RELIABLE-FRP – Development of reliability-based design guidelines for FRP structures

Summary

This project addresses the development of probabilistic-based design guidelines for FRP structures and connections, thus contributing to a safer, more economic and sustainable use of FRP structures in civil engineering.

FRP materials present several advantages over traditional construction materials, such as light weight, high strength, thermal insulation and non-corrodibility. Additionally, FRP structures allow for easier transportation and faster execution. However, the use of FRP structures in civil engineering has been strongly hindered by the lack of well-established design codes, grounded on probabilistic and structural reliability studies.

Currently, there is a wide variety of "first-generation" design guidelines for FRP structures, either proposed by manufacturers or approved by national standardization bodies. However, a well-established design basis still does not exist, as several safety parameters have been established based on engineering judgement, rather than statistically significant data and probabilistic frameworks.

Recent efforts have been put forth towards an FRP Eurocode, through the European Committee for Standardization Working Group 4 (CEN WG4 TC250). In this process, two significant gaps were identified: (i) the mechanical variability of these materials is still poorly characterized; and (ii) current resistance model uncertainties are yet to be quantified for many structural cases.

The current project aims to solve both aforementioned research gaps. In a first stage, this will be achieved by developing a database of experimental results, validated through acritical analysis, for a wide range of FRP structural cases, focusing on structural profiles and bolted connections. The database will be prepared in an open access format, in cooperation with manufacturers and relevant organizations, such as the CEN WG4 TC250, the International Institute for FRP in Construction (IIFC) and the European Composites Industry Association (EuCIA). This extended cooperation is intended to widen the reach of the database, seeking further contributions from manufacturers.

The database will also be used to identify the structural cases in need of further research. This selection will complement the experimental study in its two major components: (i) mechanical variability assessment; and (ii) structural scale tests.

The relevant mechanical properties for each structural case will be characterized, as well as other mainstream properties, namely strength and elastic properties, in the longitudinal and transverse directions, for tensile, compressive and shear loading. The mechanical characterization study will include a wide sample of materials, including different manufacturers, fibres and resins. A significant number of coupon tests will be performed (Figure 1), in order to define which probability distribution provides the best fit for each mechanical property. The study also includes the characterisation of the geometrical imperfections of composite members (Figure 2).

The structural scale test programme (Figure 3) has been planned based on current gaps of experimental data and its scope will also be complemented by research needs found in the open access database. Through this study, the database will be continuously updated, in order to understand how the new data adds to the validation of each resistance model and if further testing is required.

Finally, building on the data gathered in the database and on the experimental data of structural scale and mechanical characterization tests, structural reliability analyses will be performed, grounded in the Eurocode framework (Figures 4 and 5). These analyses will lead to (i) an assessment of reliability indices of current design guidelines for FRP structures; (ii) a format for semi-probabilistic design equations; and (iii) the calibration of new partial factors. Finally, these results will be condensed into design recommendations and added to the open access database.

The research team has vast and complementary expertise, namely: (i) significant knowledge about the structural analysis of FRP members and connections, aside from profound expertise in the mechanical characterization of FRP materials; (ii) well-established knowledge on structural reliability analyses, spanning different topics, as concrete, FRP and steel structures. It is also noteworthy that some team members have actively contributed to the envisaged Eurocode for FRP structures, through CEN WG4 TC250.

Expected results:

- Open access database of experimental results for a wide variety of FRP members and connections.
- Advanced knowledge on the mechanical variability of several key FRP properties.
- Appropriate partial factors derived from structural reliability analyses, contributing to safer, more economic and sustainable FRP structures.
- Reliable design guidelines for a variety of structural cases, providing a solid basis for the new generation of FRP design codes.

Project Reference

PTDC/ECI-EGC/3916/2021

Leading Institution

IDMEC – Instituto de Engenharia Mecânica (Portugal)

Partners

IST-ID – Associação do Instituto Superior Técnico para a Investigação e Desenvolvimento (Portugal), EPFL – École Polytechnique Fédérale de Lausanne - School of Engineering (Switzerland), UniNotts – The University of Nottingham (United Kingdom)

CERIS Principal Investigator

João Ramôa Correia
(joao.ramoa.correia@tecnico.ulisboa.pt)

CERIS Research Team

Fernando Branco, José Gonilha, Mário Sá

Funding

FCT – Fundação para a Ciência e a Tecnologia

Period

2022-2024

Total

244 919.63€

CERIS

91 424.00€

Project Website

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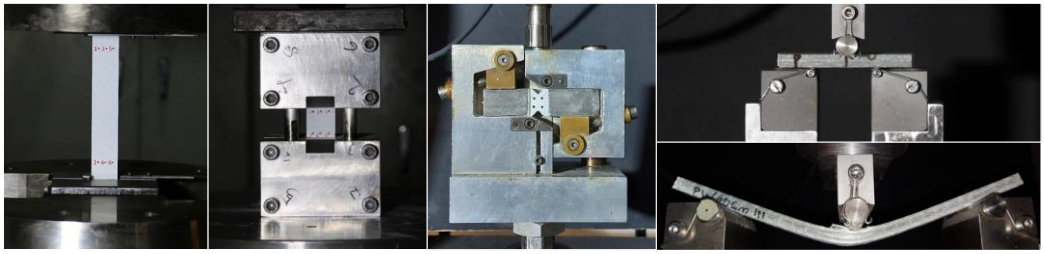

Figure 1. Coupon tests on pultruded GFRP composite laminates.

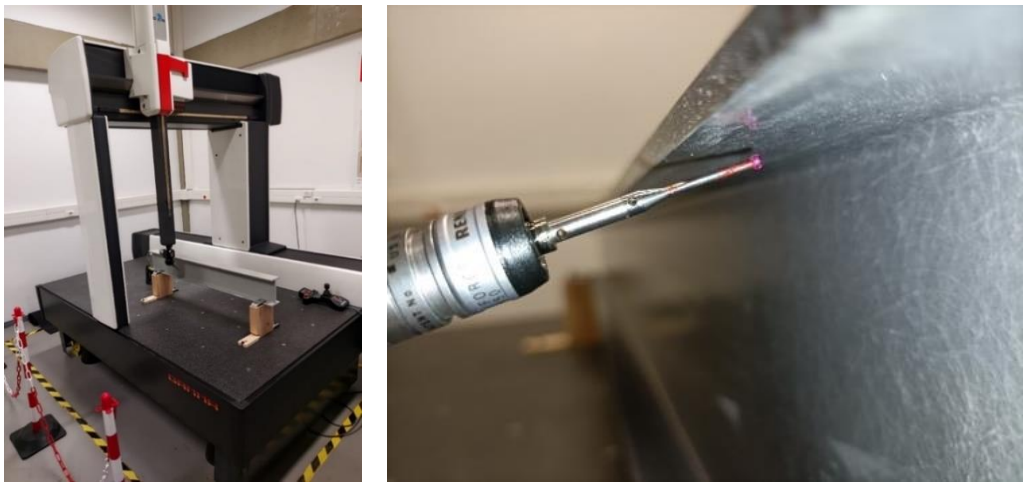

Figure 2. Measurement of geometric imperfections in GFRP pultruded profiles.

Figure 3. Structural tests (left to right): flexural buckling of pultruded columns, local buckling of pultruded columns, shear failure of sandwich panel.

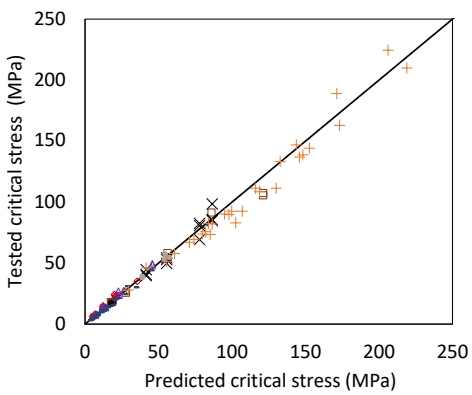

Figure 4. Assessment or resistance model for flexural buckling of columns.

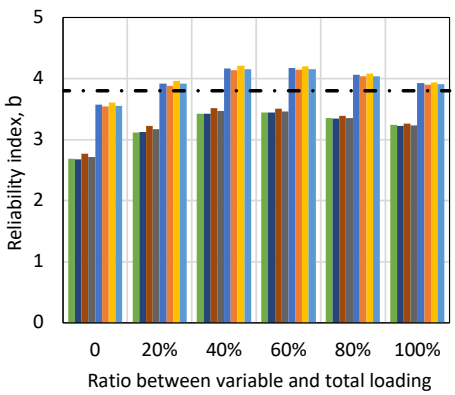

Figure 5. Calibration of partial factor gRd for lateral torsional buckling of beams: 8 different cases of design and 6 load ratios.