Application of the serial/parallel mixing theory to compute RC structures reinforced with FRP to improve their seismic load capacity

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Abstract:

Strengthening or retrofitting existing structures in order to increase their ductility and improve their seismic response has traditionally been accomplished using conventional materials and constructions techniques. Composite materials of a polymeric matrix reinforced with long fibres (FRP) have emerged as an alternative to these methods.

This paper presents a numerical procedure, based on the finite element method, able to develop numerical simulations of RC structures reinforced or retrofitted with FRP. Composites are treated using the Serial/Parallel mixing theory, which obtains the composite behaviour by means of the composition of each component material properties. Each component is simulated with its own constitutive equation. This theory takes into account the unidirectional behaviour of fibrous materials such as carbon fibres or steel reinforcements, defining a iso-strain behaviour of the composite in the fibre longitudinal direction and a iso-stress behaviour in the other ones. A construction stages algorithm has been developed in order to compute retrofitted structures. This algorithm allows introducing the composite in the calculation when the structure has a certain damage level.

The numerical procedure presented is validated using available experimental data of a reinforced concrete beam reinforced with FRP. This is a simply supported beam in which two equidistant loads are applied producing a constant bending moment between them. The good agreement obtained between experimental and numerical results allow considering the numerical procedure proposed an accurate tool to develop this sort of simulations.

The same beam used to validate the code is used to validate the construction stages algorithm developed. These retrofitting simulations show that, even the structural stiffness does not depend on when the reinforcement is applied; its capacity strength is reduced if the FRP is applied when the structure is already damaged.

To view the performance of FRP reinforcements when seismic loads are considered, this work studies the structural response of a framed structure when a horizontal load is applied to it (pushover analysis). As the frame joints are, under a seismic load, one of the weakest parts of these structures, this will be the structural component to be reinforced. The response of a plain concrete frame joint is compared with the response obtained when it is reinforced using FRP. Different configurations of FRP reinforcements are considered to compare their behaviour. The framed structure is studied using two dimensional and three dimensional finite element models. The comparison of the results obtained with each simulation shows the necessity to work with three dimensional elements to obtain an adequate structural behaviour.

Finally, all simulations included in this work conclude on the ability of the serial/parallel rule of mixtures to simulate composite structures, as well as the improvement obtained in the structural performance when it is reinforced or retrofitted with fibre reinforced polymers.