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

Yu-Fu Ko, PhD, PE
Jessica Gonzalez, EIT

Project 2241
August 2023

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 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.

The proposed fiber-based nonlinear FEMs and damage indices can assist engineers and researchers to identify and prioritize RC bridges for seismic retrofit and maintenance.

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.

About the Authors

Dr. Yu-Fu Ko, Ph.D., P.E. (Principal Investigator)

Dr. Yu-Fu Ko is a professor in the Department of Civil Engineering and Construction Engineering Management at California State University, Long Beach (CSULB). He received his M.S. and Ph.D. (outstanding Ph.D. award recipient) degrees in Civil Engineering, focusing on Structural Mechanics and Structural Engineering/ Dynamics from the University of California, Los Angeles. He is a registered Professional Civil Engineer in the state of California. Dr. Ko's areas of research interest include micromechanical damage mechanics modeling and associated applications, damage assessment and experimental mechanics of structural materials, nonlinear/ linear structural dynamic analysis of structures subjected to earthquake motions, finite element method code-based and performance-based structural design of structures, and seismic retrofitting of existing structures.

Jessica Gonzalez, EIT

Jessica Gonzalez is a research graduate assistant at California State University, Long Beach (CSULB) where she also received her B.S. in Civil Engineering. She is currently enrolled as a graduate student working towards her master's degree in Civil Engineering.

To Learn More

For more details about the study, download the full report at transweb.sjsu.edu/research/2241

MTI is a University Transportation Center sponsored by the U.S. Department of Transportation's Office of the Assistant Secretary for Research and Technology and by Caltrans. The Institute is located within San José State University's Lucas Graduate School of Business.