Shaking Table Test of a Seismically Isolated Bridge Under Horizontal and Vertical Motions

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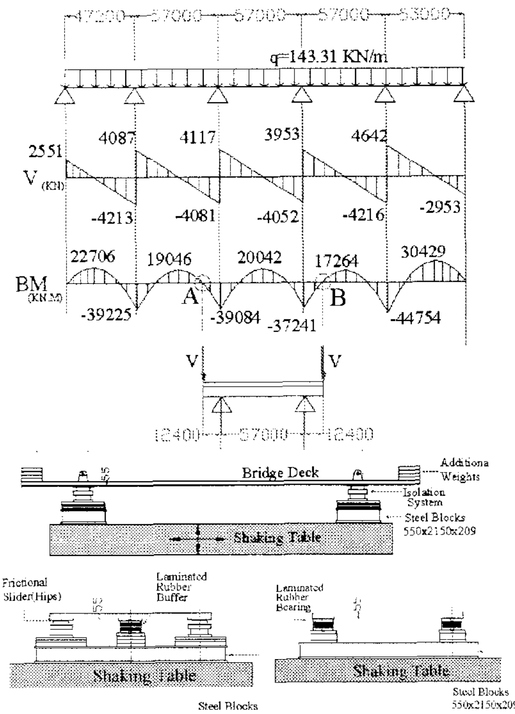
Introduction

This paper describes earthquake simulator test of scaled model of a part of a highway bridge seismically isolated respectively by five types of isolation systems. Series of shaking table tests were performed on the seismically isolated bridge model for four real and three standard earthquakes of isolation systems in turn, to obtain direct comparison of performance of the isolation systems and also to study the effect of vertical component of excitation on their behaviour. Response the experiments are compared with numerical simulation.

Shaking Table Test

The structure considered in the study is a five-span steel highway bridge supported by reinforced concrete piers. Total length of the bridge is 271.2m. Figure 1 shows design procedure of test model of this bridge. First, the real size bridge was analyzed for gravity loads and the bending moment and shear force diagram for the bridge deck are plotted. As shown in the figure, A and B are points of contra flexure where only shear force is acting. In fact the portion of the bridge between these two points was taken as test model to simulate the behaviour of proto type bridge structure. The geometrical scale for the model was selected considering the limitations of the shaking table and its value for the study was taken as 1:15.45. The bridge deck was simulated by steel plate. To simulate the shear force acting at the points of contra flexure, additional weight in the form of steel plates were put at both the ends.



(a) System I,II,III (b)System IV,V

Fig. 1- **Design of Test Model**

Five types of isolation systems were used in the earthquake simulator tests. As shown in Fig.1, isolation system I and II comprise of slider and natural rubber buffers. Isolation system III also has same configuration but buffers used super high damping rubber. Isolation system IV and V comprise of two laminated rubber bearings at each support. Rubber bearings in isolation system IV were made using natural rubber and for isolation V from super high damping rubber. Design stiffness of rubber bearings /buffers for all isolation systems except system II, corresponds to target period of 0.33 second. In system II, combination of slider and rubber had effective period, at design displacement, of 0.33 sec.

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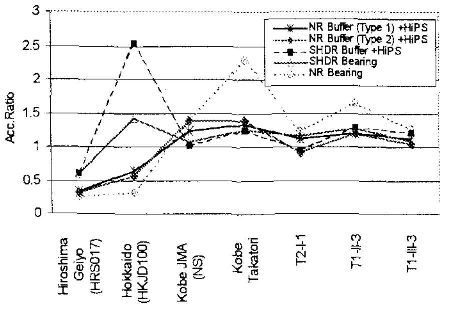

Fig2: **Amplification ratio of isolation systems**

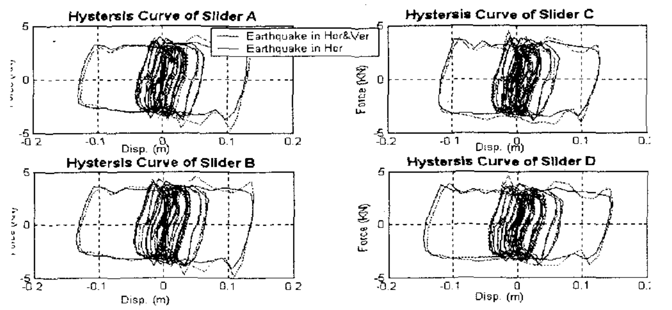

Fig3: **Hysteresis Behaviour of Sliders in Isolation System I under Takatori earthquake**

Discussion of Test Results

Ratio of peak response acceleration to peak shaking table acceleration (amplification ratio) was obtained for different isolation systems and earthquake motions and are illustrated in Fig 2. Amplification ratio for isolation system I and II increases from less than 0.6 in high frequency earthquake like Geiyo and Hokkaido until 1.37 for long period motion of Kobe (Takatori). On the other hand, this ratio for isolation system III and V is considerably high in Hokkaido earthquake and for Geiyo too, it is more than other low damping isolation systems. But these systems have lower acceleration response for long period motions. Result of this tests exhibited that the maximum relative displacement of the deck top with respect to shaking table is least for isolation system III and V. This shows efficiency of super high damping systems to reduce displacement at isolation level. Dynamic response of the test model isolated respectively with different isolation systems were obtained under simultaneous vertical and horizontal excitations. Fig 3 shows hysteresis behavior of four sliders used in isolation system I under Takatori earthquake with and without vertical component. Other response parameters like acceleration and displacement also didn't undergo any significant change due to presence of vertical component

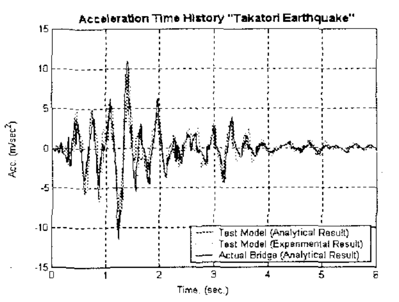

Fig 4. **Comparison of experiment and analytical results**

Analytical Prediction of Response

In this study numerical analysis was carried out in two parts namely (i) the test model and (ii) proto type bridge. In Fig. 4, acceleration of deck for Kobe (Takatori) computed analytically is compared with experimental results. This figure shows good compatibility between experimental and analytical response. It can be observed that simple analytical models that doesn't considered the behaviour of sliders under variable vertical loads can be used to obtain structural response of full-scale isolated bridge with sufficient accuracy.

Conclusions

The results show that seismic behaviour of resilient sliding isolators is almost same under earthquake excitation with and without vertical components. In addition, isolators with natural rubber have good performance in high frequency earthquake while isolation system with supper high damping performs better for low frequency earthquake.

Reference

1. Nakajima K., Iemura H., Takahashi Y., Ogawa K.(2000) "Pseudo Dynamic Tests and Implementation of Sliding Bridge Isolators with Vertical Motion" Proc. of 12th World Conference on Earthquake Engineering New Zealand, Paper number 1365