Center for Transportation Infrastructure and Safety

Adding Faculty in Transportation Areas - Year 2 & 3: Research Progress on Seismic Fragility Assessment of Bridge Structures

by

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16. Abstract

The NUTC provides funds to help departments build up their faculty in the transportation field over the next five years. Broad areas will be considered as listed in the UTC mission or other areas that relate to State Departments of Transportation and MoDOT in particular as stated in their goals, interests, and objectives.

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Adding Faculty in Transportation Areas - Year 2 & 3:

Research Progress on Seismic Fragility Assessment of Bridge Structures

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(Formerly employed at Missouri University of Science and Technology, 2008 ~ 2010)

For the two years (2008~2010) while Dr. Kwon was supported by NUTC Faculty Support Funds, he continued his research from his Ph.D. study and made a notable progress in seismic fragility assessment of bridge structures. During the period, two journal papers, one ACI Special Publication, and one conference proceeding were published. As a final report, the abstract of the publications are attached.

Kwon, O., Sextos, A.G., and Elnashai, A.S. (2009) "Seismic Fragility of a Bridge on Liquefaction Susceptible Soil," 10th International Conference on Structural Safety and Reliability, Sep 13-17.

This paper presents the development of fragility curves for a bridge on liquefaction susceptible soil layers. A refined computational scheme is implemented for this purpose involving both a three-dimensional inelastic multi-platform model and a simplified nonlinear model calibrated with the three-dimensional model. Artificial and natural, near- and far-field, earthquake records are used to account for input motion uncertainty. Both uniform and non-uniform soil conditions along the bridge length are assumed to investigate the effect of incoherent input ground motion. Global damage indices which can account for different soil, foundation and superstructure failure modes are proposed. The results of the study indicate that the inelastic dynamic response and the subsequent damage of a soil-structure-interacting system may be significantly affected by the liquefaction of soil layers. Moreover, it is shown that the spatial extent of liquefaction is a parameter that has to be considered as a source of uncertainties in input ground motion.

Mwafy, A., **Kwon, O.**, and Elnashai, A.S. (2010). "Seismic Assessment of an Existing Non-Seismically Designed Major Bridge-Abutment-Foundation System," Engineering Structures, Vol. 32, No. 8, p2192-2209.

A comprehensive study carried out to assess the seismic response of a 59-span bridge using a refined inelastic modeling approach and considering Soil-Structure Interaction (SSI) is summarized in this paper. The focus is on describing the methodology adopted to idealize the bridge and its foundation system, while only highlights from the extensive elastic and inelastic analyses are presented. The bridge represents a typical case of vulnerable complex bridges since it was built in the early seventies with minimal seismic design requirements at a distance of about 5 km from a major fault. The SSI analysis is significant in this study due to the length of the bridge, the massive and stiff foundation, and the relatively soft deep soil of the site. A series of three-dimensional dynamic response simulations of the entire bridge are conducted using several analysis tools to verify the developed analytical models. The performance-based assessment study employs 144 site-specific input ground motions representing three seismic scenarios, corresponding to 500, 1000 and 2500 years return periods, to identify areas of vulnerability in the 2164-meter bridge at various hazard levels. It is concluded that the seismic response of the bridge at the 500 years ground motions does not meet today’s standards, while the demands under the effect of the

1000 years ground motions almost exceed the capacity of most bridge components. The demands significantly increase under the effect of the 2500 years earthquake scenario and considerably exceed the collapse limit states. The results clearly reflect the benefit of retrofitting different bridge components to mitigate anticipated seismic risk. The presented assessment study contributes to improve public safety by exploiting the most recent research outcomes in predicting the seismic response of complex highway bridges, which are essential for developing reliable and cost-effective retrofit strategies.

Kwon, O. and Elnashai, A. S. (2010). "Seismic fragility analysis of a bridge in Central and Eastern United States," Structure and Infrastructure Engineering, Vol 6, No. 1-2.

Seismic fragility relationships, including soil-structure interaction (SSI) of a common bridge configuration in the Central and Eastern United States, are derived in this study. Four different modeling methods are adopted to represent abutments and foundations of the bridge, namely, (a) fixed abutments and foundations, (b) lumped springs developed from conventional pile analysis of piles at abutments and foundations, (c) lumped springs developed from three-dimensional finite element analysis of abutments and foundations, and (d) three-dimensional finite element models. Seismic demand on the bridge components is estimated from inelastic response history analysis of the soil-structure interacting systems. Finally, fragility curves of the components and bridge system are derived. The four different SSI approaches result in different seismic fragility. The implication of this work is that careful consideration is necessary when selecting an analytical representation of a soil and foundation system to obtain reliable earthquake impact assessment. In addition, it is found that abutment bearings are the most critical components for the studied bridge configuration.

Kwon, O., Mwafy, A., and Elnashai, A.S. (2010). "Analytical Assessment of Seismic Performance Evaluation Procedures for Bridges," ACI Special Publication, SP271-03, p45-62.

The multi-limit state seismic design and evaluation procedure allows structures to satisfy different performance criteria against different levels of seismic excitation. To achieve the simultaneous satisfaction of the multi-level design approach, it is essential to employ accurate analysis procedures which can be consistently applied to various levels of ground motions. In this study, several analytical evaluation procedures are compared via the application of the methods to two bridge structures. In the first application, a bridge considered typical of the inventory in the Central and Eastern United States is analyzed. Inelastic Response History Analysis (IRHA), two Capacity Spectrum Methods (CSMs), two Elastic Response History Analysis (ERHA) approaches with different stiffness approximation, and SDOF simulations are conducted. The second and more complex application, a 59-span irregular bridge crossing the Mississippi River is also analyzed in the elastic and inelastic ranges. Results from IRHA and simplified analysis procedures are compared to assess their applicability and limitations. It is concluded that the approximate methods have limited applicability, which depends on several parameters including intensity of ground motions and characteristics of bridge structures. The importance of inelastic and dynamic analysis in seismic assessment is emphasized, while cases where the simplified procedures yield acceptable response are presented.