ABSTRACT

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A Cracked Concrete Material Model for the Nonlinear Finite Element Analysis of Slab-On-Girder Bridges

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This research investigates three-dimensional finite element modeling techniques for slab-on-girder bridges, and develops a concrete crack model which is implemented within a nonlinear finite element framework. The concrete crack model is used to investigate the effect of pre-existing cracks on the live load distribution on steel girder bridges.

First, the behavior of composite steel girder bridges is examined by means of sophisticated three-dimensional finite element analyses. Several finite element models have been implemented and tested to determine their accuracy and limitations. The selected model is such that the deck is represented by shear flexible shell elements and the structural steel girder is idealized by Timoshenko beam elements. Full composite action between slab and girder is guaranteed by multi-point-constraints.

Cracking in bridge decks may result in a significant reduction in their stiffness and strength. Most concrete crack models based on the smeared crack technique take into account these effects by reducing the shear modulus using a shear retention factor. However, the selection of shear retention is somewhat empirical and has no physical justification. In this study, instead of using the shear retention factor, a concrete crack model based on the strain decomposition technique has been adopted. The strain decomposition technique enables the explicit inclusion of physical behavior across the cracked concrete surface such as aggregate interlock and dowel action rather than intuitively defining the shear retention factor. In this study, this concrete material model has been extended to three-dimensional problems using a layered approach. The proposed material model has been integrated into the commercial finite element (FE) software ABAQUS shell elements through a user-supplied material subroutine. The FE results have been compared to experimental results reported by other researchers. It has been found that the developed bridge FE model is capable of accurately predicting the initial cracking load level, the ultimate load capacity, and the crack pattern.

Finally, the proposed concrete crack model has been extended to investigate the effect of pre-existing cracks in reinforced concrete bridge decks on the live load distribution of steel girder bridges. Three Indiana steel girder bridges, which have pre-existing cracks, have been identified and analyzed using the developed nonlinear finite element framework. Numerical results indicate that transverse cracking of the concrete deck at the negative moment zone does not significantly influence the transverse distribution of the design moment. Thus, the load distribution factor equation in the AASHTO-LRFD code can be used safely in transversely cracked bridge decks. Longitudinal cracking, on the other hand, has been found to have a significant influence on the lateral load distribution. Thus, an increased load distribution is expected in case, which can affect the rating of bridge experiencing longitudinal cracking.