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A Nonlinear Model for Predicting Intermediate Crack-Induced Debonding in FRP-Retrofitted Beams in Flexure

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Abstract

A nonlinear analytical model is presented and used to determine the interfacial shear and normal stresses at the FRP/concrete interface for RC beams externally strengthened with CFRP sheets. The computed stresses can be used to predict intermediate crack-induced debonding near the section of maximum moment. The model is based on composite beam theory with partial slip at the FRP-concrete interface permitted. Nonlinearity in the retrofitted beam is accounted for via consideration of the full moment-strain response of the unretrofitted beam. For model validation, the computed longitudinal strain along the laminate and the debonding load for a number of tested beams are compared with their corresponding experimental values. Furthermore, the shear and normal stresses distribution were also predicted. The theoretical predicted delamination load is in good agreement with the experimental results. The model yielded a reasonable theoretical load for beams with anchors and as predicted using ACI (08) method.

CE Database subject headings: Analytical model; Beam; Intermediate Crack, Debonding; FRP; Interfacial stresses; Laminate; Reinforced concrete.

1.0 Introduction

To increase the ultimate moment capacity of an existing Reinforced Concrete (RC) beam, a modern method is to bond Fiber Reinforced Polymer (FRP) laminates and/or sheets to the tension face of the beam. The ability of the FRP-concrete interface to resist the induced interfacial stresses and allow the laminate to reach a reasonably high percentage of its strength without premature debonding is key to the successful performance of this strengthening technique. Interfacial debonding is a brittle phenomenon and it precipitously nullifies the strength gained through FRP retrofitting. Knowledge of the debonding stresses and loads are essential for accurate estimation of the load carrying capacity of the retrofitted beam and the safety of the structure involved. The problem of delamination, its causes, and procedures for delaying/preventing it have been studied by a number of researchers over the past two decades. Various failure modes in structures externally strengthened with FRP laminate have been observed and reported by Teng et al. (2002), Oehlers and Seracino (2004) and Mostafa (2010) such as (a) flexural failure due to crushing of concrete in the compression zone, (b) flexural tension failure due to rupture of FRP , (c) failure initiated by separation of the concrete cover at the tension steel reinforcement level, (d) delamination of FRP at the concrete-adhesive interface near the section of maximum moment, and (e) delamination of the FRP at the plate ends due to high interfacial shear and normal stresses. The above failure modes can be generally

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