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DEVELOPMENT AND TESTING OF TEFLON SLIDING BEARINGS.

R. ZAMORANO, M. SARRAZIN, and G. TORO
Department of Civil Engineering, University of Chile
Blanco Encalada 2120, Santiago, Chile

ABSTRACT

The teflon sliding bearings are an alternative to rubber bearings for seismic isolation. The results of a testing program to evaluate the friction coefficient between teflon pads and stainless steel plates is presented here. The variables considered were the contact pressure, the frequency, and the velocity.

KEYWORDS

Base isolation; teflon sliding bearings; energy dissipation.

INTRODUCTION

The University of Chile, in cooperation with the Ministry of Housing and City Planning, has been developing methods for the seismic protection of apartment buildings. One of these methods is base isolation, by which the ground vibrations are partially dissipated before they reach the structure. A prototype building using this technology was constructed in Santiago and is being monitored in order to get information about its behavior during strong earthquake motions (Sarrazin *et al.,* 1996*)*. In that particular case, high damping rubber was used for the isolation bearings. In the present work, the development of a new type of isolation device for low cost housing buildings is presented, namely, teflon - stainless steel sliding bearings.

This type of bearing has been successfully used for many years in other applications, such as the support of bridge girders, allowing for thermal deformations. Experience has shown that they have a good behavior with time, conserving invariant its properties for many years. For base isolation the works done by Constantinou *et al.*, (1990), Mokha *et al.*, (1990), and Nagarajaiah *et al* (1991) are worth mentioning.

In the case of low cost house buildings, the sliding bearing have the following advantages over the rubber ones:

- Considerably lower cost than the rubber bearings.
- Less displacement at the bearing during earthquakes.
- Smaller size and, consequently, lower cost and less design problems.
- Less problems with aging than the rubber ones, considering that teflon and stainless steel don't change their properties with time.
- No stability problems for low vertical loads, as it happens for elastomeric bearings.

On the other hand, the teflon pads presents some disadvantages as compared with the rubber bearings:

- A permanent displacement at the bearing after the earthquake may happen. To reduce this effect, the teflon bearings have to be combined with other devices that could provide a restitutive horizontal force. Experience has show that a small horizontal spring force is enough to reduce the permanent displacement to near zero.

- The force-displacement characteristic of the teflon device, almost rigid-plastic, produces excitation of the higher modes of vibration of the structure. The result is higher accelerations in the different levels of the building. However the base shear force and global moment are very similar to the ones for elastomeric bearings.

TESTING.

A test program was designed aiming to study the following parameters:

- The friction coefficient for different interfaces teflon-stainless steel plates.
- Friction coefficient versus normal load.
- Friction coefficient versus velocity.
- Variation of friction coefficient for different surface finishing of the stainless steel.

The general testing arrangement is shown in figure 1. The cyclic motion is generated by means of an MTS machine, while the normal load is applied by 4 long bolts, stressed to the desired level of load. These bolts have strain gauges bonded to their surface thus allowing the control of normal loads.

The testing sample consists of a 12 mm thick steel plate vulcanized to a reinforced elastomeric pad sized 100/100/10 mm. Attached to this pad there is a 4 mm steel plate with a circular cavity 1.6 mm deep to receive the teflon sheet that is 800 mm diameter and 3.2 mm thick. The material used was glass filled sheet type teflon at composition 25% by weight. The elastomeric pad was included to allow small rotations during the test.

The central steel plate is 530/210/13 mm and is covered at both sides with 2 mm stained steel plates, quality ASTM A-240 type 304, finishing 2B and roughness 0.12 μm in the parallel to lay direction and 0.18 μm in the perpendicular to lay direction.

The testing program consisted of a series of specimens loaded at nominal normal stresses of 7, 14, and 21 Mpa, subjected to sinusoidal cycles of controlled displacement with frequencies varying from 0.01 to 2.5 Hz, and velocities ranging from 0.3 to 50.0 m/sec. Afterwards the same tests were redone for stainless steel plates with the surface lay perpendicular to the direction of motion.

Afterwards a new set of testing was carried out improving the testing device for better control of the normal loads and reduction of the vibration problems that were detected in the first set of tests. Furthermore, two type of specimens were considered: with a reinforced elastomeric pad and without it, aimed at comparing the different behavior of both testing dispositions (see figure 1).

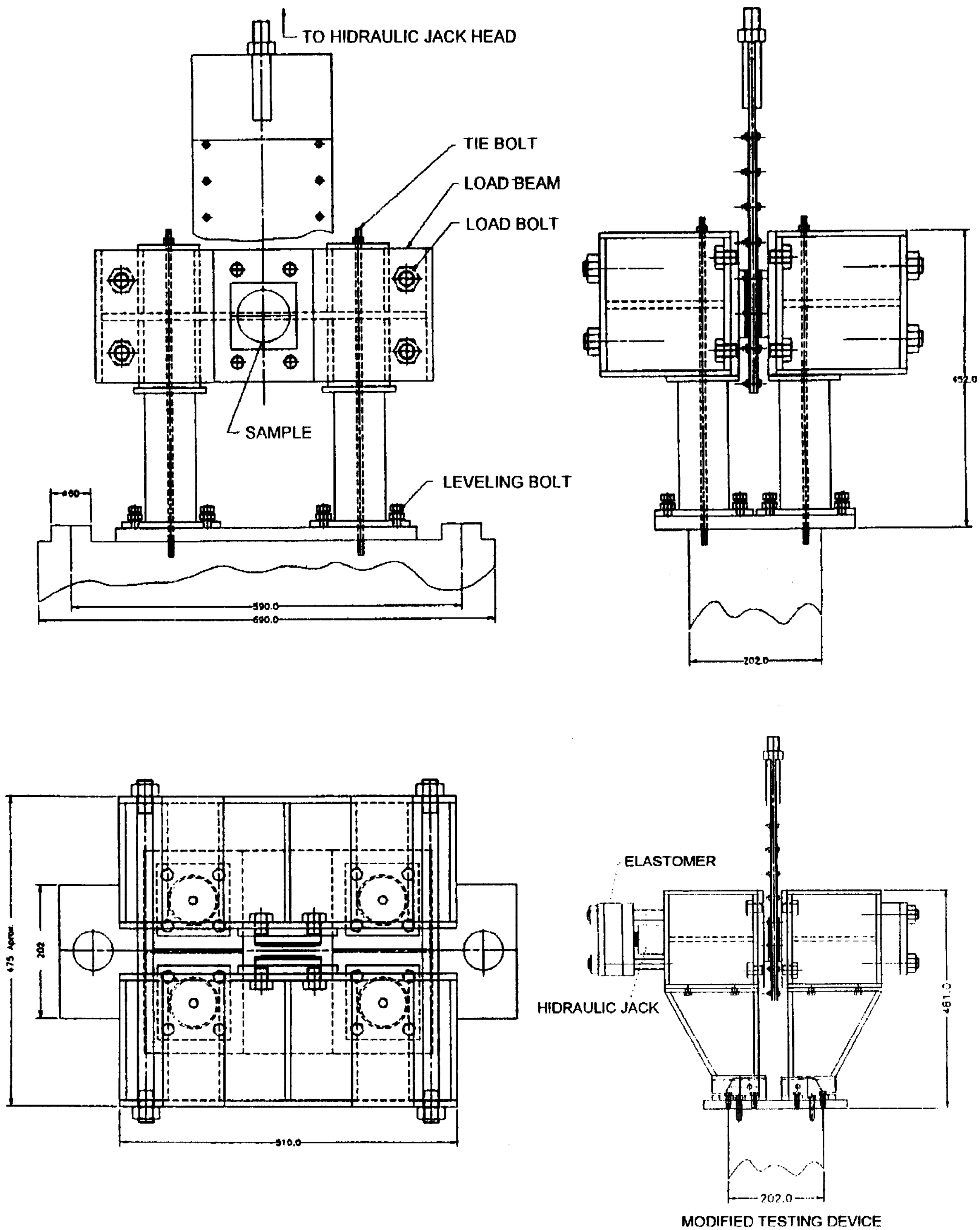

Figure 1. General testing arrangement.

RESULTS.

For each test, the friction forces versus displacement of the acting plate, as well as the deformation of the rubber pad and the variation of the bolt forces were measured. Figure 2 shows several force-displacement cycles obtained in a test for 13.9 Mpa of normal force (measured at the bolts) for a frequency of 2.5 Hz, for motion parallel to the surface lay. As it can be observed, in this case the friction coefficient slightly decreases as the number of cycles increases. An important decrease in the roughness of the stainless steel plate was observed after the test was over (aprox. 40 %). In only 2 of the 72 tests carried out the static coefficient of friction was larger than the dynamic one. Both cases were for displacements perpendicular to the direction of surface lay, low velocity, and for teflon pads that had been used previously. Figure 3 shows the same case but for a sample without the elastomeric layer. This last test was carried out in the improved testing device.

In all cases the friction coefficient was lower when the normal load was larger.

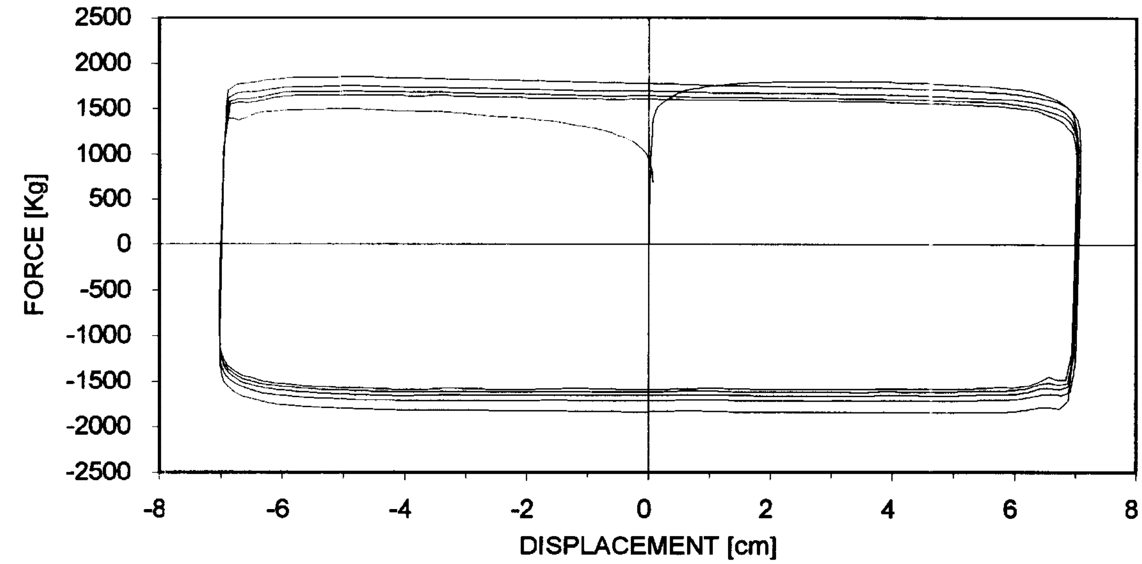

Figure 2. Force-displacement cyc les, with elastomeric pad.

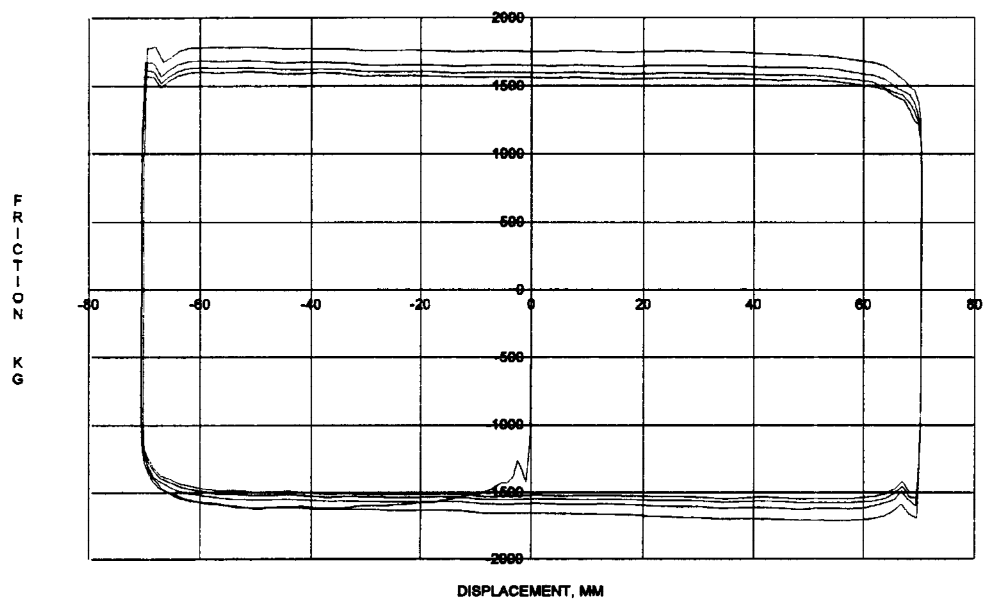

Figure 3. Force-displacement cycles, wthout elastomeric pad.

The effect of peak velocity on the friction coefficient for the case with elastomeric pad is shown in figure 4 for direction parallel to lay. Figure 5 shows the same case for the sample without the elastomeric layer, tested in the improved machine. Figure 6 shows the case with elastomeric pad for direction perpendicular to lay. Its value increases quickly, in both cases, with the displacement peak velocity up to a value that remains approximately constant afterwards. For low velocity (around 0.3 cm/sec) it varies between 0.05 and 0.12, while for high velocities remains between 0.10 and 0.18, depending on the applied normal force.

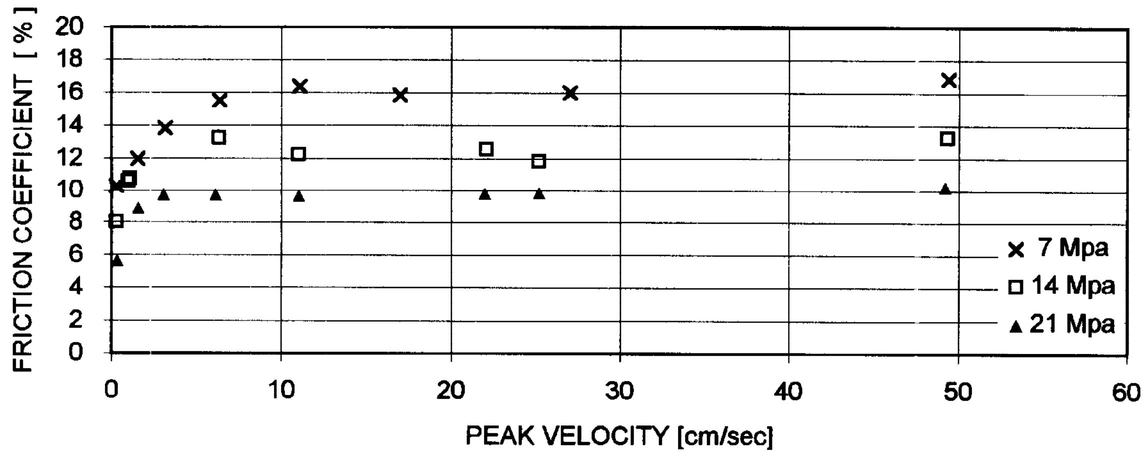

Figure 4. Effect of peak velocity, with elastomeric pad.

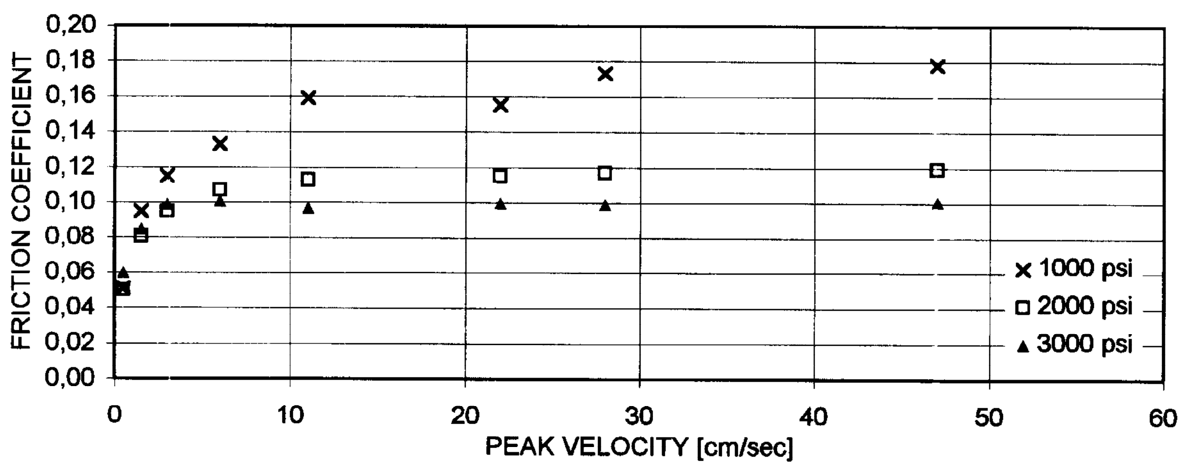

Figure 5. Effect of peak velocity, without elastomeric pad.

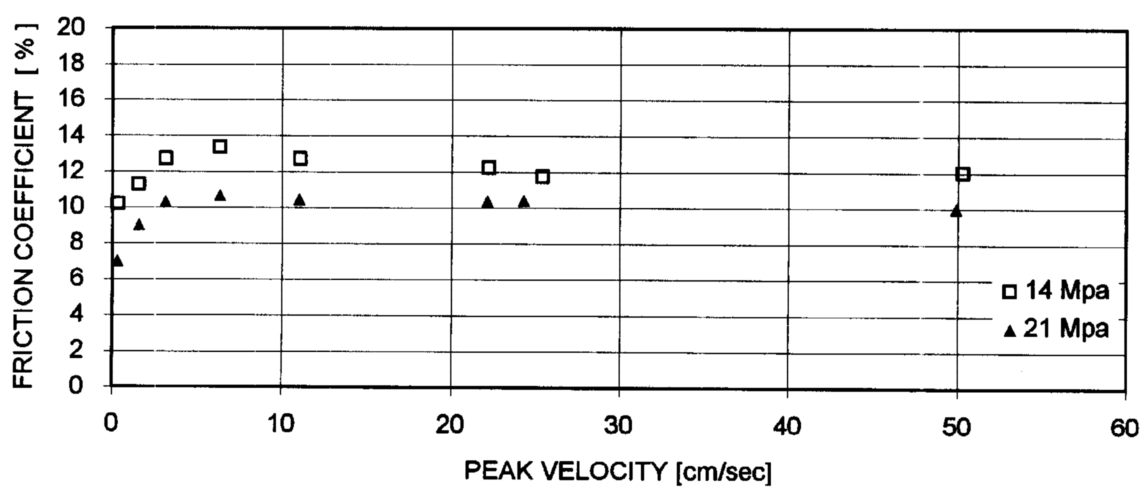

Figure 6. Effect of peak velocity, direction perpendicular to lay.

The friction coefficient depends weakly on the steel surface roughness. In effect, although the roughness was twice in the direction perpendicular to lay, the coefficient of friction was only 10 % larger in the former case. During the test, the surface roughness decreases substantially to approximately 40% its original value.

ANALYSIS OF A BUILDING OVER SLIDING BEARINGS.

In order to investigate the behavior of a building over sliding bearings of the type previously described, the same building that was mentioned at the beginning of this paper was analyzed using 8 teflon bearings to take the vertical loads and one rubber bearing for the control of the permanent horizontal displacements. The 3D-BASIS program (Nagarajaiah *et al.*, 1991) was used for this analysis. As input motion, the Llolleo N10E, 1985 record was used. The results are shown in Table 1 and figure 7.

Isolation Type	Motion	Rubber Damping	Displac 4° floor, cm	Accel. g		ISOLATORS	
					Displ., cm	Perm. Displ., cm	Base Shear, kN
Sliding	X	0.05	0.13	0.54	9.26	0.53	216
Sliding	X	0.10	0.13	0.57	8.90	0.54	223
Sliding	Y	0.10	0.11	0.55	8.70	0.68	225
Rubber	X	0.10	0.13	0.19	15.79	-	232
Rubber	Y	0.20	0.13	0.21	11.79	-	217

TABLE 1. Response of the isolated building, 4° floor.

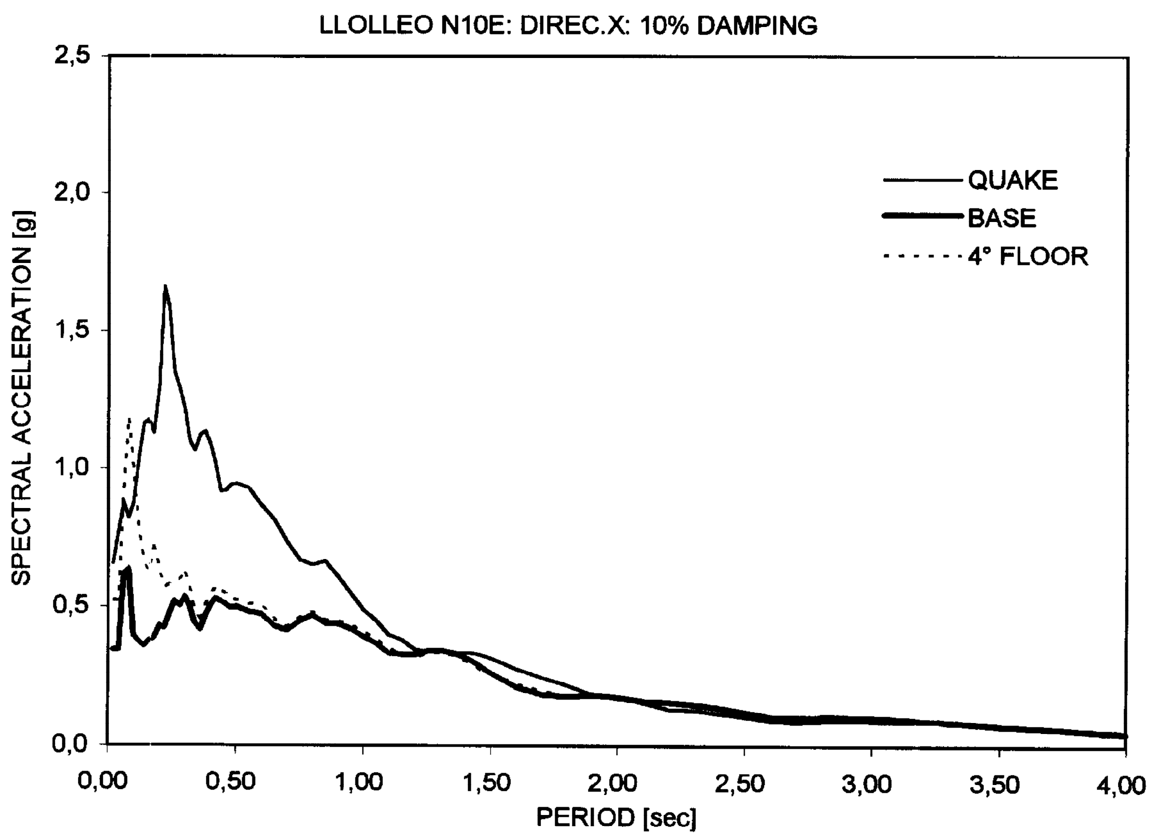

Figure 7. Earthquake response of a building resting on sliding bearings.

The following conclusions follow from the comparison between the results obtained for sliding bearings and the ones obtained for rubber bearings:

- The total displacement of the isolators are smaller for the sliding bearings.
- Although the maximum deformation of the bearings for the sliding case was 9 cm, the permanent displacement was only 0.5 cm.
- The relative displacement between the 4° floor and the base was almost the same for both type of isolators (0.13 cm).
- The acceleration at the 4° floor was larger in the sliding case (0.57g) that in the rubber bearing case (0.19), but in both cases was lower than the maximum peak acceleration of the ground (0.66g). This can be explained by the greater participation of the higher modes in the sliding case, because of the sharp changes in the force-displacement relationship.
- The maximum base shear force is almost the same for both kind of supports.

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