

Maximum Reinforcement Ratio of Concrete Beam Prestressed with Unbonded CFRP Tendons

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Extended Abstract

The material properties of Fiber Reinforced Polymers (FRP) such as corrosion-free and high tensile strength have led them to be considered as an ideal substitute for corrosive steel tendons in prestressed concrete structures (Burgoyne, 1993; Maissen and Smet, 1995). However, FRPs have inherent weakness of non-ductile tensile behaviour. Different efforts to improve the ductility of FRP prestressed concrete beams have been made such as unbonding FRP tendons (Burgoyne 1993, Kato and Hayashida 1993).

In previous research, a theoretical model was developed to predict the flexural load-deflection of simply supported concrete beams internally prestressed with unbonded carbon-fiber-reinforced polymer (CFRP) tendons under 4-point loading (Lee et al., 2014). As tendons are unbonded, the increase in flexural stress for unbonded strands is independent of the cross section but depends mainly on the deformation of the member (Naaman and Alkhairi, 1991a, b; Du et al., 2008). Consequently, strains in an unbonded tendon are relieved from critical sections and averaged out along the beam length. Since strain compatibility at a section is not satisfied, a direct evaluation of unbonded tendon stress at ultimate state is not available. This may hinder an assessment of maximum amount of FRP tendons to be used as unbonded tendons. In this research, a theoretical model is presented for the assessment of maximum reinforcement ratio of reinforced concrete beam internally prestressed with unbonded CFRP tendons to avoid brittle failure by tensile fracture of CFRP tendons at ultimate state. The model is developed for a simply supported prestressed concrete beam with straight tendons and subjected to a symmetric 3-point or 4-point loading. In modelling, when an extreme fiber of concrete in compression at a section of the maximum moment reached its ultimate state, curvatures at two additional characteristic sections along the beam span were defined: cracking and yielding sections. The cracking section is the one with the initiation of flexural crack and the yielding section with the initiation of yielding of flexural steel (if any). The curvatures at these three characteristic sections were found. With the assumption that linearly varying curvatures between the characteristic sections and supports, three equivalent rectangular curvature blocks were obtained. These three equivalent blocks were estimated so that they can closely simulate the beam rotations at the supports and the mid-span beam deflection. Iterative scheme was developed to find the equivalent curvature blocks at ultimate state and based on which, the maximum reinforcement ratio of the unbonded CFRP prestressed concrete beam was identified so that concrete failure precedes the tensile fracture of the unbonded CFRP tendons. The developed iterative algorithm could successfully yield the maximum amount of unbonded CFRP tendons. The maximum reinforcement ratios (or balanced ratios) were generally smaller than their bonded equivalents.

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