LIQUEFACTION-DEPENDENT FRAGILITY RELATIONSHIPS OF COMPLEX BRIDGE-FOUNDATION-SOIL SYSTEMS

Oh-Sung Kwon [1], Anastasios Sextos [2] and Amr S. Elnashai [3]

[1] *Post-Doctoral Research Associate, Department of Civil and Environmental Engineering, University of Illinois at Urbana-Champaign, Urbana, IL, USA, E-mail: okwon2@uiuc.edu*

[2] *Lecturer, Civil Engineering Department, Aristotle University Thessaloniki, Greece*

[3] *Bill and Elaine Hall Endowed Professor, Director of the Mid-America Earthquake Centre, University of Illinois at Urbana-Champaign, Urbana, IL,, USA*

ABSTRACT: This paper presents the development of liquefaction-sensitive fragility curves for a bridge-foundation-soil system. A refined computational scheme is implemented for this purpose involving both a 3-dimentional inelastic multi-platform model and an appropriately calibrated simplified model supported on nonlinear foundation springs. Artificial and natural, near- and far-field, earthquake records are used to account for input motion uncertainty while uniform and non-uniform soil conditions along the bridge length are assumed for the central pier and the abutments of the bridge. The results of the study indicate that the inelastic dynamic response of such systems maybe significantly affected by the liquefaction of upper soil layers. Moreover, it is shown that the spatial extent of liquefaction is an additional parameter that has to be considered as an important source of ground motion and ductility demand variation.

1. INTRODUCTION

The impact of an earthquake on the performance of a highway transportation network depends on the extent of damage sustained by its individual components, particularly bridges. This critical seismic vulnerability of bridges is often described by fragility curves which express the conditional probability that a bridge will exhibit certain damage states, subject to the intensity of the earthquake. The complexity and computational cost of modeling the inelastic response of the superstructure hampers the development of equally refined finite element models to consider the role played by the foundation and the supporting soil in terms of incident ground motion modification, local (at each foundation) radiation and material damping as well as changes in structural dynamic characteristics. Due to this complexity, the computationally intensive case of soil liquefaction susceptibility at certain depths below the bridge foundation and its overall effect on the dynamic response of soil-foundation-superstructure systems is commonly ignored. The scope of this paper therefore is to investigate the importance of considering the liquefaction potential of soils in the vulnerability analysis process for bridges supported on loose-to-moderate saturated cohesionless soils. Along these lines, the well-studied (Zhang and Makris, 2001; Kwon, 2007) Meloland Road Overcorssing (MRO) bridge is adopted for the current study. The bridge was built in 1971 and is located over Interstate 8 approximately 0.5 km from the fault rupture of the 1979 Imperial Valley earthquake. The bridge consists of two spans of pre-stressed box-girder decks monolithically connected to the center pier. The abutments are placed on fill. Seven piles support each abutment. Each side of abutment has 5.9 m of wing-wall. The pier at the center of the bridge has a diameter of 1.5 m and is 7.9 m is high from the top of piles. A total of 18 longitudinal reinforcement bars are used in the pier, the foundations of which are supported on 25 timber piles spaced at 0.91 m. The procedure of earthquake selection, site response and liquefaction consideration, analysis environment and vulnerability assessment is presented below.

2. GENERATION AND SELECTION OF EARTHQUAKE GROUND MOTIONS

2.1 Generation of artificial ground motions

As a means to consider and quantify the inherent uncertainty of earthquake ground motion, six levels of ground motion intensity are established for the fragility analysis, i.e., 0.05g, 0.1g, 0.2g, 0.3g, 0.4g, 0.5g, all assumed at the bedrock level. It is worth noting that in contrast to a typical vulnerability assessment process, it is necessary to select (or generate) intensity compatible