# Seismic Performance of Isolation Systems in Highway Bridge with Flexible Girder under Horizontal and Vertical Motion

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## Introduction

This paper describes earthquake simulation test of scaled model of a part of a highway bridge, which is seismically isolated by five types of isolation systems. Series of shaking table tests were performed on the seismically isolated bridge models for four real and three standard earthquakes, to obtain direct comparison of performance of the isolation systems. Effect of vertical component of excitation on behaviour of isolation system that is used in the bridge with flexible girder is also investigated. At the end, partitioning of input energy is discussed for different isolation systems.

## 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. For design of test model, the real size bridge was analyzed for gravity loads and the bending moment and shear force diagram for the bridge deck were plotted. The part of the bridge between two contra-flexure points in moment diagram is considered to simulate the behavior of proto type structure. In these points, moment force under gravity load is zero and only shear force is acting. 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. Additional weights in the form of steel plates were put at both the ends to simulate the shear force acting at the points of contra flexure (see Fig. 1). Five types of isolation systems were used in the earthquake simulator tests. As shown in Fig.2, isolation systems I and II consist of slider and natural rubber buffer. Isolation system III also has same configuration but buffer super high damping rubber bearing is used. Isolation system IV and V comprise of two laminated rubber bearing in 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 (HiPS) and rubber had effective period, at design displacement, of 0.33 second.

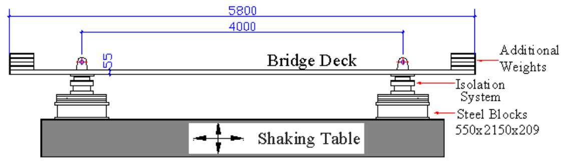
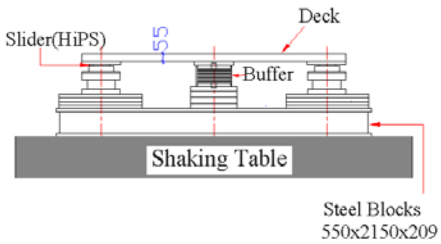
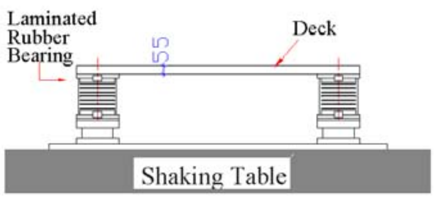



Fig.1 **Test Model (Longitude View)**




a) Isolation System I, II and III




b) Isolation System IV and V

**Fig.2 Placement of Isolators for Different Isolation System**

## Acceleration and Displacement Response

Ratio of peak response acceleration to peak shaking table acceleration (amplification ratio) was obtained for different

Bridge, Shaking Table, Seismic Isolation, Resilient Sliding.

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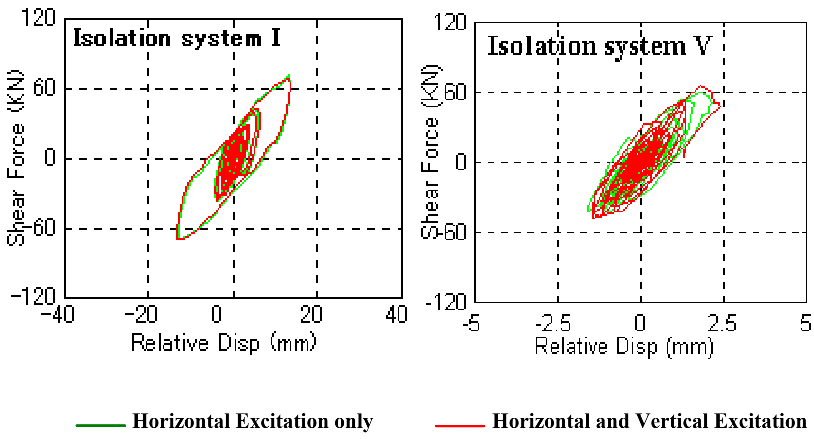


Fig.3 **Comparison of Hysteretic Behaviour of Isolation System I, V under Horizontal and Vertical Acceleration of Takatori Earthquake**

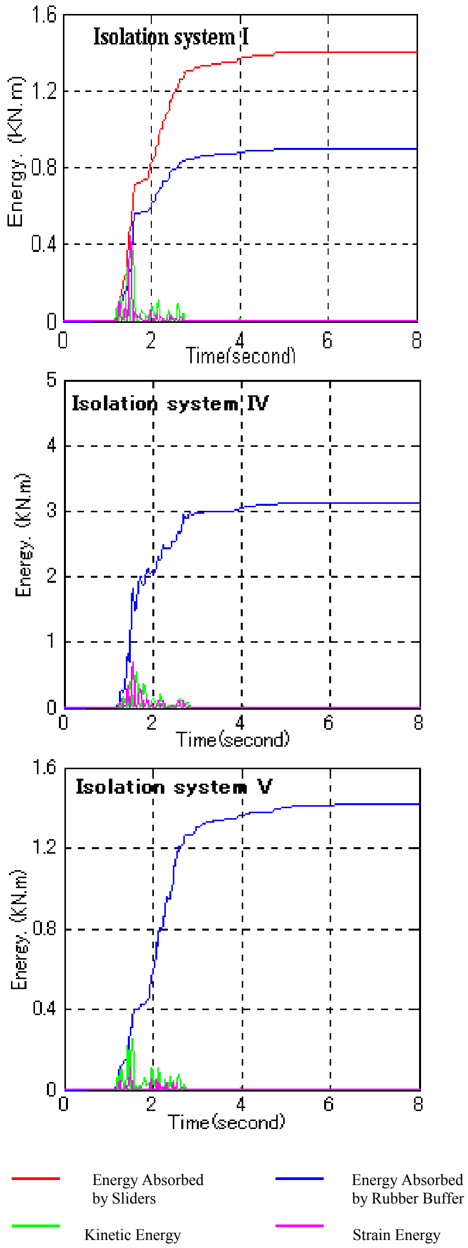


Fig.4 **Partitioning of Input Energy for Kobe (JMA) Earthquake**

isolation systems and earthquake motions. Amplification ratio for isolation system I and II increases from less than 0.6 in high frequency earthquake like Geiyo and 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 under Hokkaido earthquake that has higher frequency content. Amplification ratio for these two systems under Geiyo motion is more than other low damping isolation systems. But these systems have lower acceleration response for earthquakes with longer period of contents. Result of this tests exhibited that the maximum relative displacement of the deck top with respect to shaking table is lowest for isolation system III and V. This shows efficiency of super high damping systems to reduce displacement at the isolation level.

**Effect of Vertical Motion**

To study effect of vertical motion, dynamic response of the test model was obtained for simultaneous vertical and horizontal excitations. Fig 3 shows hysteretic behavior of two isolation systems I and V under Takatori earthquake with and without vertical component. This figure and same results for other isolation systems confirm that response parameters like acceleration and displacement do not have any significant change due to presence of vertical component.

**Partitioning of Energy**

Partitioning of input energy for isolation system I, IV and V under Kobe (JMA) earthquake is illustrated in Figure 4. From this figure can be understood that total (input) energy in isolation I and V is less than isolation IV. Results of test show that for isolation system I and II generally the energy absorbed by sliders is about two time of energy absorbed by rubber buffers. In isolation system III, super high damping rubber buffers absorbed more energy than sliders, that indicates contribution of sliders in absorbing energy was less as compared to isolation system I and II. Results confirms that dynamic energy (kinetic energy + strain energy) under Kobe (Takatori) and Kobe (JMA) in isolation system III and V is considerable less than other system.

**Reference**

1. Nakajima K., Iemura H., Takahashi Y. and 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