CERIS Civil Engineering Research and Innovation for Sustainability

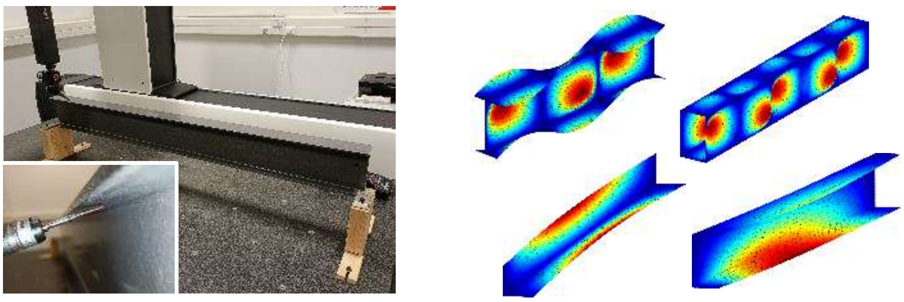
Direct strength method for pultruded FRP members: experiments, numerical simulation and design

Summary

During the last decades, the costs related to strengthening and maintenance of civil engineering structures made of traditional materials (such as steel or reinforced concrete) have been rising considerably. Moreover, there has been an even greater demand for lighter and faster construction. Due to their low self-weight, high strength, high durability and reduced maintenance requirements, pultruded fiber reinforced polymer (FRP) profiles are becoming a competitive option as structural materials. However, the use of pultruded FRP profiles is being hindered by their high deformability (serviceability limit states), buckling sensitivity (ultimate limit states), fire behaviour and lack of consensual design codes. Despite the amount of work that has been done worldwide, no consensus has been achieved on the most adequate procedure for design and safety checking of FRP members. All the existing FRP structural standards adopt a basic approach for the design of FRP members: the nominal strength of a member is the minimum between (i) the strength associated to material failure and (ii) the strength associated to elastic buckling phenomena. Even though being conservative in some cases, this approach is also known to fail in several situations where other factors come into play. These factors can be summarized in three classes: (i) the interaction between material strength and elastic buckling of members; (ii) the coupling between several types of buckling modes; and (iii) the influence of unavoidable geometrical imperfections arising from manufacturing and execution. Based on the need of a consensual design procedure, the main goal of this work is to propose a Direct Strength Method (DSM) to the design and safety verification of pultruded glass-fiber reinforced polymer (GFRP) members (columns and beams). Despite the structural behaviour and failure modes of steel and GFRP members may look similar at first glance, their material behaviour is not. Therefore, huge efforts will be put on the material side to identify the most relevant ultimate properties of GFRP for a given type of loading (columns and beams), failure mode (flexural, lateral-torsional, local) and initial geometrical imperfection. In view of the main goal, there are seven main tasks to be accomplished: (i) to implement a Finite Strip Method (FSM) tool in order to calculate the critical buckling stresses; (ii) to develop an equivalent ultimate stress criterion; (iii) to collect experimental results of failures loads/moments of GFRP members; (iv) to conduct experimental tests on GFRP members (columns and beams) and to provide a statistical treatment of the measured geometrical imperfections of GFRP members, using a 3D contact coordinate-measuring machine (CMM); (v) to develop nonlinear shell finite element models to accurately simulate the damage progression and ultimate strength of GFRP members; (vi) to calibrate the strength curves of DSM on the basis of the database acquired from the literature and the experiments performed and (vii) to evaluate the reliability of the proposed DSM. Finally, this work will allow developing safer and more reliable design of FRP structures, promoting their widespread application and making use of their advantages towards more sustainable and durable constructions.

Keywords

Direct Strength Method (DSM), pultruded GFRP profiles, Finite Strip Method (FSM), Shell Finite Element Method (SFEM), equivalent ultimate stress criterion, geometrical imperfections.



General view of the 3D contact coordinate-measuring machine (CMM) for measurements of the geometrical imperfection of pultruded GFRP profiles, and some typical critical buckling modes of GFRP profiles modelled in the Finite Strip Computer Application *(FStr).*

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