CERIS Civil Engineering Research and Innovation for Sustainability

Web crippling of GFRP pultruded beams: testing, analysis and design

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Summary

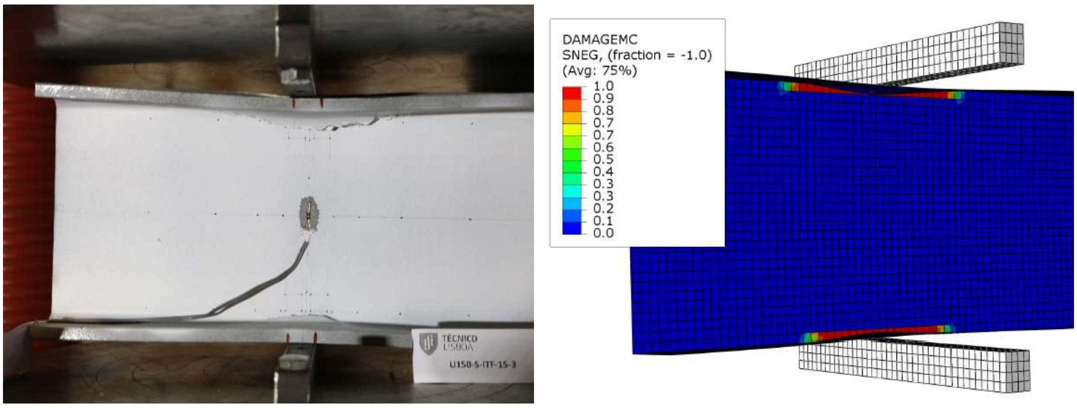
This thesis addresses two main research topics, both of which are applied to pultruded glass fibre reinforced polymer (GFRP) materials and profiles: (i) fracture toughness; and (ii) webcrippling of structural beams. These are considerably different topics, as fracture toughness is a topic that can be implemented in a wide variety of frameworks, whereas web-crippling is a wellknown and specific structural case, involving concentrated transverse loads. However, these two topics closely intersect in this thesis, as fracture toughness properties can be implemented in finite element (FE) numerical models to simulate damage evolution of brittle materials, such as GFRP composites. This numerical methodology was thus selected to simulate the web-crippling failure of pultruded GFRP profiles, a topic that currently has significant research needs. In an initial stage, several pultruded GFRP materials, produced by different manufacturers and comprising different fibre contents and layups, were subjected to a comprehensive mechanical characterization campaign, focusing on determining the elastic and strength properties in tension, compression and shear. In addition, these materials were subjected to calcination tests to assess the fibre layup of each material and the fibre content in each direction. Through this experimental programme, the transverse mechanical properties of each test material were fully characterized and assessed in respect to the fibre layup.

The numerical study on web-crippling consisted of developing relatively simple simulation models, based on commercial FE software. The numerical methodology consisted of using standard shell elements and homogenized mechanical properties through the thickness of the GFRP materials. The numerical models were found to present a good agreement in respect to most of the generated experimental data. The shear strain distributions were found to present higher discrepancies, which were attributed to the simplified simulation of the web-flange junction. The good agreement found between numerical and experimental failure loads further validated the experimentally based fracture toughness properties.

Finally, based on the experimental and numerical web-crippling results, an analytical study was performed, with the goal of generating novel design expressions. The direct strength method (DSM) was implemented to simultaneously address web buckling and web crushing failure modes. Both experimental and numerical results were very well approximated by unified DSM expressions, that fitted both ETF and ITF configurations simultaneously, for a significant variety of materials and section dimensions.

Keywords

Pultruded GFRP profiles, fracture toughness, damage evolution, web-crippling, design, DSM.



(a) *(b)*

Experimental and numerical (DB) failure modes of U-section series:

(a) U150-S-ITF-15-3 test; and (b) U150-S-ITF-15 model.