ABSTRACT

Reinforced concrete members are strengthened with Fiber Reinforced Polymer (FRP) composites in the form of laminates and fabrics, using externally bonded (EB) technique for strengthening. However, the utilisation of FRP composites capacity is limited due to the debonding phenomenon existing in the strengthening system, due to FRP and concrete interfacial shear stress. Presently, prestressing and anchors are in use to avoid or delay FRP debonding. A new type of carbon and aramid FRP, in the form of strand sheets was developed a few years ago and is not been adequately investigated upon for the purpose of strengthening. It may noted that such strand sheets likely to enhance the bond strength due to inherent gap between the fibre strands. These strands are less than 1.0 mm in diameter is woven with thread to make the desired width of sheet. These gaps allow the epoxy (adhesive) to cover the entire out surface of each strand, resulting a better bond mechanism as compared to plate (laminate), which is attached to the concrete surface with one face only. In this study, the effectiveness of CFRP and AFRP strand sheets in the flexural strengthening of RC members with and without CF-anchor were investigated experimentally. The modified procedure was proposed for double lap shear test developed by Larralde *et al.*(2001) and maximum bond widths of double lap shear test have also been proposed in relation to the flexural strength of concrete used in the test. The bond strength improvement was quantified by a modified procedure of double-lap shear test using strand sheets and laminates to establish the improved bonding behaviour. A laboratory study to examine the effectiveness of strand sheets and to validate the shear stress obtained from the double-lap shear test was conducted on concrete beam specimens (with and without notch) strengthened with CFRP and AFRP strand sheets. Further, to validate the shear stress obtained from the double-lap shear test by the modified procedure and effectiveness of the strand sheets on reinforced concrete beams, experimental study was conducted using rectangular reinforced concrete (RC) beams with different types of FRP materials and their varying width ratio. The main parameters varied were width ratio (w_f/b) of high strength CFRP strand sheets (0.83 and 0.33) and for high modulus CFRP and AFRP strand sheets, it was kept as 0.33. The reinforced concrete (RC) beams were tested under four-point knife-edge loading. The experimental research includes tests on (1) un-strengthened RC beams, (2) RC beam strengthened with high strength CFRP laminate, high strength and high modulus CFRP strand sheets and AFRP strand sheets, (3) CF-anchors as end anchorages on RC beams strengthened with CFRP and

AFRP strand sheets keeping the width ratio as 0.33. The proposed modified procedure of double-lap shear test was validated successfully in the strengthened specimens. The relative contribution of the CFRP and AFRP strand sheets to the bending moment capacity was observed to be significantly higher than that in the case of the CFRP laminate. The failure mode debonding (FD) shifted to concrete cover separation (CCS) with increase in width ratio (w_f/b) from 0.33 to 0.83 in high strength CFRP strand sheets, The specimen strengthened with high modulus CFRP strand sheets had a failure mode of rupture (FR). Further, CF-anchors successfully delayed the debonding of CFRP and AFRP strand sheets. Based on the observed failure modes, models for predicting the mechanical behavior of various systems were recommended. Overall, it was seen that the bending-moment capacity and ductility of the beams increased when strand sheets were used in comparison with laminates as a result of the improved bond. A further improvement was observed with the use of CF-anchors.

KEYWORDS: CFRP, AFRP, strand sheets, laminates, CF-anchors, end anchorage, PC beam, RC beam, double-lap shear test (DLST), FRP tensile strain, debonding.