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Simple Finite-Element Procedure for Modeling Crack Propagation in Reinforced Concrete Bridge Deck under Repetitive Moving Truck Wheel Loads

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Abstract : Modeling cracks in concrete is complicated by its strain-softening behavior which requires the use of sophisticated energy criteria of fracture mechanics to assure stable and convergent solutions in the finite-element (FE) analysis particularly for relatively large structures. However, for small-scale structures such as beams and slabs, a simpler approach relies on retaining some shear stiffness in the cracking plane has been adopted in literature to model the strain-softening behavior of concrete under monotonically increased loading. According to the shear retaining approach, each element is assumed to be an isotropic material prior to cracking of concrete. Once an element is cracked, the isotropic element is replaced with an orthotropic element in which the new orthotropic stiffness matrix is formulated with respect to the crack orientation. The shear transfer factor of 0.5 is used in parallel to the crack plane. The shear retaining approach is adopted in this research to model cracks in RC bridge deck with some modifications to take into account the effect of repetitive moving truck wheel loads as they cause fatigue cracking of concrete. First modification is the introduction of fatigue tests of concrete and reinforcing steel and the Palmgren-Miner linear criterion of cumulative damage in the conventional FE analysis. For a certain loading, the number of cycles to failure of each concrete or RC element can be calculated from the fatigue or S-N curves of concrete and reinforcing steel. The elements with the minimum number of cycles to failure are the failed elements. For the elements that do not fail, the damage is accumulated according to Palmgren-Miner linear criterion of cumulative damage. The stiffness of the failed element is modified and the procedure is repeated until the deck slab fails. The total number of load cycles to failure of the deck slab can then be obtained from which the S-N curve of the deck slab can be simulated. Second modification is the modification in shear transfer factor. Moving loading causes continuous rubbing of crack interfaces which greatly reduces shear transfer mechanism. It is therefore conservatively assumed in this study that the analysis is conducted with shear transfer factor of zero for the case of moving loading. A customized FE program has been developed using the MATLAB software to accomodate such modifications. The developed procedure has been validated with the fatigue test of the 1/6.6-scale AASHTO bridge deck under the applications of both fixed-point repetitive loading and moving loading presented in the literature. Results are in good agreement both experimental vs. simulated S-N curves and observed vs. simulated crack patterns. Significant contribution of the developed procedure is a series of S-N relations which can now be simulated at any desired levels of cracking in addition to the experimentally derived S-N relation at the failure of the deck slab. This permits the systematic investigation of crack propagation or deterioration of RC bridge deck which is appeared to be useful information for highway agencies to prolong the life of their bridge decks.

Keywords : bridge deck, cracking, deterioration, fatigue, finite-element, moving truck, reinforced concrete
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