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Analysis of RC Continuous Beams Strengthened with FRP Plates: A Finite Element Model

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Abstract

Strengthening of reinforced concrete (RC) beams with externally bonded fibre reinforced polymer (FRP) plates/sheets technique has become widespread in the last two decades. Although a great deal of research has been conducted on simply supported RC beams, a few studies have been carried out on continuous beams strengthened with FRP composites. This paper presents a simple uniaxial nonlinear finite-element model (UNFEM) that is able to accurately estimate the load-carrying capacity and the behaviour of RC continuous beams flexurally strengthened with externally bonded FRP plates on both of the upper and lower fibres. A 21-degree of freedom element is proposed with layer-discretization of the cross-sections for finite element (FE) modelling. Realistic nonlinear constitutive relations are employed to describe the stress-strain behaviour of each component of the strengthened beam. The FE model is based on nonlinear fracture mechanics. The interfacial shear and normal stresses in the adhesive layer are presented using an analytical uncoupled cohesive zone model with a mixed-mode fracture criterion. The results of the proposed FE model are verified by comparison with various selected experimental measurements available in the literature. The numerical results of the plated beams (beams strengthened with FRP plates) agreed very well with the experimental results. The use of FRP increased the ultimate load capacity up to 100 % compared with the non-strengthened beams as occurred in series (S). The major objective of the current model is to help engineers' model FRP-strengthened RC continuous beams in a simple manner.

Keywords: Finite Element; Continuous Beams; Plated Beam; Interfacial Stresses; Maximum Capacity; Debonding.

1. Introduction

In recent years, the external bonding of carbon (CFRP) or glass (GFRP) FRP plates/sheets to the beam tension face has become a common practice and is widely used to strengthen or repair structures. Strengthening RC beams in flexure with FRP plates/sheets is a powerful strengthening technique due to its simplicity of in situ application, small increase of the beam size and weight, and good resistance to corrosion.

Extensive numerical and experimental research efforts have been carried out to study and model the behavior of simply supported beams with external FRP plates; as a result, there are many design guidelines for such beams [1-3]. However, many in situ RC beams are used in continuous construction; there has been very limited research into the behavior of such beams with external strengthening. Experimental studies were conducted to compare the behavior of RC continuous beams strengthened with FRP plates with non-strengthened beams (control beams) [4-15]. They concluded that the use of FRP plates/sheets to strengthen continuous beams was effective for reducing deflections and for increasing their load carrying capacity.

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