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Numerical Modeling of the Debonding Mechanisms in FRP-RC Strengthened Beams

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ABSTRACT

The continual deterioration of infrastructure has motivated researchers to look for new ways of repairing and monitoring existing structures. A particularly challenging problem confronting engineers in the revival of the infrastructure is the rehabilitation of reinforced concrete (RC) structures. Traditionally, the repair of RC beams has been achieved by bonding steel plates to the structure. Although this technique has proven to be reasonably effective, it has several distinct disadvantages such as susceptibility of the steel plates to corrode and the excessive weight of steel plates when used in long-span beams. Recently, there has been an emergence of structural engineering applications employing fiber reinforced polymer (FRP) composites as an alternative to steel plates. FRP composites are well known for their high strength-and stiffness-to-weight ratios, corrosion resistance, durability, and ease of application. Numerous studies have been conducted to prove the efficiency of bonding FRP on structural elements [1]. In spite of this, industrial practitioners are still concerned about premature debonding of the plates before reaching the desired strength or ductility. Premature debonding initiates from the ends of the plate or from intermediate cracks (IC) in the concrete. While end initiated debonding and peeling mechanisms have been researched extensively, researchers have unanimously recognized the lack of data for the FRP-RC structural members subjected to IC debonding [2]. The scarcity of data complied exemplifies the need to develop more refined numerical analysis tools to reduce the high cost and significant time required to conduct full-scale physical testing.

In this study, the results of a comprehensive numerical investigation are presented to asses the failure mechanisms caused by different types of flexural and shear crack distributions in RC beams strengthened with FRP composites. The model is based on damage mechanics modeling of concrete and a bilinear bond-slip relationship with softening behavior to represent the FRP-concrete interfacial properties. A discrete crack approach was adopted to simulate crack propagation through a nonlinear fracture mechanics based finite element analysis to investigate the effects of crack spacing and interfacial parameters such as stiffness, local bond strength, and fracture energy on the initiation and propagation of the debonding and structural performance. Results from the analysis reveal that the debonding behavior and load-carrying capacity are significantly influenced by interfacial fracture energy and crack spacing. The debonding propagation is mainly governed by mode II fracture mechanisms. The results provide an insight on the long-term behavior of a repair system that is gaining widespread use and will be of interest to researchers and design engineers looking to successfully apply FRP

products in civil engineering applications.

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