CERIS : Civil Engineering Research and Innovation for Sustainability

Development of hybrid FRP composites for strengthening concrete columns through confinement

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Summary

The main objective of this work was to study the possibility of improving the performance of FRP-confined concrete columns. An innovative confining interlayer (layer-by-layer) hybrid FRP jacket was developed, in which two reinforcing materials, synthetic (carbon and glass) or natural (basalt), were combined in the same matrix. This type of solution has proved to be very interesting, because it can promote synergies between the involved reinforcing materials, conducting, for instance, to: (i) pseudo-ductile tensile responses, characterized by fragmentation of the low strain material and dispersed delamination of the low strain material fragments from the undamaged high strain material; and (ii) an increase (until 50%) of the apparent strain at failure of low strain fibres, known as 'hybrid effect'.

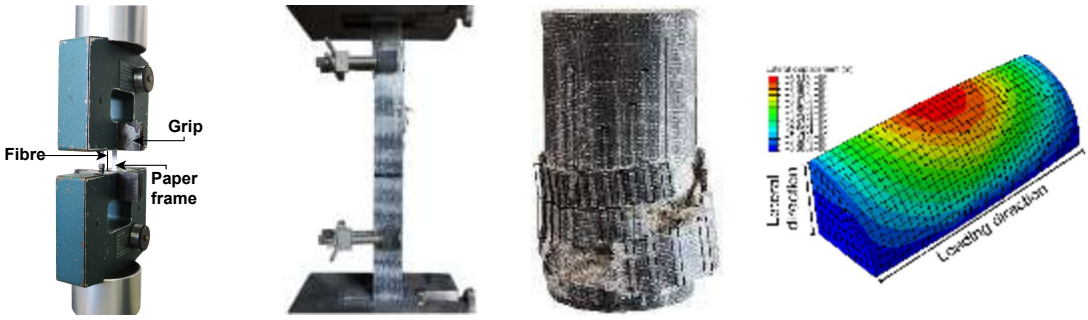
In the first phase of the work, an experimental study on the tensile stress–strain curves of hybrid FRP composites was conducted aiming at evaluating the corresponding hybrid effect and pseudo-ductility of this innovative solution. An existing analytical model in the literature was satisfactorily adopted to predict the tensile stress-strain curve of these hybrid composites. Besides, it was demonstrated that elastic modulus and tensile strength can be predicted following simple models as the linear rule of mixtures and the bilinear rule of mixtures, respectively. Then, tensile tests on single fibres were performed to determine their Weibull strength distribution parameters (shape and scale). The described factors were used as inputs to assess the performance of a progressive damage model on the prediction of hybrid effect.

In the second phase of the work, the performance of the different hybrid composites (previously tested in tension) was assessed in the confinement of small-scale plain concrete columns, exploiting the demonstrated hybrid effect and pseudo-ductility of this confining material. It has been shown that abrupt failure can be avoided, since the hybrid FRP may exhibit a pseudo-ductile tensile behaviour. In this way, the confining system maintains its integrity even after reaching its tensile strength. Besides, it has been shown that it is possible to increase the efficiency of the low strain material.

Finally, a three-dimensional finite element model using ABAQUS was developed to predict the compressive behaviour of hybrid FRP-confined concrete. This was achieved through the modification of the concrete damaged plasticity model available in the adopted software. It was demonstrated that, by turning both the yield function and the flow rule dependent on the confining pressure, it is possible to use the referred to model and obtain accurate results.

Keywords

Hybrid composites, fragmentation, mechanical properties, analytical/numerical modelling, FRP-confined concrete.



(a) (b) (c) (d)

Ilustrative figures: (a) single fibres' test; *(b) fragmentation of hybrid FRP in tension; (c) failure mode of hybrid FRP-confined concrete; and (d) distribution of FRP-confined concrete lateral displacement obtained with finite element model.*