Experimental Rocking Response Of Direct Foundations Of Bridges

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1. INTRODUCTION

In the conventional design, uplift of direct bridge foundations from the underlying ground is minimized to prevent overturning of the pier. However, rocking of piers exhibits a clear seismic isolation effect that leads to lower ductility demand at the pier. In this study the rocking response of piers is investigated through experimental response of models representing the footing-pier-deck system and analytical simulation of the experimental data.

2. EXPERIMENTAL MODEL AND TEST PROCEDURE

The tests were conducted at the Earthquake Engineering Laboratory in Tokyo Institute of Technology, using a one dimensional shake table. A model idealizing the bridge pier consisted of steel top plates (deck), a column (pier), bottom plates (footing), and a rubber block (ground) as shown in Fig. 1. The column was 840mm tall, 100mm wide and 6mm thick. The deck mass was 8.5kg. The footing with a section of 300mm and a thickness of 30mm was designed so that the deck displacement due to the rocking response of the footing was in the range of 30-60% of the total deck displacement. The rubber block had a section of 500mm, a thickness of 100mm, and a shear modulus of 0.6 MPa. The rubber block was laterally restrained to prevent shear deformation during the excitation.

When the model is excited, various modes of structural response occur. However by restricting sway motion of the footing, only rocking oscillation was modeled here. Both free oscillation tests and seismic excitation tests were conducted.

3. SHAKING TABLE TEST

The ground motions recorded at Japan Meteorological Agency Kobe Observatory (JMA Kobe) during the Kobe, Japan earthquake in 1995, near Bolu viaduct during the Duzce, Turkey earthquake in 1999 and Ojiya (NIG019EW) during the Niigata-chuetsu, Japan earthquake in 2004 were used. Intensity of the ground motions was scaled down to 10% and 25% of the original so that the response amplitude of the model reduced to suitable levels.

Figs. 2 and 3 show the response acceleration and displacement under 10% and 25% intensity levels of the original JMA record respectively. The analytical responses, which will be described later, are presented here for comparison. Uplift of the footing from the underlying ground (rubber block) occurred under 25% JMA Kobe record but did not occur under 10% JMA Kobe record.

4. ANALYTICAL SIMULATION

The column was idealized with linear beam elements, the footing with linear beam elements of sufficiently high stiffness and the deck mass was lumped at the top of the column, as shown in Fig. 4. The nonlinear contact between the footing and the ground was idealized by contact spring elements, which resisted compression but not tension.

As shown in Fig. 2 the analytical response correlates well the experimental response when uplift of the footing does not take place. As shown in Fig. 3 under 25% JMA Kobe record the computed response represents satisfyingly the overall response of the model when the footing uplifts. However detailed rocking response of the footing needs further improvement although the peak responses are quite close to the experimental results. Several improvements in analysis can be performed. The first is the dependence of damping ratio on the amplitude of uplift. It is obvious from the free oscillation test that the damping ratio of the rocking response decreases as the uplift increases. The second is the radiation energy dissipation from the footing to the ground (rubber block), which is not taken into account in analysis.

5. CONCLUSIONS

Based on the experimental and analytical resulted presented herein, the following conclusions may be deduced:

1) The peculiar rocking response of the bridge model was obtained from the free oscillation and shake table tests. The experimental data provide insight on the effect of uplifts and contacts of the footing.

Keywords: Seismic design, seismic isolation, bridge, foundation

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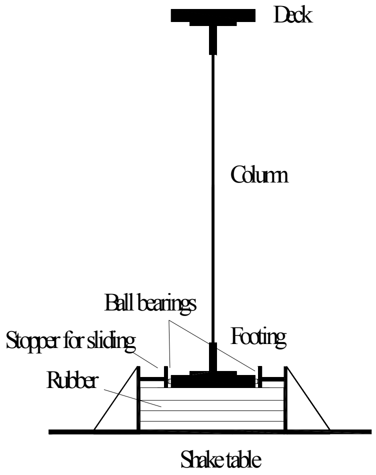

Fig.1 Bridge model

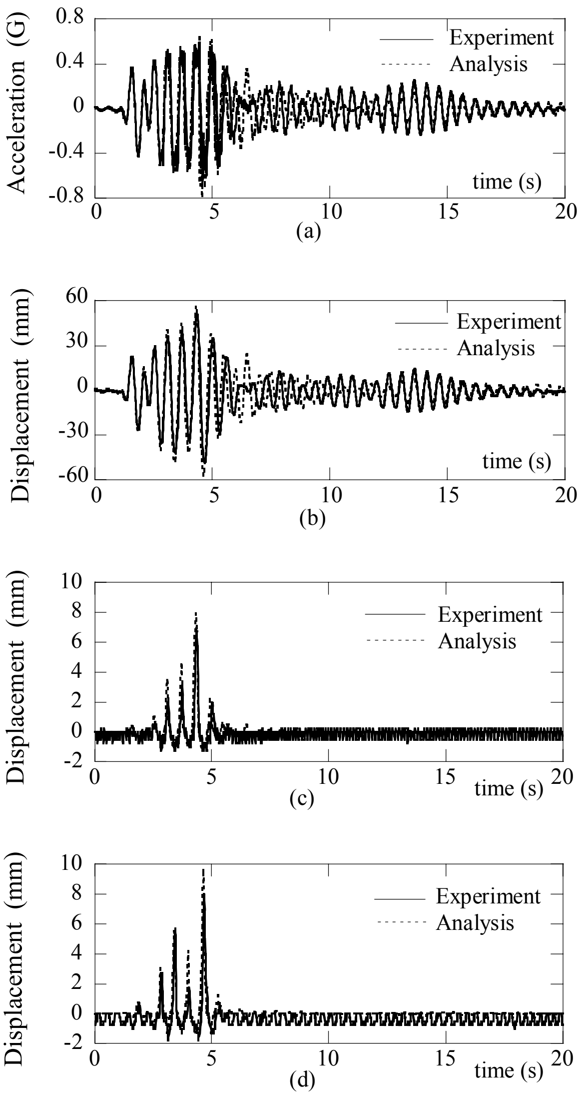

Fig.3 Correlation on experimental response under 25% JMA Kobe record: (a) horizontal deck acceleration, (b) horizontal deck displacement, (c) vertical footing displacement at the left edge and (d) vertical footing displacement at the right edge

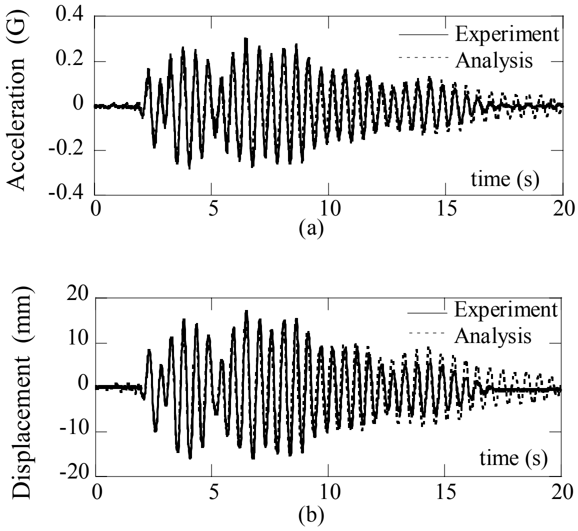

Fig.2 Correlation on the experimental response under 10% JMA Kobe record: (a) horizontal deck acceleration and (b) horizontal deck displacement

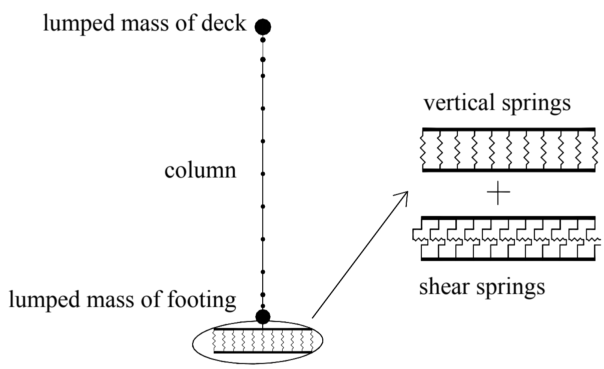

Fig.4 Model used for the analysis

2) An analytical model of the model bridge was developed using contact spring elements with nonlinear stiffness in the separation and contact. The analytical model provides good correlation on the experimental response.

3) The analytical model requires improvement on the idealization of damping characteristics of the rocking foundation.

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References:

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