Abstract

Several factors can adversely affect the true shear capacity of existing reinforced concrete (RC) beams, such as the corrosion of the internal shear links, over-loading, less conservative initial designs and construction defects. One possible solution is to use external carbon fibre reinforced polymer (CFRP) straps to strengthen existing RC beams. Previous research has been conducted to investigate the short-term behaviour and the advantages of the strengthening system has been demonstrated. However questions relating to the fundamental mechanisms over the longer term remain to be solved. Moreover, a greater confidence in the long-term safety of the system needs to be developed before this strengthening technique can be fully accepted in practice.

This thesis describes an investigation into the time-dependent behaviour of RC beams strengthened with pre-stressed CFRP straps. A total of four short-term beam tests and five long-term beam tests were performed. The concrete strength, load level and level of initial pre-stress in the straps were varied and the influences of these parameters were assessed. The experimental results indicated that the CFRP strap strengthening system can efficiently enhance the short-term shear capacity of RC beams. When subjected to the sustained load, shear metrics such as the shear reinforcement strain and shear deformations all increased to a certain degree over the long term. With the exception of a specimen with a high level of initial pre-stress in the CFRP straps, the long-term performance of the strengthened system was found to be reliable across different parameters. The findings from the experiments provided insight of the fundamental shear transfer mechanisms.

To better understand the experimental results, numerical analyses were conducted using smeared crack shear models including the modified compression field theory (MCFT), rotating angle-softened truss model (RA-STM) and disturbed stress field model (DSFM). To decouple the shear behaviour from the bending behaviour, these shear models were used in conjunction with finite element (FE) models. Different combinations of creep simulation methods were incorporated for the time-dependent analyses. The analyses confirmed the observed experimental behaviour. However, the shear behaviour was typically more difficult to accurately predict than the bending behaviour. Moreover it was found that there was not a single smeared crack shear model that could simulate every aspect of the shear behaviour. Inclusion of a high-stress effect (HSE) was required for more accurate long-term shear predictions.

One of the fundamental load transfer mechanisms, time-dependent tension stiffening, was also simulated using the FE approach. This work was used to validate modifications to the time-dependent tensile stress-strain relationship used in the smeared crack shear models to reflect time-dependency.

Time-dependent design equations suitable for hand calculations were developed based on modifications to an existing time-dependent truss model. The proposed factors were calibrated using the experimental results.