CERIS Civil Engineering Research and Innovation for Sustainability

# DURABLE-FRP – Towards Durability Design of FRP Composites for Civil Engineering Structures

## Summary

The durability problems of civil engineering structures made of traditional materials and the associated rehabilitation costs have promoted the use fibre-reinforced polymer (FRP) composites, due to their non-corrodibility, lightness, high specific strength, and stiffness. Previous experience of using FRP composites has proved their susceptibility to degradation and highlighted the main factors it depends on, such as polymer matrix, fibre reinforcement, fibre-matrix interphase, processing method, special protective measures, and maintenance. Previous studies on durability of FRPs, mostly concerning industries other than civil engineering, also highlighted the main environmental agents that potentially affect their physical and mechanical properties, and the key degradation mechanisms, such as moisture and chemicals; temperature variations; UV radiation and thermal and freeze-thaw cycles.

Although providing useful background knowledge, such studies comprise a set of limitations: (i) FRP laminates are usually much thinner (typically <4-5 mm) than those required for civil structural applications (ii) little data is available on FRPs produced by vacuum-infusion (relevant in construction); (iii) only a few studies provide a direct comparison of alternative resin systems (iv) the vast majority of studies were conducted in the laboratory, under accelerated conditions, rarely exceeding 12 months; (v) test methods vary considerably, which explains why results are often contradictory and/or exhibit significant differences; (vi) little information is available on synergistic effects caused by various environmental agents acting together and/or combined with mechanical load; and (vii) very few durability data is available from FRP structures under real in-service conditions for long periods. Besides, the only durability models developed so far comprise curve fitting procedures to test data: (i) Fickian-based models, to simulate mass uptake due to water immersion, and (ii) Arrhenius-type models, to simulate variation of mechanical properties over time of immersion. In summary, despite several works done on the durability of FRP composites, there is a significant lack of: (i) comprehensive and validated data about the durability of FRPs, namely those used in civil engineering; (ii) degradation models, and (iii) reliable guidelines for durability design of FRP structures. Hence, paradoxically, durability is hampering the widespread use of FRPs.

This project aims to address these issues. The objective of the project includes i) obtaining in-depth understanding of the durability of FRPs used in civil engineering, particularly GFRP produced by vacuum infusion, by assessing the corresponding degradation mechanisms and relevance of synergistic effects; ii) providing a wealth of experimental data about the durability of GFRPs, from laboratory (accelerated) and in-service (normal) conditions, for long periods of time; iii) developing an open-access and comprehensive database of validated durability test results; iv) to develop degradation models able to predict changes of physical and mechanical properties of GFRPs subjected to different environmental conditions, and correlate accelerated ageing with natural ageing; v) to draft codified recommendations for GFRP durability design, including conversion factors, a harmonized framework for durability tests, and recommendations of good practice.

To achieve these objectives, a detailed experimental program has been designed to analyze thick (6 to 7 mm) glass fibre reinforced polymer (GFRP) composites that have been produced by vacuum infusion, from two alternative resin systems. This includes i) Laboratory ageing of GFRP composites at different conditions such as hygrothermal (figure-1), thermal (figure-2), thermal cycles, freeze-thaw cycles, and QUV accelerated weathering, and monitoring the changes in physical-chemical (water uptake, FTIR) and thermo-mechanical (Tg/DMA, tension, compression, flexure, in-plane and interlaminar shear-Figure 3) properties; ii) The same GFRP composites will be exposed to natural ageing (figure-4) in 5 locations in Portugal (different climates) and similar tests will be conducted to monitor changes in properties. The data obtained from these tasks will be used to achieve the previously mentioned objectives and thus, this project will allow for a widespread use of FRP in civil engineering structures, making a safer and more economic use of their significant advantages over traditional materials.

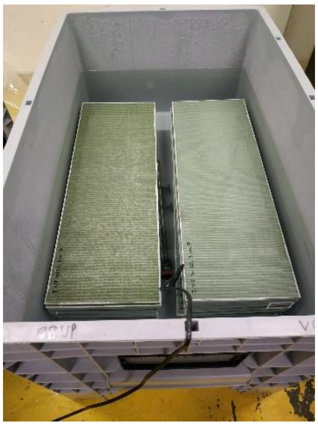

*Figure 1. Hygrothermal Ageing.*

**Project Reference**

PTDC/ECI-EGC/4609/2020

**Leading Institution**

IST-ID – Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento (Portugal)

**Partners**

S&P – Clever Reinforcement iberica - Materiais de Construção Lda (Portugal), ALTO – Perfis Pultrudidos, Lda (Portugal), LNEC – National Laboratory for Civil Engineering (Portugal), STEP – Sociedade Técnica de Estruturas Pultrudidas (Portugal)

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249 935.00€

**CERIS**

115 521.25€

**Project Website**

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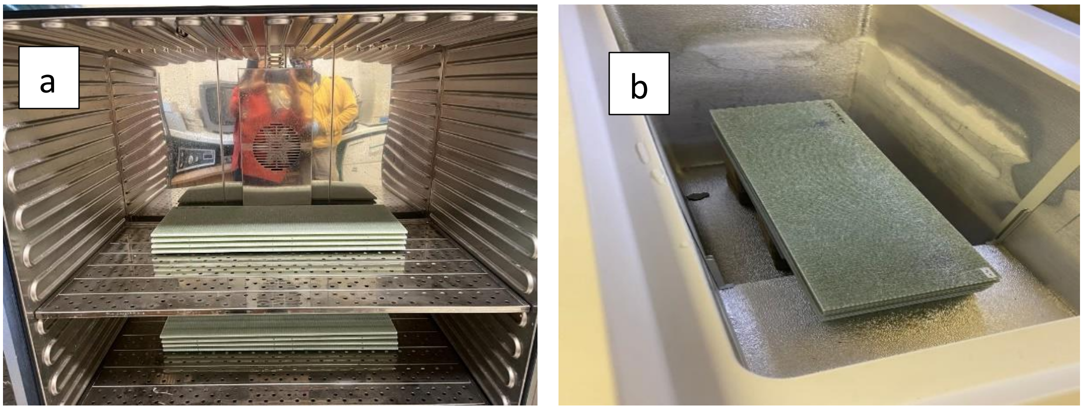


*Figure 2. Thermal Ageing: a) 40ºC; b) -15ºC.*

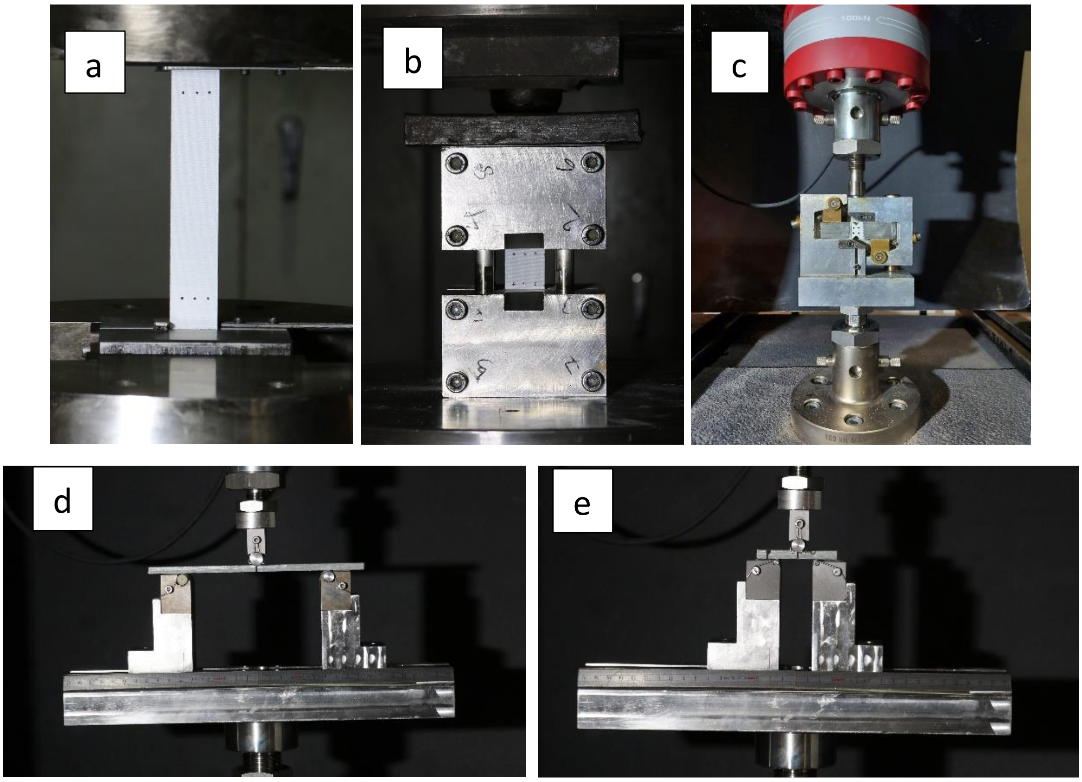


*Figure 3. Test Set Up: a) Tensile; b) Compression; c) In-Plane Shear Test; d) Flexure; e) In-Plane Shear.*

*Figure 4. Natural Ageing (Elvas, Portugal).*