Seismic response of bridges with massive foundations

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Abstract

The dynamic response of vehicular overpasses with massive foundations built in highly populated earthquake prone regions is studied, to assess the massive foundation potential of being a technically sound mean to reduce the structural response during major earthquakes. The study consists on numerical simulations using 3-D finite element models. Two typical supports of a major 23 km long vehicular overpass currently under construction in the north east part of Mexico City valley were considered in this research. Initially, a conventional raft foundation structurally connected to four precast closed-end concrete piles was considered. Then, a massive foundation of variable depth was assumed. Lateral dynamic stiffness and damping were computed for all cases in order to evaluate the effect of the massive foundation. Sets of 3-D finite element models were developed and the response of the systems was evaluated for a typical seismic scenario such as that prevailing at the zone, assuming a potential $M_w = 8.1$ seismic event. Important attenuations of about 30% to 50% at the upper deck spectral accelerations and of 17% to 30% in displacements were achieved with the massive soil improvement, for the case analyzed. Thus, the massive foundations seem to be a convenient alternative to reduce the overall structural seismic response.

1 INTRODUCTION

Modern design of bridges and overpasses, and seismic retrofit of existing ones, has moved towards performance based evaluations (e.g. Zhang & Makris, 2001). These evaluations usually include various seismic scenarios expressed in terms of uniform hazard spectra for a given return period and time domain analyses to account for nonlinearities in the soil-foundation-structure system (e.g. Maheshwari et al., 2004). In particular, in highly populated areas, such a Mexico City, restrictions regarding allowable displacements both at the foundation and upper deck becomes more restrictive to avoid damage not only at the upper deck, caused by to relative movements of the bridge supports, but also in nearby structures through waves radiating away from their foundation system which can interact with incoming wave patters generated during a major earthquake (e.g. Groby et al., 2005) leading to beneficial or detrimental interaction (e.g. Mylonakis & Gazetas, 2000).

This paper presents the seismic performance evaluation of massive foundations used as an alternative to positively modify the dynamic response of an urban overpass currently under construction in Mexico City. Sets of 3-D finite element models were developed using the program SASSI2000. Initially, a conventional raft foundation structurally tie to four precast closed end concrete piles was considered. Then, a massive foundation of variable depth was proposed as a technically sound alternative that presents interesting advantages over the conventional design. The systems responses were computed for a typical seismic scenario such as that recommended by the Mexico City Building code, which assumes a 8.1 M_w event.

2 SEISMIC PERFORMANCE EVALUATION OF A MASSIVE FOUNDATION

To study the effect that a massive foundation can have on the seismic response of a typical support of an urban overpass currently under construction in Mexico City, a numerical study was conducted, considering the configuration presented in Figure 1. As depicted in this figure, the overpass is comprised by an upper deck resting on top of central and support beams that are structurally tied to the columns, which, in turn, are monolithically attached to a rectangular foundation. The upper part of this foundation consists of a reinforced 1.7 m mat covered by concrete filling. This mat rests on top of a reinforced 0.25 m concrete slab, which, in turn, is underlain by a 3.6 by 4.6 m^2 massive un-reinforced concrete block, of variable depth. The mat foundation is connected to four 0.8 m diameter, cast-in-place, concrete piles. Initially, a conventional mat foundation structurally tied to the four piles was considered as a potential foundation solution. Afterwards, seeking reducing the seismic response of both foundation and structure, a massive foundation of variable thickness was