The resistance of reinforced concrete is mobilized through the composite action of two materials with different mechanical behaviors and physical features. Enabling the composite action requires a transfer mechanism between the concrete and the reinforcement which is referred to as bond. The bond model can be defined as a traction-slip relation tangent to the interface. The bond strength between different types of concrete, internal reinforcement, and external reinforcement has been of interest to structural engineers for decades. Experimental tests have been carried out to validate the existing bond models and introduce new bond models for special cases of concrete or reinforcement. The effect of various parameters on the bond stress, such as bar diameter, concrete compressive strength, presence of fibers, cyclic loading, etc. have been investigated. However, little attention has been directed to the contribution of normal (to the interface) force and state of stress of the substrate layer on the mechanical response of the interface. Since the state of stress (tangential, normal, and substrate) within each type of experimental test is different, the resulting bond models are not consistent.

Behavior of ultra-high performance concrete (UHPC) composite flexural members are studied using experimental, analytical, and numerical approaches in this research. A new bond-slip model is proposed that contains an explicit representation of the normal stress and constitutive model of the substrate. The parameters of the model were calibrated from beam and pullout tests using UHPC and HSS. The calibrated results showed consistency in the material point behavior between the pullout and beam test although the states of stress were different. The effect of the normal force was verified throughout a numerical model compared with experimental flexural tests. Single and double lap shear tests were carried out for UHPC and FRP, and parameters of the bilinear model were calibrated and used in the finite element model of the new composite deck.

A new lightweight composite deck system is proposed that uses fiber reinforced polymers (FRP) bonded to UHPC using vacuum-assisted resin transfer molding. The high performance deck system has application in deck design and replacement for bridges with weight restrictions as well as for accelerated bridge construction. Results show the deck satisfies strength and serviceability criteria under monotonic load. The bond strength between the UHPC and the glass fiber reinforced polymers (GFRP) plays a significant role in the performance of the proposed deck and controls the behavior of the system. However, live loads on bridges are inherently cyclic and therefore research on serviceability and fatigue behavior of UHPC and UHPC composite members were carried out. The UHPC beams were strengthened using glass GFRP plates on compression side to obtain data that could be utilized for the future design. The effect of fatigue loading on the interfacial shear stress between UHPC and GFRP was also investigated and it is found to be minor under low load level. However, a noticeable progression in the interfacial shear stress was found for the higher load ratio.

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