International Post-SMiRT Conference Seminar on Seismic Isolation, Passive Energy
Dissipation and Active Control of Seismic Vibrations of Structures
Taormina, Italy, August 25-27, 1997

THE ISOLATED BUILDING AT COMUNIDAD ANDALUCIA, SANTIAGO-CHILE

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ABSTRACT

The technical feasibility of applying high damping rubber isolators to the protection of low-cost housing has been researched through a demonstration project in which a four-story apartment building was constructed. The building, and a conventional twin standing nearby, were outfitted with a local network of digital accelerometers. At least 35 earthquakes of different intensities have been registered in the past three years by the recording system, with Richter magnitude ranging from 4.1 till 5.9, peak accelerations at the ground level ranging from 0.65 to 59.88 cm/sec^2 and dominant frequency between 2 and 20 Hz.

This paper contains the analysis of the records obtained -- for both the isolated and the conventional building-- using parametric and non-parametric identification techniques. For the earthquake records obtained, the reduction in the maximum acceleration at the roof level for the isolated building, as compared to the conventional one, varies from 1 to 4.5 times, depending on the level of the maximum ground acceleration and the characteristics of the earthquake motions.

1. INTRODUCTION

The technical feasibility of applying high damping rubber isolators to the protection of low-cost housing has been researched through a demonstration project in which a four-story apartment building was constructed. The building, and a conventional twin standing nearby, were outfitted with a local network of digital accelerometers. At least 35 earthquakes of different intensities have been registered in the past three years by the recording system, with Richter magnitude ranging from 4.1 till 5.9, peak accelerations at the ground level ranging from 0.65 to 59.88 cm/sec^2 and dominant frequency between 2 and 20 Hz.

This paper contains the analysis of the records obtained -- for both the isolated and the conventional building-- using parametric and non-parametric identification techniques.

2. BUILDING LAYOUT

The low cost housing buildings, weighing 1630 kN, measure 10 by 6 mts in plan. The first floor is composed of reinforced concrete, with the upper three of confined masonry.

Figure 3 shows the ratio of the maximum peak acceleration on the roofs of the conventional and isolated buildings as a function of the maximum peak ground acceleration for different earthquake. Each point represents the average ratio of the two perpendicular directions. Clearly, the effectiveness of the isolation system increases with the intensity of the motion. The same figure shows the ratio between the roof acceleration at the isolated building and the ground acceleration. The results suggest a trend toward a reduction as the intensity of the earthquake increases.

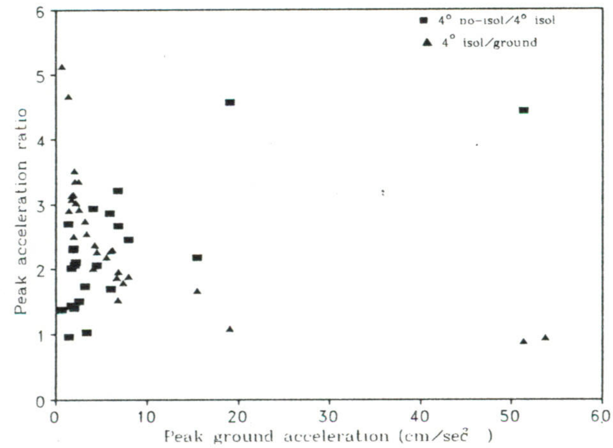

Figure 3: Peak acceleration ratio

The same ratios but for peak vertical acceleration are shown in Figure 4. In this case amplification in the isolated building is higher than in the conventional one. Part is due to the isolators flexibility (as seen in the acceleration ratio between the roof and the first floor) and part is due to the building flexibility itself.

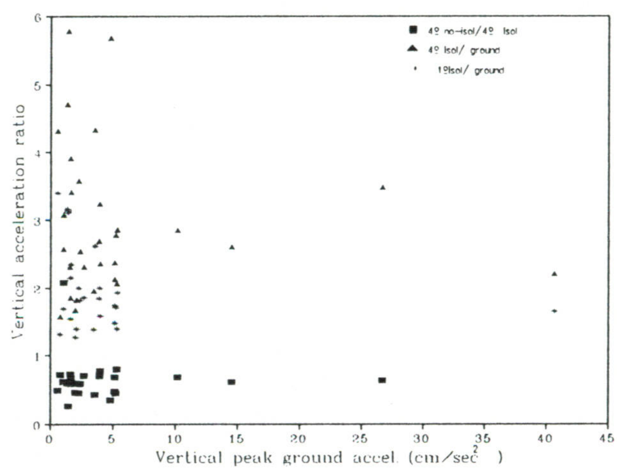

Figure 4: Vertical peak acceleration ratio

The Arias intensity (1970) represents the energy of the motion. Therefore, a good indicator of the effectiveness of the isolation system is the relationship between the Arias intensity calculated for the isolated building and for the traditional one. It represents the reduction in the energy of the motion transferred to the isolated building as compared to the conventional one. Figure 5 shows the ratio of the Arias intensity calculated for the roofs of the conventional and the isolated building and the ratio of the Arias intensity calculated for the roof of the isolated building and the ground as a function of the ground Arias intensity. In order to have a single value and consider orthogonal directions root mean square values were used.

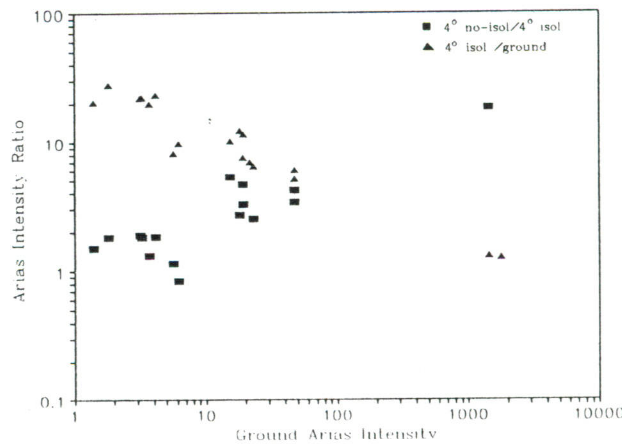

Figure 5: Arias intensity ratio

4. SYSTEM IDENTIFICATION

Different methods were used to determine the dynamic characteristics of the isolated building and to reproduce the recorded information. Non-parametric system identification in the frequency domain was performed using the records obtained on February 22, 1996 at the ground level and on the fourth floor of the isolated building. Fourier spectra and transfer function of the earthquake responses were evaluated and the fundamental frequencies were determined as the characteristics peaks of Fourier amplitude. Both the amplitude and the phase were considered in this identification process. The frequencies obtained from these processes show nonlinear behavior; the first two modes vary between 1-3 Hz and 8-10 Hz, respectively. This represents a reduction from the microtremors measures; although it is far from the target value of 0.5 Hz considered in the design phase, it agrees with the low intensities of these events.

Frequency of the vertical ground acceleration signal is around 15 hz, very similar to the value determined for the vertical frequency of the isolated building. Considering a single degree of freedom model, an average vertical stiffness of the isolators determined from test of 3028 kN/cm and a building mass corresponding to the design minimum vertical load on each bearing (216 kN) or to the design maximum vertical load on each bearing (350 kN), the vertical frequency varies between 14.65 and 19.2 hz.

The simplest model used to reproduce the recorded information consisted of a linear SDOF system with viscous damping, and the application of modal identification proposed by Beck, 1978. By minimizing the difference between the real and the predicted fourth floor lateral displacements relative to the foundation, the following values were obtained: period equal to 0.59 sec (1.7 hz) and 0.16 equivalent critical damping ratio in the longitudinal direction and 0.15 equivalent critical damping ratio in the transversal direction. Figure 6 shows the comparison between the predicted and recorded fourth floor displacements relative to the foundation. The agreement observed in the two responses is very good, specially considering the simplicity of the model.

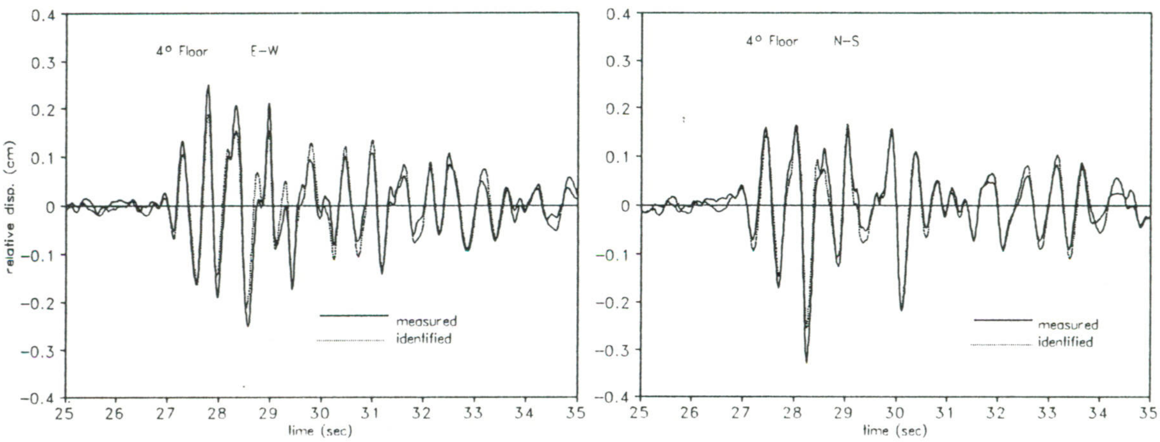

Figure 6: SDOF Model

The second model used consisted of a three-dimensional member-by-member definition of the isolated superstructure and equivalent linear model with viscous damping to represent the individual isolators. Complete time histories were obtained using the 3D-BASIS-TABS, 1994 computer program. This program represents the isolated structure as a reduced linear superstructure plus a spatially distributed set of linear or nonlinear hysteretic isolators supporting the superstructure. The output includes the deformation and force histories of the isolators, and displacements and acceleration time histories at each level of the building. The input motions are two horizontal components of earthquake ground motion.

The bearings stiffness properties were selected to match the fundamental periods obtained from the acceleration response spectra. They were 34.6 kN/cm in the longitudinal direction and 25.7 kN/cm in the transversal direction. These values were above those assumed in the design phase (2.16 kN/cm) and represent negligible deformation at the isolators. With respect to damping, equivalent ratios of 8.5% and 13.5% were used, respectively. Superstructure modal damping was set at 2% in each mode.

Figure 7 shows the comparison between the predicted and recorded acceleration response and Figure 8 shows a comparison of Fourier Spectra. The model reproduced the real response quite well. The first mode depended mainly on bearing stiffness properties, while the second mode depended on the superstructure properties. In the latter case, relevant parameters included the geometric and mechanical properties assumed for the masonry elements.

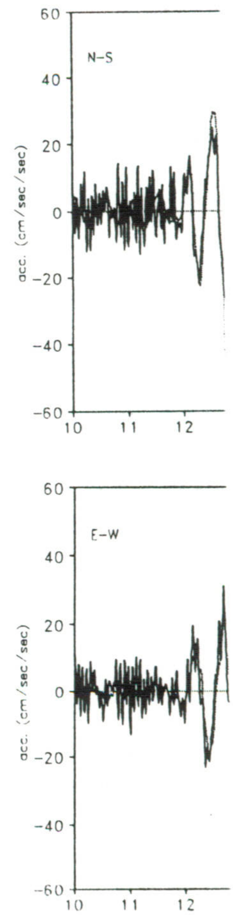

Figure 7

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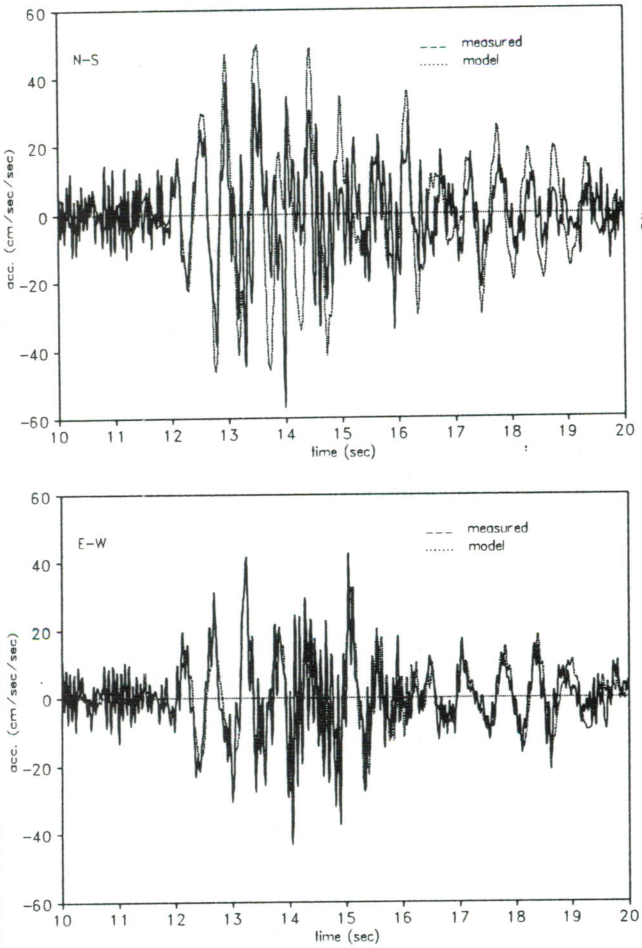

Figure 7: Predicted and recorded acceleration response

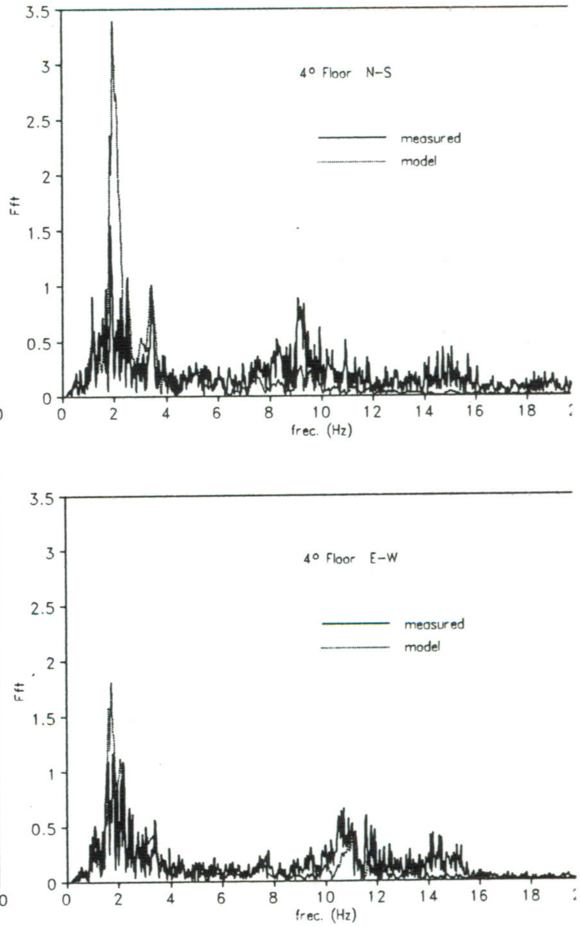

Figure 8: Fourier Spectra

5. CONCLUSIONS

The technical feasibility of applying high damping rubber isolators to the protection of low-cost housing was researched through a demonstration project in which a four-story apartment building was constructed. The building, and a conventional twin standing nearby, were outfitted with a local network of digital accelerometers. At least 24 earthquakes of different intensities were registered over the past three years by the recording system.

It can be seen from the data obtained that, although the intensities of the motions were small, the isolation system was effective in reducing the building peak accelerations. For larger motions, the effectiveness of the isolation should increase given the non-linearity of its force-displacement relationship. The isolators were designed to have a lateral stiffness, for 50% deformation in the rubber, such that the natural period of the system was 2 sec. For small deformations, the rubber is stiff and, therefore, the filtering of high frequencies is less effective, but nevertheless appreciable.

The use of system identification techniques to study the buildings earthquake response provides valuable information on the dynamic characteristics of those buildings. Very simple models can reproduce the recorded seismic response with reasonable accuracy.

For the earthquake records obtained, the reduction in the maximum acceleration at the roof level for the isolated building, as compared to the conventional one, varies from 1 to 4.5 times, depending on the level of the maximum ground acceleration and the characteristics of the earthquake motions. In the UD-direction, a considerably amplification has been observed between the foundation, the first floor and the roof due to the bearings vertical flexibility and the dynamic characteristic of the superstructure.

ACKNOWLEDGMENTS

The authors want to express their thanks to the University of Chile, FONDECYT, Project 1940466 and 1970732, the Ministry of Housing and City Planning, and the VULCO Rubber Company for their support for the research. Professor James Kelly of the University of California, Berkeley, and Engineer Pedro Soto of the University of Chile played a fundamental role in the development of this project.

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