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Durability of GFRP pultruded profiles and adhesively bonded connections between GFRP adherends

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Summary

The main objective of the present thesis was to study the durability of pultruded GFRP profiles and their adhesively bonded connections. The thesis thus focused on the following four research topics: (i) the durability of pultruded GFRP profiles for civil engineering applications; (ii) the long-term behaviour of structural adhesives typically used to bond GFRP elements; (iii) the durability of GFRP bonded connections in civil engineering applications; and (iv) the performance of a GFRP structure after more than 10 years in service conditions. The research on the durability of pultruded GFRP profiles comprised an extensive experimental campaign, in which the physical, viscoelastic, mechanical and aesthetical properties of profiles made of vinylester or unsaturated polyester resins were monitored. The profiles were subjected to hygrothermal ageing, natural weathering, thermal cycles, and synergistic effects of different ageing conditions and sustained loading for periods up to two years. Results obtained showed that hygrothermal degradation was the most severe conditioning, when compared to thermal cycling or natural weathering, which produced relatively small changes over the exposure period. Post-curing phenomena were observed for all ageing environments. For immersion in water and salt water, the long-term material properties were predicted using Arrhenius models and none of the estimated properties fell below 50% after 100 years. Sustained loading produced small effects when acting synergistically with the different ageing environments. Two different structural adhesives (epoxy and polyurethane) were experimentally studied regarding their durability. Although post-curing effects were observed, hygrothermal ageing had negative effects on both adhesives, causing irreversible degradation mechanisms. In a similar way as for the GFRP profiles, the effects of natural weathering were much less severe. Single lap bonded joints were produced with the above-mentioned adhesives and GFRP adherends, and exposed to similar ageing conditions, i.e. hygrothermal ageing, natural weathering and thermal cycles. The degradation of the mechanical performance of such joints, in terms of ultimate load and stiffness and failure modes, was monitored during the exposure period. Alongside the experiments, numerical models were developed in order to simulate the tests and to obtain a better understanding of the mechanical behaviour of the bonded joints, including the effects of ageing. Both hygrothermal and thermal cycles caused detrimental effects on the joints' response and influenced their failure modes, while natural weathering produced smaller changes. Effects from post curing were also visible on the performance of such joints. Regarding the case study of a GFRP construction, the visual inspection and the laboratory tests performed on the GFRP material and profiles extracted from the construction showed that its structural safety is presently largely fulfilled and that its structural reliability should not be compromised, at least in the near future. The results obtained in this thesis showed that the degradation levels exhibited by pultruded GFRP profiles and their bonded connections, although relevant and needed to be duly accounted for at design, seem to be compatible with their structural use in civil engineering applications.

Keywords

Fibre reinforced polymers (FRP), pultruded glass fibre reinforced polymer (GFRP) profiles, durability, structural adhesives, bonded connections, experimental tests, long-term behaviour, predictive modelling.

Structural beam testing, removed from service conditions, after 15 years of ageing next to the sea.