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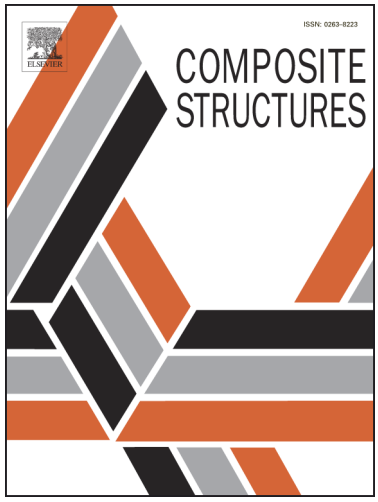

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Evaluation of stress-strain state of FRP strengthened RC elements in bending. Fracture mechanics approach

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Abstract

The evaluation of stress state of tensile reinforcements is highly important while examining the technical state of concrete structures. Normal cracks in flexural RC elements are the consequence of stress-strain state, on the other hand, the stress-strain state of flexural reinforced concrete structures, strengthened with various types of FRP reinforcements, could be analysed by observing the parameters of normal cracks. Therefore, here proposed method for analysis of such structures relating normal crack parameters to stress-strain state in the element. Not full composite action between concrete and external FRP reinforcement was taken into account by reducing FRP strain through reduction factor based on built-up bars theory. Afterwards, bending moments and mid-span deflections were retrieved using methods of classical mechanics of solids and then numerical results were reliably compared to experimental ones from the tests of RC beams, strengthened with externally bonded CFRP laminates, sheets and near surface mounted GFRP rods, with post-tensioning and initial stress state effects.

Keywords

Carbon, glass fibre reinforced polymer, strengthening, reinforced concrete, crack, deflection

1. Introduction

In the last decades fibre reinforced polymers (FRP) due to their corrosion resistance and high strength to low weight ratio has established itself in construction market as appropriate material to change steel [1–3]. Not exception retrofitting of existing reinforced concrete (RC) structures in bending where FRP changes classical materials such as concrete jackets, steel plates [4–7]. In order to use full potential of this high strength materials in most cases posttensioning will be required [8,9]. Not less important to choose appropriate anchorage to prevent or reduce the threat of sudden and brittle debonding like failure modes [10].
After retrofitting it is important to track technical state of such structures in order to prevent the accident in time. The evaluation of stress state of tensile reinforcements is highly important while examining the technical state of concrete structures. Which can be examined by observing critical parameters of normal cracks [11]. Therefore, crack model relating crack parameters to FRP strains is presented. Such a relation allows to analyse structures technical state from measured maximum crack width in normal section. However, while converting crack parameters into strains, non-full composite action in the contact surface of FRP and concrete should be taken into account. To solve this problem, contact stiffness reduction factor based on built up bars theory [12–16] is added to the model.
From the various crack models based on fracture energy or fracture parameters stands out one proposed by Jokubaitis *et al.* [11][17–21] since in their crack model for RC structures they have proposed direct relation of crack width and depth in normal section. What served as a basis for Slaitas *et al.* [22] to go further and directly relate crack parameters with strains in the element without neither fracture energy nor fracture parameter for FRP strengthened RC elements. This direct relation was used to derive here proposed stress-strain state assessment