ANL/RE/CP--90063

CONF-9606206--1

MITIGATION OF EARTHQUAKE HAZARDS USING SEISMIC ISOLATION SYSTEMS

Chung-Yi Wang
Argonne National Laboratory
9700 S. Cass Avenue
Argonne, IL 60439 USA

ABSTRACT

This paper describes mitigation of earthquake hazards using seismic base isolation systems. A numerical algorithm for analyzing system response of base-isolated structures with laminated elastomer bearings is briefly described. Seismic response analyses of both base-isolated and unisolated buildings under earthquakes #42 and #44 are performed and the results are compared to illustrate the mitigating effect of base-isolated systems.

INTRODUCTION

Seismic isolation represents a significant engineering breakthrough in structural designs due to its capabilities of protecting structures and their contents from earthquake damage. One main concept in base isolation is to reduce the fundamental frequency of structural vibration to a value lower than the energy-containing frequencies of earthquake ground motions. The other purpose of an isolation system is to provide a mechanism for energy dissipation and to reduce the transmitted accelerations to the superstructure. In other words, by using base-isolation devices at the foundation of a structure, the structure is essentially decoupled from ground motion during earthquakes.

Recently, seismic isolation has become extremely attractive in seismically active regions such as Japan and the West Coast, USA, especially after China's Tang-san and Japan's Kobe earthquakes. Structures that have been incorporated with base isolation systems include bridges, office buildings, hospitals, computer and communication centers, and nuclear facilities. Presently, Japan is the leading country in rapidly adopting the seismic isolation technology. In fact, up to now there are about seventy buildings in the Tokyo metropolitan area that have been installed with different types of isolation systems.

One type of seismic isolation system currently being widely used is the laminated elastomer bearing. It uses high-damping elastomer layered between metallic plates (shims). The design is very attractive because it combines the restoring and dissipating functions of an isolator into one compact, maintenance-free unit.

SYSTEM ANALYSIS PROGRAM

As part of the analytical development, a 3-D computer program, Seismic Isolation System Evaluation Code (SISEC) [1], was developed at Argonne National Laboratory (ANL). The aim of this code is to determine the desired global response characteristics of the isolators and isolated structures with surrounding soil under earthquake conditions.

In order to simulate the bearing behavior under earthquakes, a nonlinear viscoelastic constitutive model is utilized. The characteristic behaviors of the isolation bearing, such as the variation of shear modulus and material damping with the change of maximum shear deformation, are captured quite closely by the formulation.

Since structural response also depends significantly upon the input acceleration time histories acting on the foundation level, a soil analysis is performed to evaluate the foundation input motion as well as the stiffness and damping of the soil deposits. The analysis further accounts for isolator nonlinearities, foundation embedment, and inertia and kinematic interaction between the soil and structure.

TEST FACILITY

An international cooperation program was initiated in September, 1988 by ANL of the USA and Shimizu Corporation of Japan for studying the response of isolated structures under actual earthquakes. Within the program agreement, Shimizu provided their test facility and earthquake data collection while ANL performed most of the analytical simulations utilizing the 3-D computer program, SISEC.

To study the seismic response, two test buildings, one conventionally designed and the other base-isolated, were constructed side-by-side at Tohoku University in Sendai, which is located in the northern part of Japan. The test buildings consist of two full-size, three-story reinforced concrete structures as shown in Fig. 1. The dimensions and construction details of the superstructure were exactly the same for both buildings. The test buildings were completed in May 1986.

The isolation system of the base isolated building consists of six identical bearings designed with a medium shape factor and molded with a high damping, low shear modulus rubber. These bearings are laminated composites with 12 layers of rubber and 11 layers of steel plates (shims).

NUMERICAL SIMULATION

Three-dimensional frame models are used in numerical simulations for both convention and base-isolated buildings. In the analyses, beams, columns, and girders are all modeled by 3-D beam elements with six degrees of freedom per node to account for the translations and rotations generated from seismic events. In simulating the responses of ordinary and isolated buildings, the X (transverse) and Y (longitudinal) direction accelerations observed at the center of the basement of the isolated building are utilized as input to the basement structural nodes. the computed accelerations are then compared with the recorded observations.

For simplicity, comparison of observed and calculated peak accelerations at the first floor and the roof level of both the ordinary and isolated buildings are given in Table 1. As seen from this table, the maximum accelerations obtained from recorded data and SISEC simulations agree satisfactorily with each other.

To study the effectiveness of the base-isolation system, Table 1 further lists the acceleration ratio, i.e., the acceleration of the isolated building A_I divided by the acceleration of the ordinary building A_o. The advantage of the base isolation system in mitigating the seismic response is quite evident. For earthquake #42, the simulated transverse acceleration at the first floor of the isolation building is about 54% of the ordinary building, whereas in the recorded data it is about 66%. At the roof level, the advantage of base isolation becomes more pronounced. The analytical results indicate that, in the transverse and longitudinal directions, the accelerations of the isolated building are about 23% and 27% of the ordinary building. In the observation data the acceleration ratios are about 26% and 33%. This further demonstrates that as the floor elevation increases the degree of acceleration reduction also increases.

To illustrate the effect of the isolation system, Fig. 2 compares both observed and calculated accelerations in the transverse direction at the roof level for earthquake #44. As can be seen, the accelerations are greatly reduced for the isolated building.

CONCLUDING REMARKS

From the results of this study it can be concluded that the seismic isolation system is very effective for reducing the earthquake hazard.

ACKNOWLEDGMENT

This work was supported by the U.S. National Science Foundation, Agreement No. CES-8800871.

REFERENCES

Wang, C. Y., et al., 1991, “Seismic Response Analyses of Base Isolated Structures with High Damping Elastomeric Bearings,” PVP-Vol. 220, Book No. H00647, San Diego, CA, pp. 15-22.

Table 1. Comparison of Accelerations of Isolated and Ordinary Buildings

			Ordinary Bldg., A_o		Isol. Bldg., A_I		Accel. Ratio, A_I/A_o	
Eq. No.	Loc.	Dir.	Obs. (gal)	Cal. (gal)	Obs. (gal)	Cal. (gal)	Obs.	Cal.
42	Roof	T	7.18	6.96	1.87	1.59	0.26	0.23
		L	7.29	7.16	2.46	1.94	0.33	0.27
	1st Floor	T	2.10	2.45	1.39	1.33	0.66	0.54
		L	2.79	3.58	1.90	1.70	0.68	0.47
44	Roof	T	8.73	8.56	1.44	1.34	0.16	0.16
		L	5.43	5.27	1.09	0.86	0.20	0.16
	1st Floor	T	1.66	1.95	1.19	0.97	0.71	0.50
		L	1.43	2.05	0.93	0.76	0.65	0.37

Note: T: Transverse L: Longitudinal

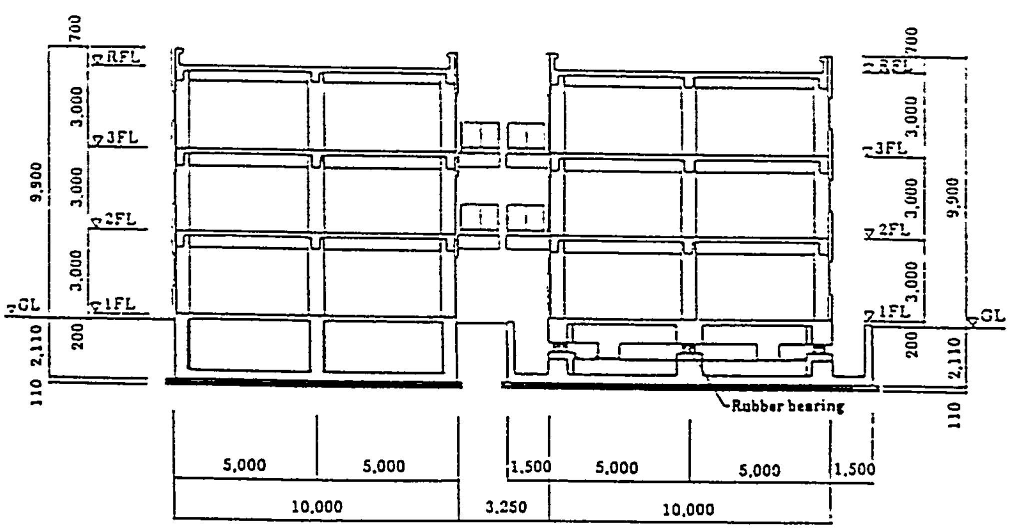
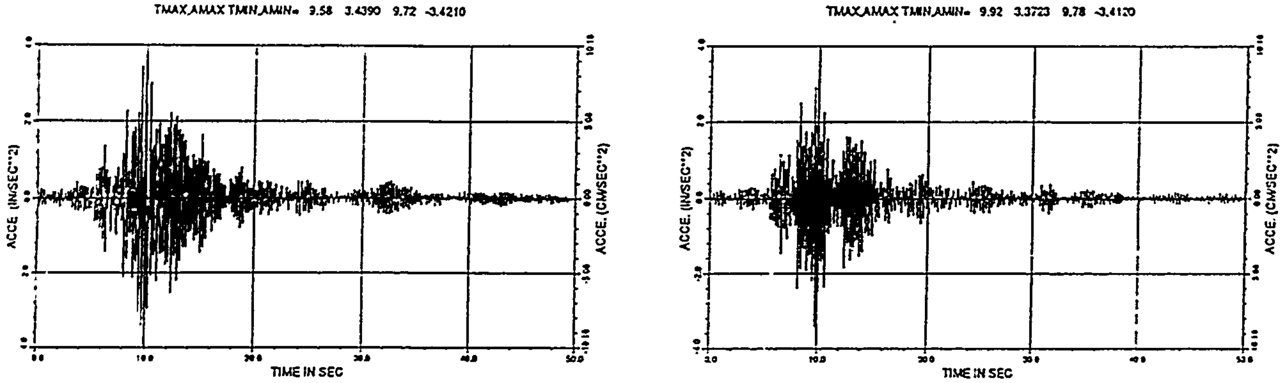
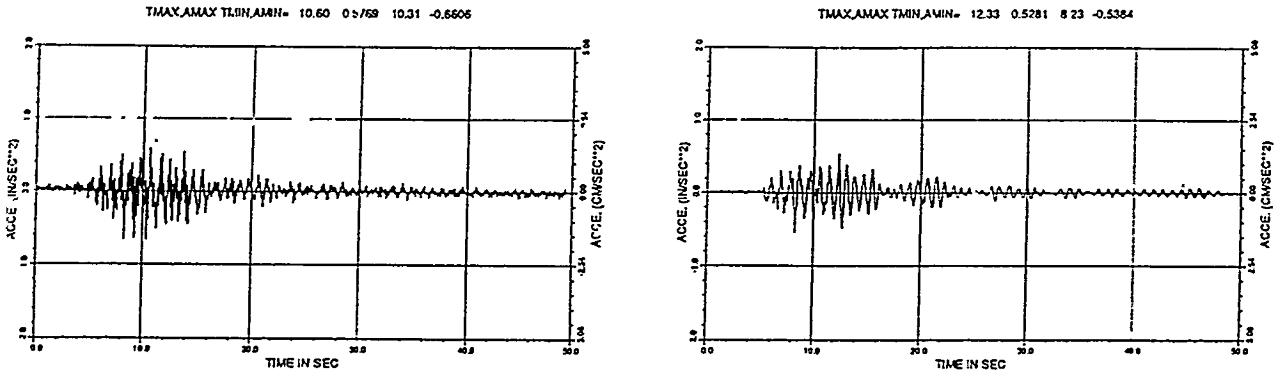


Fig. 1. Elevation of Test Buildings (left: ordinary building, right: isolated building)



Observed Ordinary Building Calculated



Observed Isolated Building Calculated

Fig. 2. Comparison of the Observed and Calculated Transverse Accelerations at the Roof Level (Eq. #44)