Announcing the Final Examination of Yasir Al-Lebban for the degree of Doctor of Philosophy

Time & Location: July 6, 2017 at 8:00 AM in Engineering II 211P
Title: POLYURETHANE FIBER REINFORCED POLYMER STRENGTHENING OF SHEAR DEFICIENT REINFORCED CONCRETE BEAMS

The use of externally-bonded fiber-reinforced polymer (FRP) composites has been established as an effective means for the strengthening of shear-deficient reinforced concrete (RC) flexural members. Epoxy-based wet layup systems were predominantly employed in previous studies. In this study, carbon FRP pre-impregnated with polyurethane resin is utilized in strengthening shear-deficient RC beams and compared to an epoxy resin. Fourteen small-scale (96 in span, 6 in width, and 12 in height) and five large-scale (132 in span, 12 in width, and 17 in height) flexural specimens were tested, considering adhesive type (polyurethane versus epoxy), size effect, shear span-to-depth ratio, FRP configuration (U-wraps versus side bonding), and FRP scheme (sheets versus strips with 45° or 90°). Experimental strength testing under four-point loading demonstrated similar or enhanced shear capacity when strengthening by the polyurethane compared to the epoxy composite systems.

The shear behavior of polyurethane-based FRP composite system is investigated in this research using analytical and numerical approaches. A closed-form mechanics-based analytical model, utilizing the principle of effective FRP stress and upper-bound theorem, illustrated that both the bond behavior and the FRP composite characteristics play significant roles in the shear behavior of the specimens strengthened by polyurethane and epoxy systems. The analytical model is expressed in terms of shear crack opening crossed by the FRP laminate and gives good agreement with experimental results. The FEA model shows that the stresses in the FRP are not in single direction as in the coupon tests, and the biaxial stress states should be taken into consideration.

The structural behavior of RC members strengthened with externally-bonded FRP composites is mobilized through the composite action technique. Bond stress can be defined as the shear stress acting in the interface between FRP and concrete. It is of crucial importance to evaluate the failure mode behavior. Debonding (loss of adhesion) failure is one of the most common modes of failure encountered in shear strengthening RC members in practice. Numerous constitutive bond-slip models have been proposed and derived numerically and mathematically based on experimental data with an assumption that the FRP width \( b_p \) be taken as a variable and all stresses or strains in the same longitudinal coordinate (L direction) be uniform. No attention has been given to study the effect of the interface and FRP states of stress (which are mainly altered by the inclined shear micro-cracks in concrete) on the bond stress transfer mechanism. A new bond-slip law was proposed to address the biaxial two-dimensional (2D) states of stress problem using the von Mises constitutive model. Numerical solution by finite difference was conducted to solve four partial differential equations per node (2 for FRP and 2 for concrete in each direction) with appropriate boundary conditions to obtain the stresses, slips, and strains based on the proposed bond-slip model. A new experimental setup was proposed to represent the 2D bond-slip model by lap shear tests in both directions by laminating two perpendicular strips on concrete blocks with the proposed strain profile. Experimental calibration has been carried out by using nonlinear least square regression (fitting) of the experimental strain data with the numerical FD equations to obtain the bond-slip parameters for the 2D FRP-to-concrete polyurethane interface system.

Major: Civil Engineering

Educational Career:
Bachelor's of Civil Engineering, BS, 2001, University of Kufa
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Committee in Charge: