Optimum Shear Strengthening of Reinforced Concrete Beams

by

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External prestressed carbon fibre reinforced polymer (CFRP) straps can be used to strengthen shear deficient reinforced concrete (RC) structures. The strengthening system is associated with a number of parameters including the number of straps, strap locations, strap stiffness, and strap prestress. The initial goal of this research was to identify the optimum values for these parameters in order to design an efficient and effective shear retrofitting system.

The shear friction theory (SFT) and modified compression field theory (MCFT) were identified as potential predictive theories to model the shear behaviour of RC beams retrofitted with CFRP straps. Possible modifications to the theories to reflect CFRP prestressed straps were investigated. Two popular optimisation algorithms namely the genetic algorithm (GA) and particle swarm optimisation (PSO) were coded and tested with six test functions. These algorithms were used to find the optimum shear retrofitting configurations and also to reduce the computational cost associated with the SFT and MCFT evaluations.

An experimental investigation was carried out to validate the SFT and MCFT predictions for various CFRP strap configurations. The investigation consisted of an unstrengthened control beam and five CFRP strengthened beams. The shear behaviour of the beams was significantly influenced by the CFRP strap configurations. A critical load level where the beam stiffness started to deteriorate significantly was identified. It was found that there was a correlation between this load level and the yielding of the internal shear links and a rapid increase in crack opening.

The SFT and MCFT were validated using the experimental results. The peak shear capacities predicted using the SFT were more consistent with the stiffness deteriorating loads identified in the experimental investigation than with the ultimate loads of the beams. The reinforcement forces and crack opening values found from the SFT were consistent with the experimental results. The MCFT predicted the total shear response, ultimate shear capacity, crack opening, and internal and external reinforcement forces in the beams. The accuracy of the MCFT predictions reduced slightly when either the strap configuration was highly nonuniform or the initial prestress level in the straps was relatively low. The shear link yielding load levels predicted by the MCFT were found to be similar to the SFT predictions.

By using the coded optimisation algorithms in combination with the SFT or MCFT, the optimum CFRP strap configurations were found for a selected case study. Both theories predicted an offset for the optimum strap locations from the locations associated with equal spacings along the shear span. A reasonable agreement between the SFT and MCFT predictions for the optimum shear strengths and strap locations was observed. A parametric study demonstrated that the concrete strength, internal shear link locations, beam depth, and shear span to depth ratio of the beam do not significantly influence the optimum strengthening configurations for the CFRP strap system.