Experimental and analytical investigation of flexural behavior of RC flat slabs strengthened with FRP composites under concentric loading

Summary

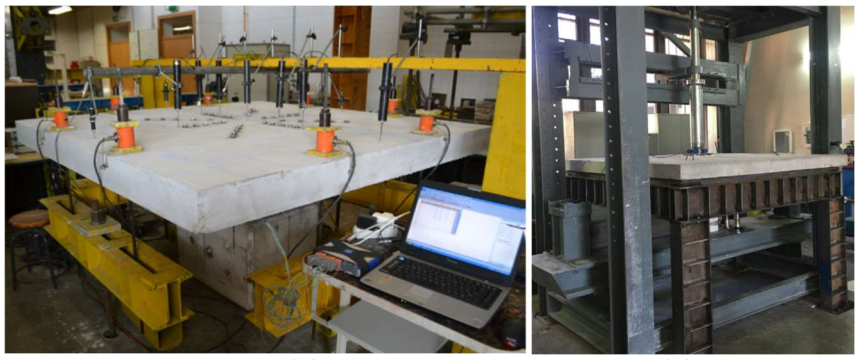
This work is concerned with study of the flexural behavior of reinforced concrete (RC) flat slabs, as well as improving the behavior of slabs with low flexural strength. For this purpose, two groups of slab specimens were tested. In the first group, all the specimens were designed with similar flexural reinforcement, but were strengthened with different external strengthening systems. In the second group, the specimens were designed differently and the effect of the internal reinforcement on the slabs' behavior was studied.

In the first group, eight specimens were designed with flexural reinforcement ratio of 0.22%, representing flat slabs which are weak in flexure, and were externally strengthened. Flexural strengthening of the specimens was performed with carbon fiber-reinforced polymer (CFRP) sheets installed with externally bonded reinforcement (EBR) and externally bonded reinforcement on grooves (EBROG) methods. In order to achieve a high level of utilization of the FRP strength and strain capacity, steel bolts were used for strengthening of the specimens against punching shear. Different patterns of the FRP sheets were also investigated in this group. Tests showed that in the slab without shear bolts, EBROG technique changed the mode of failure from FRP debonding to punching shear mode. Simultaneous flexural and punching strengthening of slab utilizing EBROG method resulted in 57% increase in the load bearing capacity. Flexural and flexural-punching strengthening of the slab specimens also improved their serviceability by decreasing their ultimate deflection, limiting the width of the flexural cracks and their propagation, increasing the cracking load, and increasing the load level corresponding to serviceability limit state. Flexural and flexural-punching strengthening decreased the ductility of the slab specimens. A new approach was developed to estimate the flexural strength of FRP-strengthened flat slabs by extending yield-line theory for such slabs.

The second group consists of six thin slabs; four slabs with flexural reinforcement ratio of 0.38% and two slabs with flexural reinforcement ratio of 1.00%. Three of these specimens were reinforced with shear headed studs as internal shear reinforcement. Results showed that decreasing the flexural reinforcement ratio as well as employing shear reinforcement changed the behavior of slab to a more ductile manner; however, punching shear failure is an unavoidable phenomenon in slab-column connections. In this group, two specimens were strengthened in flexure with FRP sheets using EBROG technique and the efficiency of external flexural strengthening was compared with that of internal flexural reinforcement. Critical shear crack theory (CSCT) was used to predict the behavior and failure mode of these specimens. The analytical results were compatible with the experimental ones. It was shown that the effect of strain hardening should be taken into account in the theoretical calculations for the thin slabs.

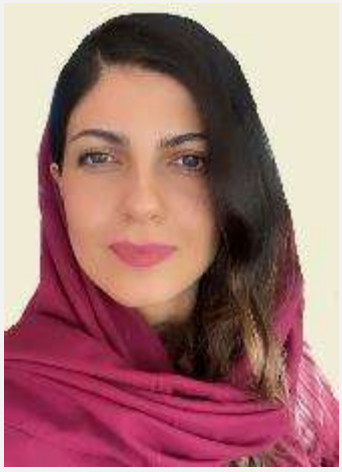
Keywords

RC flat slab, flexural behavior, FRP sheet, EBR method, EBROG method, yield-line theory, CSCT.



(a) (b)

Test setup: a) at DEC/FCT/UNL for the specimens in the first group; and b) at Isfahan University of Technology for the specimens in the second group.



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