Proposed Change for Deflection in ACI440.2R-08

Original Text

10.2.8 *Serviceability*—The serviceability of a member (deflections and crack widths) under service loads should satisfy applicable provisions of ACI 318-05. The effect of the FRP external reinforcement on the serviceability can be assessed using the transformed-section analysis.

To avoid inelastic deformations of reinforced concrete members with nonprestressed steel reinforcement strengthened with external FRP reinforcement, the existing internal steel reinforcement should be prevented from yielding under service load levels, especially for members subjected to cyclic loads (El-Tawil et al. 2001). The stress in the steel reinforcement under service load should be limited to 80% of the yield strength, as shown in Eq. (10-6). In addition, the compressive stress in concrete under service load should be limited to 45% of the compressive strength, as shown in Eq. (10-7)

$f_{s,s} \leq 0.80 f_y$ (10-6)

$f_{c,s} \leq 0.45 f_c'$ (10-7)

Proposed Text

10.2.8 *Serviceability*—Deflections under service loads should be assessed based on applicable provisions of ACI 318-11 except that the effective moment of inertia, I_e, should be calculated using Equation 10.6 (Rasheed and Charkas 2009). In general, external FRP reinforcement affect smaller and better distributed cracks than a reinforced section with similar strength subjected to the same service conditions. Equation 10.6 accounts for the effect of the external FRP reinforcement on the evaluation of I_e.

$$I_e = \left(\frac{M_{cr}}{M_a}\right)^3 I_g + \left[1 - \left(\frac{M_{cr}}{M_a}\right)^3\right] I_{ey} \leq I_g \quad (10\text{-}6)$$

Where

$$I_{ey} = 0.73 I_{cr} + 0.05 I_g \quad (10\text{-}7)$$

Equation 10-6 was validated against a database of simply-supported reinforced concrete beams subjected to four-point bending and strengthened with FRP sheets, plates and NSM bars. This approach is equally applicable to uniform loading and three-point bending conditions (Rasheed et al. 2004). Equation 10.6 has not been examined for prestressed concrete members. In lieu of the present approach, the designer may elect to use a more detailed stiffness analysis that considers the variation of the moment of inertia along the span of the member to compute immediate deflections.

To avoid inelastic deformations of reinforced concrete members with nonprestressed steel reinforcement strengthened with external FRP reinforcement, the existing internal steel reinforcement should be prevented from yielding under service load levels, especially for members subjected to cyclic loads (El-Tawil et al. 2001). The stress in the steel reinforcement under service load should be limited to 80% of the yield strength, as shown in Eq. (10-8). In addition, the compressive stress in concrete under service load should be limited to 45% of the compressive strength, as shown in Eq. (10-9)

$f_{s,s} \leq 0.80 f_y$ (10-8)

$f_{c,s} \leq 0.45 f_c'$ (10-9)

Additional References Associated with Proposed Changes

Rasheed, H. A. and Charkas, H. (2009) "Modified Branson Formula for Deflection of FRP Strengthened Concrete Beams," *ACI Special Publication SP-264*, Ospina, C., Bischoff, P. and Alkhrdaji, T. eds., American Concrete Institute, Farmington, MI.

Rasheed, H. A., Charkas, H. and Melhem H. G. (2004) "Simplified Nonlinear Analysis of FRP Strengthened RC Beams Based on a Rigorous Approach," *ASCE Journal of Structural Engineering*, Vol. 130, No. 7, pp. 1087-1096.

Additional Required Editorial Changes

Two equations are added to Chapter 10, requiring renumbering of all subsequent equations.