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Damage-Based Seismic Design and Evaluation of Reinforced Concrete Bridges

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Abstract : There has been a common trend worldwide in the seismic design and evaluation of bridges towards the performance-based method where the lateral displacement or the displacement ductility of bridge column is regarded as an important indicator for performance assessment. However, the seismic response of a bridge to an earthquake is a combined result of cyclic displacements and accumulated energy dissipation, causing damage to the bridge, and hence the lateral displacement (ductility) alone is insufficient to tell its actual seismic performance. This study aims to propose a damage-based seismic design and evaluation method for reinforced concrete bridges on the basis of the newly developed capacity-based inelastic displacement spectra. The capacity-based inelastic displacement spectra that comprise an inelastic displacement ratio spectrum and a corresponding damage state spectrum was constructed by using a series of nonlinear time history analyses and a versatile, smooth hysteresis model. The smooth model could take into account the effects of various design parameters of RC bridge columns and correlates the column's strength deterioration with the Park and Ang's damage index. It was proved that the damage index not only can be used to accurately predict the onset of strength deterioration, but also can be a good indicator for assessing the actual visible damage condition of column regardless of its loading history (i.e., similar damage index corresponds to similar actual damage condition for the same designed columns subjected to very different cyclic loading protocols as well as earthquake loading), providing a better insight into the seismic performance of bridges. Besides, the computed spectra show that the inelastic displacement ratio for far-field ground motions approximately conforms to the equal displacement rule when structural period is larger than around 0.8 s, but that for near-fault ground motions departs from the rule in the whole considered spectral regions. Furthermore, the near-fault ground motions would lead to significantly greater inelastic displacement ratio and damage index than far-field ground motions and most of the practical design scenarios cannot survive the considered near-fault ground motion when the strength reduction factor of bridge is not less than 5.0. Finally, the spectrum formula is presented as a function of structural period, strength reduction factor, and various column design parameters for far-field and near-fault ground motions by means of the regression analysis of the computed spectra. And based on the developed spectrum formula, a design example of a bridge is presented to illustrate the proposed damage-based seismic design and evaluation method where the damage state of the bridge is used as the performance objective.

Keywords : damage index, far-field, near-fault, reinforced concrete bridge, seismic design and evaluation
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