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RESULTS FROM A BASE-ISOLATED EXPERIMENTAL BUILDING IN SANTIAGO-CHILE

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ABSTRACT

An experimental 4-storied building, supported on high damping rubber isolators, was constructed in Santiago-Chile as part of a project that is been carried out at the University of Chile in cooperation with the Ministry of Housing and City Planning and the National Scientific and Research Council (CONICYT). The building, and a conventional twin standing nearby, were instrumented with a local network of digital accelerometers model SSA-2 Kinemetrics.

This work describes the analysis through non-parametric identification techniques of the response of those buildings to a number of small earthquakes that have occurred at the site. For the earthquake records obtained, the reduction in the maximum acceleration at the roof level for the isolated building, as compared with the conventional one, varies from 1 to 3.5 times, depending on the level of the maximum ground acceleration and the characteristics of the earthquake motions. As for the vertical component, a small amplification is observed. Considering the maximum ground acceleration of the records, the reduction is larger for large intensities, but the vertical amplification seems to be similar for all range of intensities.

KEYWORDS

Base isolation; High damping rubber; Ground motions; System identification

INTRODUCTION

Seismic isolation systems are very effective in protecting buildings and their contents from earthquake damage. Since 1988, a project aim to develop low cost isolation system that could be used in a massive practical application have been carried out in Chile.

As part of that project, a four-story building was constructed in 1992 on 8 high damping rubber bearings, as well as an identical adjacent building founded in the traditional way (Sarrazin et al, 1992). These 2 buildings were instrumented with a local network of four SSA-2 Kinemetrics type accelerometers. At least 14 earthquakes of different intensities have been registered in the past two years by the recording system. In this study, the dynamic characteristics of the buildings are determined by analyzing the obtained records using non-parametric identification techniques.

OUTLINE OF BUILDINGS

The buildings 10*6 mts in plan are for low cost housing. The first floor is made of reinforced concrete, been the upper 3 made of confined masonry. The isolated one is supported on eight high damping rubber isolators which rest on foot foundations, connected between them with reinforced concrete beams. The bearings are located on the external perimeter of the building, four at the corners and four at the middle of the longer sides. The bearings are 31.5 cm diameter by 32 cm height. They were made in a local rubber factory and subjected to a set of standard tests at the University of Chile and at the University of California at Berkeley, (Sarrazin et al, 1993). The buildings are instrumented with a total of 4 accelerometers located at the ground under the isolated building, at the bottom slab of the isolated building, at the roof level of the isolated building and at the roof level of the traditional building.

EARTHQUAKE RECORDS

Several small earthquakes have occurred at the site of the building, with peak accelerations at the ground level ranging from 0.65 to 9.54 cm/sec^2 and dominant frequency between 2 and 20 hz. The characteristics of the quakes on the soil surface are shown on Table 1.

Fig. 1 shows the ratio of the maximum peak acceleration at the roof of the conventional building and at the isolated one, as a function of the maximum peak acceleration of the ground. The points represent the average of the results in the two perpendicular directions. It can be seen that the effectiveness of the isolation system increases with the intensity of the motion. The same figure shows the ratio of the roof acceleration of the isolated building and the acceleration at the ground. It indicates a tendency to decrease as the intensity of the earthquake increases.

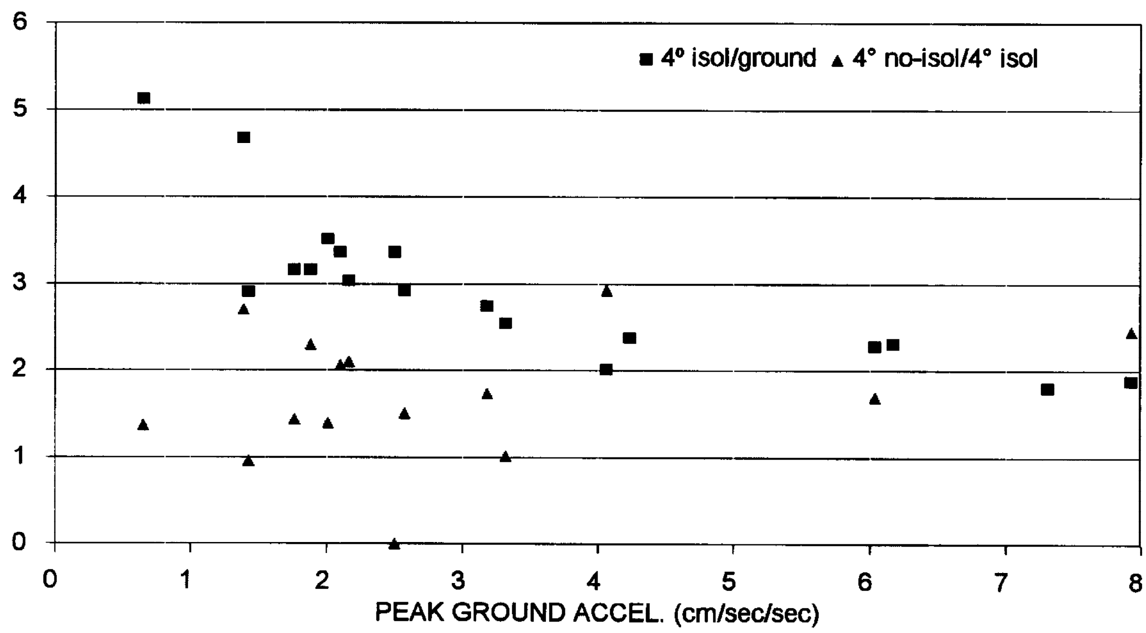

Fig. 1. Ratios of Max Peak Acceleration

The Arias intensity represents the energy of the motion. Therefore, a good indicator of the effectiveness of the isolation system is the relation between the Arias intensity evaluated in the isolated building and in the traditional one. It represents the reduction in the energy of the motion transfered to the isolated building respect to the conventional one, as is shown in Fig. 2. Furthermore, because there is a transfer of energy from the motion in one direction to the motion in the perpendicular one, the root mean square of intensities in both direction is even a better indicator.

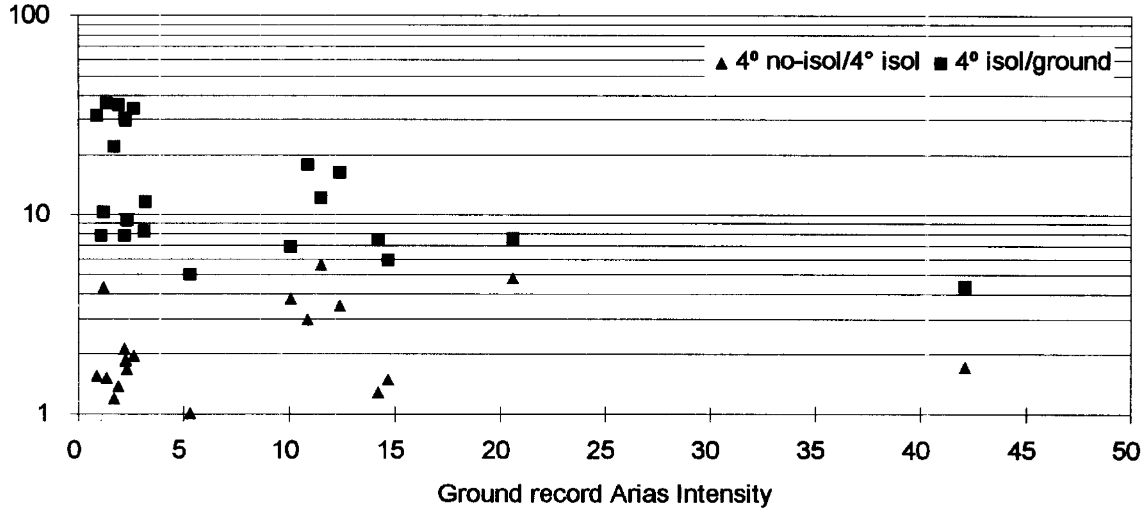

Fig. 2. Ratios of Arias Intensity

Table 1. Characteristics of the quakes on the soil surface

Date	Magnitude	Comp	Max peak acc. cm/sec^2	Arias Intensity
930716	5.3	EW	7.33	
		NS	5.03	
930806	4.9	EW	7.04	
		NS	7.60	
941018	4.2	EW	2.59	1.7
		NS	4.06	5.31
941022	4.1	EW	1.97	2.23
		NS	2.24	2.31
941028	4.9	EW	6.32	20.6
		NS	9.54	42.1
950113	4.6	EW	1.84	1.37
		NS	1.94	1.21
950201	4.1	EW	2.23	2.27
		NS	2.92	2.19
950202	4.3	EW	0.65	0.87
		NS	0.68	1.09
950315	4.7	EW	4.23	11.5
		NS	3.90	10.1
950405	4.9	EW	2.56	
		NS	2.45	
950430	4.25	EW	2.01	1.92
		NS	2.02	3.14
950602	5.3	EW	2.62	10.8
		NS	3.75	14.2
950607	5.19	EW	1.85	2.63
		NS	1.68	3.19
950612	4.81	EW	7.74	12.4
		NS	4.35	14.7
950628	4.6	EW	0.86	
		NS	1.93	
950701	5.04	EW	1.56	
		NS	1.31	
950922	4.6	EW	2.01	
		NS	2.33	
951009	5.0	EW	4.37	
		NS	4.11	

SYSTEM IDENTIFICATION

Non-parametric system identification in the frequency domain has been done using the records obtained at the ground surface, and at the 4° floor of both buildings.

Fourier spectra of the earthquake responses have been evaluated and the fundamentals frequency of both buildings have been determined as the highest peaks of Fourier amplitude. Fig. 3 shows, as an example, the FFT obtained for six records of the 941028 earthquake.

The transfer function, H(w),is determined as the ratio of the FFT of the roof acceleration to the FFT of the ground acceleration and it can be used to identify the dynamic properties of the buildings. Both the amplitude and the phase have been considered in this identification process.

Table 2 shows the frequency ranges obtained for the two first modes for both buildings using FFT or the transfer function H(w). Predominant frequencies identified from microtremors measurements for the longitudinal and transverse direction were, respectively: 7.7 and 8.8 hz for the non-isolated building and 6.2 and 6.8 for the isolated one.

CONCLUSIONS

The use of system identification techniques to study the earthquake response of two buildings, one isolated and the other supported on conventional foundations, provides valuable informations on the dynamic characteristics of those buildings.

It can be seen from the above results that although the intensities of the motions were small, the isolation was effective in reducing the building peak accelerations. For larger motions the efficiency of the isolation should be better due to its non-linearity in the force-displacement relationship. The isolators were designed to have a lateral stiffness, for 50% deformation in the rubber, such that the natural period of vibration of the system were 2 sec. For small deformations the rubber is quite stiff and, therefore, the filtering is less effective.

ACKNOWLEDGMENTS

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Table 2. Frequencies ranges (hz).

Date	Comp	FFT				H(w)			
		Isolated		Non Isolated		Isolated		Non Isolated	
		Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2	Mode 1	Mode 2
941018	NS	4-7	14-18	7-9		4-8	14-18	8-9	
	EW	5-6	12-16	7-9	14-18	5-6		7-8	
941022	NS	5-8	13-17	7-10	21-25	5-7	14-17	8-11	22-25
	EW	5-7	12-17	6-9	14-18	5-7	12-17	6-9	
941028	NS	5-7	13-17	7-9	22-26	5-7	14-16	7-9	
	EW	5-7	13-18	7-8	14-17	5-6	13-18	7-9	
950113	NS	5-7	13-17	8-10	13-16	5-7	13-18	8-10	
	EW	5-6	12-18	7-9	14-18	5-6	12-20	7-9	14-18
950201	NS	4-7	12-16	8-11		5-8		8-10	
	EW	5-7	12-16	7-9	14-18	4-6	12-15	7-9	
950202	NS	5-7	14-17	7-11	14-17	5-7		8-10	
	EW	5-6	12-16	7-8	14-16	5-6	12-18	7-8	15-16
950315	NS	5-7	12-17	7-10	20-28	5-7		8-10	
	EW	4-6	12-17	7-8		5-6	13-17	7-8	
950430	NS	4-6	12-17	7-10	21-25	5-7		7-10	
	EW	4-6	12-17	7-9	14-19	5-6	12-17	7-9	
950602	NS	4-7	12-16	7-10		4-7		7-10	
	EW	4-7	11-15	6-9	15-18	4-7	11-16	7-9	15-18
950607	NS	5-7		5-10		5-7		7-10	
	EW	4-6		6-9		4-6		7-8	
950612	NS	4-7	12-17	7-10	23-26	4-8		8-11	
	EW	4-7	12-17	6-9	14-18	4-7	12-18	6-8	
950701	NS	4-8		6-10		5-8		8-10	
	EW	4-7		6-9		5-6		7-9	
950922	NS	4-7	12-16	7-9		5-7		8-10	
	EW	4-7	12-15	6-8	15-18	5-7	12-16	6-8	
951009	NS	3-7	11-12			4-7			
	EW	2-6	11-15			4-7	12-16		

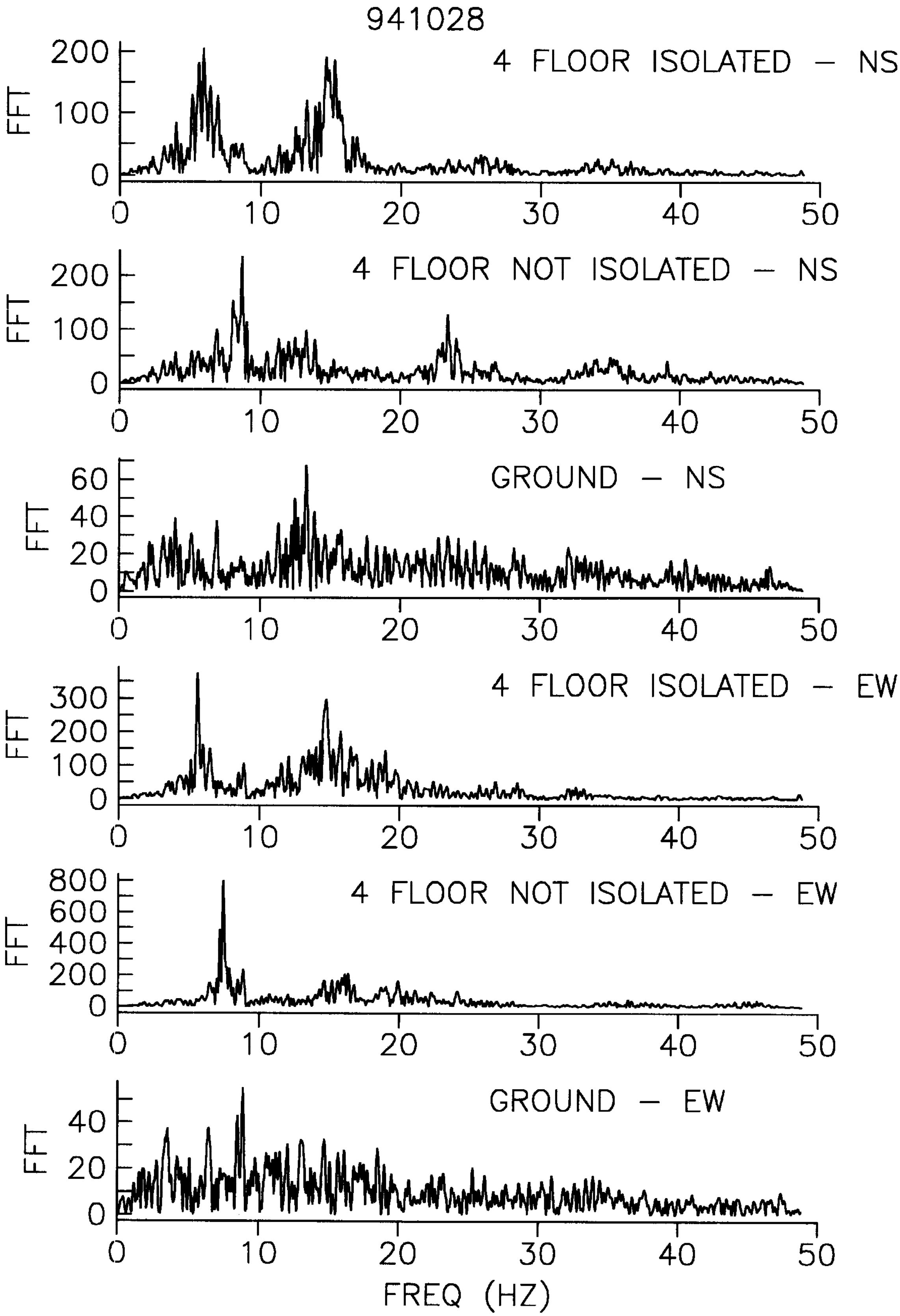

Fig. 3. FFT of October, 28, 1994 records.