Size Effects in Reinforced Concrete Beams Strengthened with CFRP Straps

By

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Abstract

In the current work, a new 'generalised characteristic length' was developed in order to determine the size effect in reinforced concrete beams strengthened with CFRP straps. The method is based on the superposition of mode I stress intensity factors which can be applied to both bonded internal and un-bonded external reinforcement. Therefore, two different bending fracture models, which are applicable for either steel or FRP reinforcement, were developed for the bonded and un-bonded cases. To validate the developed fracture bending models, a series of mode I three-point bending experiments was undertaken.

The proposed generalised characteristic length depends on the concrete material, the shape of the beam, the shape of the stress distribution in the fracture process zone and the force in the reinforcement. It was identified that the generalised characteristic length varies as the crack propagates. In order to determine the size effect reduction factor at failure, the generalised characteristic length was calculated for unstable and stable crack propagation. The generalised characteristic length was compared with existing experimental results for beams with or without longitudinal reinforcement. Based on the experimental validation, it was shown that the generalised characteristic length can be applied to beams which fail due to the propagation of a vertical or inclined crack.

In order to effectively apply the combined generalised characteristic length size effect equation, a single shear crack rotation model was employed to determine the forces in the internal and external reinforcement. It was found that the internal vertical steel stirrups and external CFRP straps reduce the size effect on the concrete shear strength. Providing more than a nominal level of stirrups and/or CFRP straps effectively eliminates the size effect. Furthermore, it was concluded that the size effect reduction factor depends on the crack bridging force in the reinforcement across a crack which implicitly depends on the bond properties between the reinforcement and concrete, the type of reinforcement and the area of reinforcement.