve the thermal problem in order to obtain the temperature profiles of the GFRP structural member. Hereafter, this data is used as input for the mechanical problem in a one-way coupling strategy.

For the thermal part, the most important phenomena related to high temperature modelling are taken into account. In the solid material, heat conduction is considered. At the internal cavities, fluid convection is taken into account using Navier-Stokes equation (with Boussinesq approximation), together with a convection-diffusion equation for the heat transport. Moreover, internal radiation is considered at the cavity walls.

The mechanical part is modelled using a geometrically exact shell theory considering thickness variations. The latter feature is added so that the model is able to work with general 3D constitutive relations. The developed shell code is integrated with the Matlib library, where a non-isotropic thermo-dependent visco-hyperelastic constitutive model was implemented and applied to the problem in hand.

Keywords

Multi-physics, non-linear FEM, shell models, variational constitutive modelling.



Mechanical model results for three distinct time instants.