Hassan Dirar, S.M.O.

Shear Strengthening of Pre-cracked Reinforced Concrete T-Beams Using Carbon Fibre Systems

Samir Mohammed Osman Hassan Dirar

The shear strength enhancement of existing reinforced concrete (RC) infrastructure using fibre reinforced polymers (FRPs) is an application of considerable economic and strategic importance, particularly in the case of bridges. However, this topic is not yet fully understood. Much of the research in the area of shear strengthening of RC structures has considered uncracked specimens but an existing RC structure may well be cracked and have been subjected to countless load cycles prior to strengthening. Other parameters that may also influence the strengthened behaviour – such as the type of shear strengthening system and beam depth – have not yet been sufficiently studied.

This thesis investigates the structural behaviour of pre-cracked RC T-beams strengthened in shear with external carbon FRP (CFRP) systems. Using both bonded passive and unbonded prestressed CFRP shear strengthening systems, eleven tests on a total of nine RC beams were conducted, identifying the influence of the load history, type of shear strengthening system, beam depth and percentage of longitudinal reinforcement on the strengthened behaviour. The experimental results indicated that the contributions of the external CFRP systems to the shear force capacity can be significant and depend on most of the investigated variables.

Numerical analyses using smeared crack approaches were undertaken to simulate the behaviour of the tested specimens. Predictions based on phased non-linear finite element (NLFE) analyses using a variety of material models were established to support the experimental work. The FE results confirmed the experimental behaviour and the peak loads and modes of failure were predicted fairly accurately. The numerical analyses provided valuable insight into the material models used in NLFE analysis and highlighted their advantages and limitations.

A review of existing models and design guidelines proposed to predict the shear contribution of external FRP systems was conducted. For prestressed CFRP systems, most promise is shown by shear friction models modified to incorporate crack widths. For externally bonded FRP systems, the prediction of debonding failures is a critical feature. This study shows that three of the existing international design guidelines, namely TR 55, fib Bulletin 14, and ACI 440.2R-02 overestimate the shear contribution of the externally bonded FRP systems. This thesis proposes a more conservative analytical model based on bond mechanism.

In general, the project has drawn together innovative experiments and advanced numerical simulations to improve our understanding of the behaviour of CFRP-strengthened RC beams. It has also investigated the reliability of the current design guidelines for strengthening RC structures in shear and improved their predictions.