Flexural Behavior of Concrete Beams Reinforced with Hybrid FRP and Steel Bars

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Abstract

This research study presents an experimental and theoretical investigation on the flexural behavior of concrete beams reinforced with hybrid glass fiber reinforced polymer (GFRP) and steel bars. The experimental work consisted of the construction and testing of twelve beams in the lab. Type of reinforcement, the ratio between steel and GFRP bars and length of steel bars were the main parameters in this study. All beams were tested under four-point bending set-up. The measurements included deflections, strains in reinforcement and concrete, number and propagation of cracks, ultimate capacity and mode of failure. The theoretical part consisted of calculating the beams’ capacities, load versus mid-span deflection curves, and load versus maximum crack width curves.

The results indicated that the hybrid beams had higher flexural capacities compared to the pure steel beam (4S8). This increase varied from 22 to 146%. Using the hybrid reinforcement enhanced the deflection behavior of the beams at service load level compared to the pure FRP reinforced beam. In addition, the results showed that the cracks in the GFRP reinforced beam can be restrained by using the hybrid system (steel and GFRP). Moreover, increasing the GFRP or steel reinforcement ratio resulted in an increase in the ultimate capacities, however, reduced the ductility of the beams. When comparing the behavior of beams with the same amount of hybrid reinforcement (GFRP+Steel), the beams with more GFRP reinforcement showed higher capacities than the beams with more steel reinforcement. This increase ranged between 15 and 39%.

Reducing the steel length in hybrid beams changes the mode of failure to debonding failure. To have a yielding of steel before debonding, it was found that the development length should not be less than twice beam depth.

Comparisons between the experimental results and the theoretical predictions showed that the adopted models could predict the ultimate capacities of the beams as well as mid-span deflection and crack width at service load level of the beams with reasonable accuracy.