

Optimum Design of FRP-Reinforced Concrete Flexural Members

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Recently, several code committees and other research groups worldwide have recommended design guidelines for concrete reinforced with FRP reinforcement. The Canadian Highway Bridge Design Code (CHBDC) includes provisions for the design of FRP-reinforced concrete. In addition to flexural provisions at serviceability limit states and at ultimate limit states, several other provisions pertaining to deformability, creep-rupture, fatigue, and redundancy have to be considered. The relatively large number of design provisions associated with the application of FRP materials in concrete structures makes the traditional design approach of trial and error extremely tedious and time consuming. This is why it would be logical to use design optimization techniques for this type of problem.

This paper presents a systematic approach to the design of FRP-reinforced concrete flexural members that is based on numerical optimization techniques. A recent rational design procedure¹ is adopted in this study. The procedure gives the cross-sectional area of FRP reinforcement required for a section subjected to flexure. A modification to the concept of deformability given in the CHBDC was suggested in this procedure. It was shown that when, in addition to the crack control requirement, an upper limit is imposed on the cross-sectional area of the FRP, no calculation would be necessary to check the deformability. One drawback of this procedure is that it assumes that the concrete dimensions have been selected and that the deflection criteria will be satisfied at service. Deflection of FRP-reinforced flexural members can be more critical than that of members reinforced with steel. Controlling deflection through the selection of minimum member thickness is crucial.

This study integrates the design procedure described above with a method for controlling deflection through the use of numerical optimization techniques. Deflection is taken as the objective function to be minimized subject to the relevant design constraints. Design variables include the concrete dimensions and the cross-sectional area of FRP reinforcement. The resulting optimization system would be of benefit to designers in reducing the amount of time and effort required to design optimum FRP-reinforced concrete flexural members. Parametric studies are conducted to explore the effects of a range of material and geometric properties.

¹ Newhook, J., Ghali, A., and Tadros, G., "Concrete Flexural Members Reinforced with Fiber Reinforced Polymer: Design for Cracking and Deformability," *Canadian Journal of Civil Engineering*, Vol. 29, No. 1, 2002, pp. 125-134.