Fiber-Based Seismic Damage and Collapse Assessment of Reinforced Concrete Single-Column Pier-Supported Bridges Using Damage Indices

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Introduction
Near-fault earthquakes can have major effects on transportation systems due to the structural damage they impose on bridges. Therefore, it is imperative to assess the seismic damage of bridges appropriately. This research focuses on reinforced concrete (RC) bridges. An improved understanding of the deterioration on the RC bridge column's structural performance lends itself to better assessment procedures and retrofitting methods. This research advances the seismic assessment of RC single-column pier-supported bridges with flexural failure under near-fault ground motion by using ductility coefficient and damage indices.

Study Methods
The methodology consisted of modeling nonlinear fiber-based beam-column elements together with ductility coefficient and proposed damage indices to simulate the ductile responses and damage development process of RC bridge piers under earthquake loadings considering the global buckling, yielding, and fracture of longitudinal steel bars; examining the cracking and spalling of cover concrete; and analyzing the effects of bond-slip. Two innovative nonlinear fiber based damage finite element models (FEMs) were developed: Model 1 (excluding bond slip) and Model 2 (including bond-slip). Nonlinear static cyclic pushover analyses and nonlinear response history analyses were conducted. The simulation results were compared with available pseudo-dynamic testing results.

Findings
The results demonstrated that under near-fault ground motion, Model 2 (including bond-slip) underestimated the lateral stiffness, longitudinal reinforcing steel bar strain, and cover concrete strain. When compared with pseudo-dynamic testing results, Model 1 (excluding bond-slip) was found to be optimal to assess the seismic performance of RC single-column pier-supported bridges with flexural failure under near-fault ground motion. The
The proposed assessment method will avoid overconservative condition ratings of RC bridge columns. The proposed numerical FEMs improve the accuracy in the predictions of nonlinear flexural failure behaviors of RC single column pier-supported bridges during seismic events. The proposed damage indices can indicate the damage state at any stage and the gradual accumulation of damage in RC bridge piers, which are more convincing than most other indices in the literature. The proposed damage indices can reasonably reflect the damage states at the onset of spalling, significant spalling, bar buckling, and failure in accordance with the experimental results and as observed in the field during post-earthquake damages. The importance of the research results could change the way engineers identify and prioritize RC bridges for seismic retrofit and bridge maintenance. The proposed fiber-based nonlinear FEMs together with the use of ductility coefficients and proposed damage indices can also assist engineers and researchers in simulating the seismic behavior and assessing the damage state of RC bridge piers in a computationally effective manner.

Policy Recommendations
The research and discussions presented here provide insight into the key behavioral characteristics of seismic performance of RC single-column pier-supported bridges under near fault ground motion. The proposed fiber-based nonlinear FEMs together with the use of ductility coefficients and proposed damage indices can also assist engineers and researchers in simulating the seismic behavior and assessing the damage state of RC bridge piers in a computationally effective manner.

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