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Effect of soil structure interaction on the dynamic responses of base isolated bridges and comparison to experimental results

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ABSTRACT

In this paper, the effect of soil structure interaction and base isolation on the dynamic characteristics of an instrumented bridge is examined using transfer functions and measured motions in the frequency domain. A three dimensional structural model in the frequency domain which accounts for continuous mass distribution along each member and the effect of axial forces as well as rotary inertia is adopted. The dynamic stiffness of pile foundations and surface mat foundation underneath piers, determined separately using appropriate numerical methods, is incorporated into the structural model and the global stiffness matrix. Results are obtained for models of a bridge both without and with isolation pads for various values of the equivalent shear stiffness. This allows one comparing the values of the predominant frequencies and the dynamic amplification of the motions over the frequency range of interests. The transfer functions are also obtained at the bottom of the piers to evaluate the impact and importance of soil structure interaction effect on the dynamic behavior of the system. Results are then compared to the power spectra of the motions recorded at various points of an instrumented bridge (the base, the top of the pier, and the same location on the deck) from an actual earthquake. The method and results can explain many of the observed behavior very well although there are still some points that cannot be resolved due to lack of accurate input information and limitation of the method.

1. Introduction

Base isolation has been extensively used for bridges and buildings in the many countries worldwide, with excellent performances under strong ground motions. The application to bridges was a logical step, because bridges already have, in most cases, horizontal stiffness bearings located in between the desk and the piers that allow thermal expansion of the deck in the horizontal direction. The use of multi-layer elastomeric bearings for seismic protection was thus a natural extension of the rubber pads used for thermal expansion. A large number of studies have been conducted over the last a couple of decades to investigate the effectiveness of various types of isolation pads and the effect of their properties on the seismic response of bridges [1–7]. Recent research efforts include evaluation of hybrid isolation systems [8], comparison of performances of different isolation systems [9], performances of isolates structures subject to extreme seismic events [10], etc. In this paper, the application of base isolators to a real and specific structure, the Marga-Marga Bridge, near Viña del Mar, in the central coastal region of Chile, is evaluated. The effect of pile foundations and surface mat foundations underneath the piers (effect of soil structure interaction) on the shift of the natural frequencies of the structure and the change of dynamic amplification factors over the frequency range of interest, is considered and evaluated in this research as well. The bridge, built in 1996, was instrumented with 21 accelerometers distributed over the deck, along one pier, and in the free field. A number of earthquakes have been recorded by these instruments, including one happened on Feb 27, 2010, with a magnitude of 8.8, peak ground acceleration in the free field of about 0.35 g in the longitudinal direction of the bridge, over 0.34 g in the transverse direction and about 0.26 g vertically. The existence of these data and results of ambient vibration tests conducted immediately after completion of the construction provide a unique opportunity to evaluate the accuracy of different analytical models of the structure and our capacity to predict the observed behavior. This research is based on a new structural model, therefore provided a different perspective as a continuing effort interpreting the seismic behavior of the bridge.

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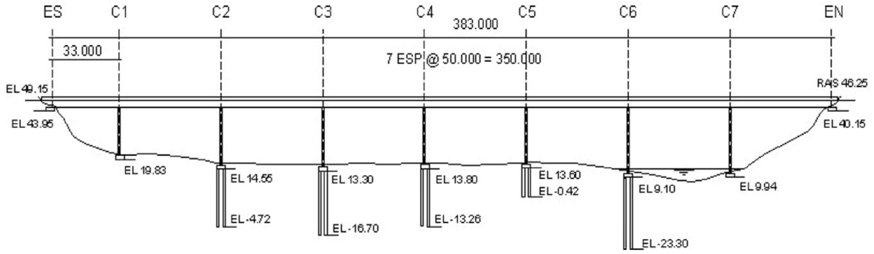
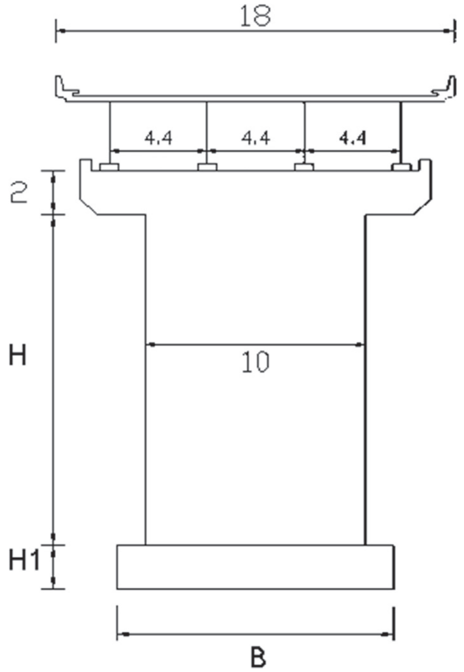


Fig. 1. Structural overview of Marga-Marga Bridge.



Pier #	H (m)	H1 (m)	B (m)
1	21.865	1.5	10.5
2	26.317	2.0	13.5
3	27.138	2.0	13.5
4	26.260	2.0	13.5
5	26.082	2.0	13.5
6	30.154	2.0	13.5
7	30.086	1.5	10.5

Fig. 2. Transverse view of pier and its dimensions.

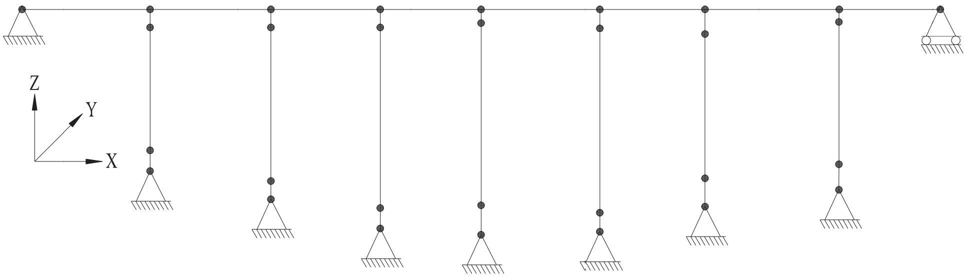


Fig. 3. Structural Model (without rubber pads).

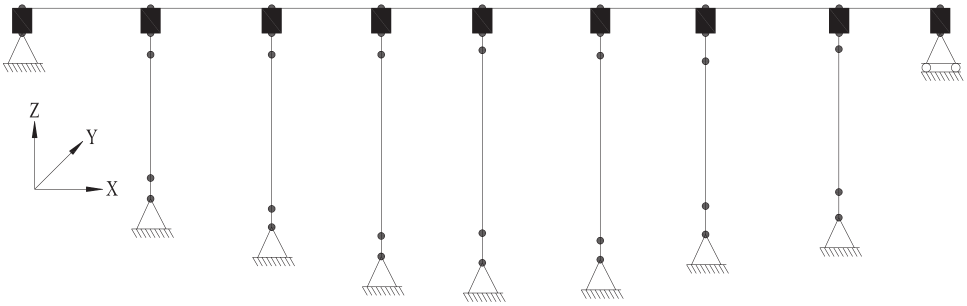


Fig. 4. Structural Model (with rubber pads, free deck).