LOW FRICTION SEISMIC ISOLATION DEVICE FOR STRUCTURES: CHARACTERIZATION AND EXPERIMENTAL TESTS

Hector Valencia Aguilar[1], Fortunato Espinoza Barreras[2], Carlos Isidro Huerta López[3]

[1] *Architect, Director Seismic Filter Company*
[2] *Professor, Ensenada Engineering School, Autonomous University of Baja California, Ensenada. Mexico.*
[3] *Senior-Research Scientist/Professor, Dept. of Seismology, Center for Scientific Research and Higher Education of Ensenada, Ensenada, Mexico*
Email: filtrosismico@prodigy.net.mx, fortunato@uabc.mx, m-huerta@alumni.utexas.net

ABSTRACT :

The Seismic Filter (SF) is a device that nearly suppresses seismic energy from being transmitted to structures. Likewise, applicative to any structure with no restrictions as to weight, shape or architecture. Basically, it consists of two plates, one fixed to the foundation and the other to the structure, that between them confine a non-compressible fluid in a sealed environment. Thereby, during an earthquake, allows the former to remain practically motionless as it slides over the latter. The very low shearing forces thus obtained permit hydraulic jacks to be fitted on top of SF that can be used to solve inclinations due to differential sinking of foundations.

KEYWORDS: Seismic filter, seismic isolation, experimental tests

1. TESTS

A 400-ton capacity model was tested at the Powel Seismic Laboratory of UCSD: University of California at San Diego (Filiatrault, 2001). The testing program (Table 1), inspired from the “Testing of Seismic Isolation and Energy Dissipating Devices” prepared by the Highway Innovative Technology Center (HITEC, 1996), included 3 sets, under three different loads (1400, 3500 and 6000 psi) of 14 frequency dependence tests and 6 simulations of major earthquakes to obtain the SF’s response to different loads, frequencies, speeds and ground accelerations.

The sliding plate of the seismic filter was inserted horizontally between the earthquake simulator and a stiff pre-stressed concrete reaction wall that is located adjacent to the earthquake simulator. The self-reacting vertical reaction frame of the seismic filter was located on the strong floor of the laboratory between the earthquake simulator and the reaction wall. This self-reacting frame can apply a vertical confining pressure to the two sliding surfaces. Two photographs of the test set-up are presented in Figure 1.

Figure 1 Photographs of the test set-up

Table 1 Test Sequence

Test Name	Confining Pressure	Test Type	Excitation
SF-B1	1400 psi	Benchmark	Sinusoidal Displacement, 10 cycles, 0.5 Hz, +-1 in
SF-F1		Frequency	Sinusoidal Displacement, 3 cycles, 0.05 Hz, +-1 in
SF-F2			Sinusoidal Displacement, 3 cycles, 0.05 Hz, +-3 in
SF-F3			Sinusoidal Displacement, 3 cycles, 0.05 Hz, +-5 in
SF-F4			Sinusoidal Displacement, 3 cycles, 0.5 Hz, +-1 in
SF-F5			Sinusoidal Displacement, 3 cycles, 0.5 Hz, +-3 in
SF-F6			Sinusoidal Displacement, 3 cycles, 0.5 Hz, +-5 in
SF-F7			Sinusoidal Displacement, 3 cycles, 1.0 Hz, +-1 in
SF-F8			Sinusoidal Displacement, 3 cycles, 1.0 Hz, +-3 in
SF-F9			Sinusoidal Displacement, 3 cycles, 1.0 Hz, +-5 in
SF-F10			Sinusoidal Displacement, 3 cycles, 2.0 Hz, +-1 in
SF-F11			Sinusoidal Displacement, 3 cycles, 2.0 Hz, +-3 in
SF-S1		Seismic	Tarzana, Full Scale or Table Stroke Limit
SF-S2			Tarzana, Full Scale or Table Stroke Limit
SF-S3			Mexico City, Table Stroke Limit
SF-S4			Mexico City, Table Stroke Limit
SF-S5			Saguenay, PHA = 2.1 g
SF-S6			Saguenay, PHA = 2.1 g
SF-B2	3500 psi	Benchmark	Sinusoidal Displacement, 10 cycles, 0.5 Hz, +-1 in
SF-F12		Frequency	Sinusoidal Displacement, 3 cycles, 0.05 Hz, +-1 in
SF-F13			Sinusoidal Displacement, 3 cycles, 0.05 Hz, +-3 in
SF-F14			Sinusoidal Displacement, 3 cycles, 0.05 Hz, +-5 in
SF-F15			Sinusoidal Displacement, 3 cycles, 0.5 Hz, +-1 in
SF-F16			Sinusoidal Displacement, 3 cycles, 0.5 Hz, +-3 in
SF-F17			Sinusoidal Displacement, 3 cycles, 0.5 Hz, +-5 in
SF-F18			Sinusoidal Displacement, 3 cycles, 1.0 Hz, +-1 in
SF-F19			Sinusoidal Displacement, 3 cycles, 1.0 Hz, +-3 in
SF-F20			Sinusoidal Displacement, 3 cycles, 1.0 Hz, +-5 in
SF-F21			Sinusoidal Displacement, 3 cycles, 2.0 Hz, +-1 in
SF-F22			Sinusoidal Displacement, 3 cycles, 2.0 Hz, +-3 in
SF-S7		Seismic	Tarzana, Full Scale or Table Stroke Limit
SF-S8			Tarzana, Full Scale or Table Stroke Limit
SF-S9			Mexico City, Table Stroke Limit
SF-S10			Mexico City, Table Stroke Limit
SF-S11			Saguenay, PHA = 2.1 g
SF-S12			Saguenay, PHA = 2.1 g
SF-B3	6000 psi	Benchmark	Sinusoidal Displacement, 10 cycles, 0.5 Hz, +-1 in
SF-F23		Frequency	Sinusoidal Displacement, 3 cycles, 0.05 Hz, +-1 in
SF-F24			Sinusoidal Displacement, 3 cycles, 0.05 Hz, +-3 in
SF-F25			Sinusoidal Displacement, 3 cycles, 0.05 Hz, +-5 in
SF-F26		Frequency	Sinusoidal Displacement, 3 cycles, 0.5 Hz, +-1 in
SF-F27			Sinusoidal Displacement, 3 cycles, 0.5 Hz, +-3 in
SF-F28			Sinusoidal Displacement, 3 cycles, 0.5 Hz, +-5 in
SF-F29			Sinusoidal Displacement, 3 cycles, 1.0 Hz, +-1 in
SF-F30			Sinusoidal Displacement, 3 cycles, 1.0 Hz, +-3 in
SF-F31			Sinusoidal Displacement, 3 cycles, 1.0 Hz, +-5 in
SF-F32			Sinusoidal Displacement, 3 cycles, 2.0 Hz, +-1 in
SF-F33			Sinusoidal Displacement, 3 cycles, 2.0 Hz, +-3 in
SF-S13		Seismic	Tarzana, Full Scale or Table Stroke Limit
SF-S14			Tarzana, Full Scale or Table Stroke Limit
SF-S15			Mexico City, Table Stroke Limit
SF-S16			Mexico City, Table Stroke Limit
SF-S17			Saguenay, PHA = 2.1 g
SF-S18			Saguenay, PHA = 2.1 g

The horizontal force-displacement hysteresis loops are experimental results of the earthquake simulation tests (Figures 2 to 7). Note that the hysteresis loops are nearly rectangular indicating a coulomb-type frictional response. The static coefficient of friction varied from 0.08 to 0.025. The kinematic coefficient friction varied from 0.003 to 0.013 (Filiatrault, 2001).

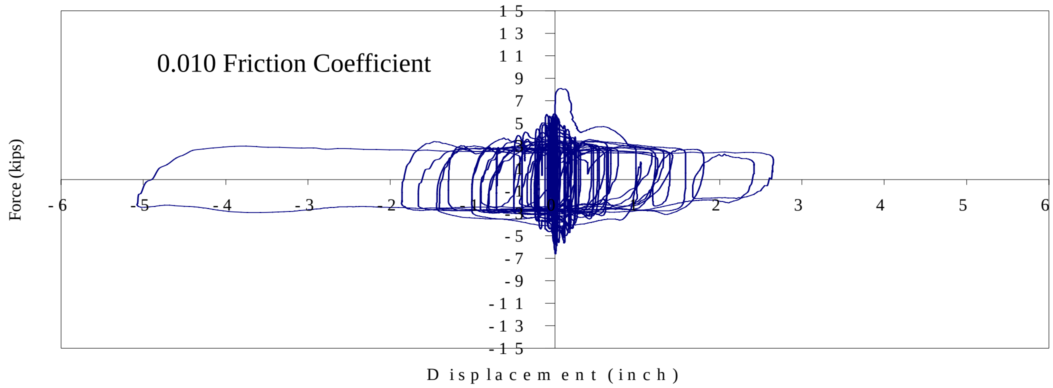

Figure 2 Force-displacement graph of Seismic Filter response to Northridge ’94 with 1400 psi confining pressure.

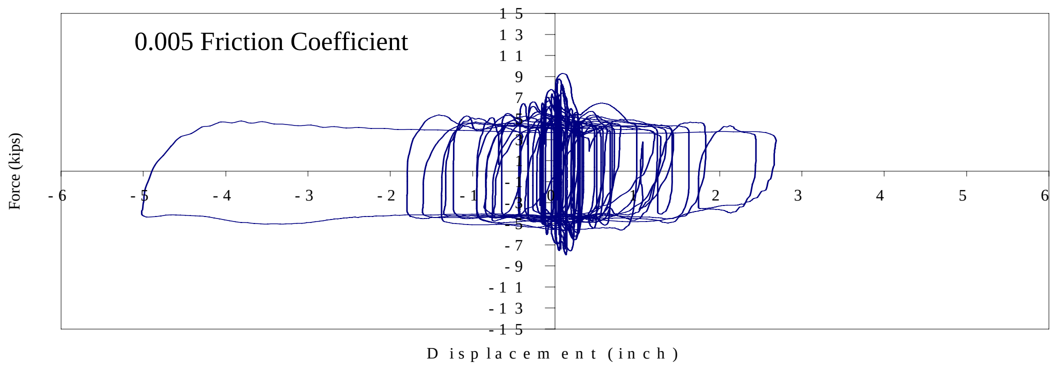

Figure 3 Force-displacement graph of Seismic Filter response to Northridge ’94 with 3500 psi confining pressure.

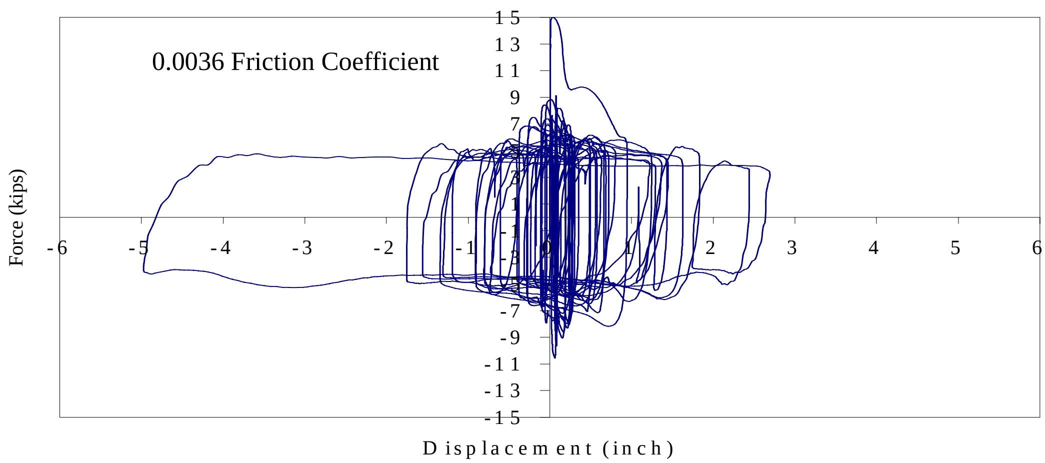

Figure 4 Force-displacement graph of Seismic Filter response to Northridge ’94 with 6000 psi confining pressure.

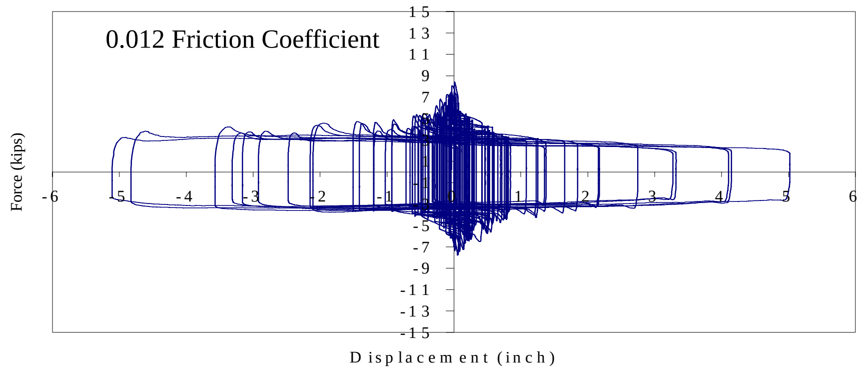

Figure 5 Force-displacement graph of Seismic Filter response to Mexico ’85 with 1400 psi confining pressure.

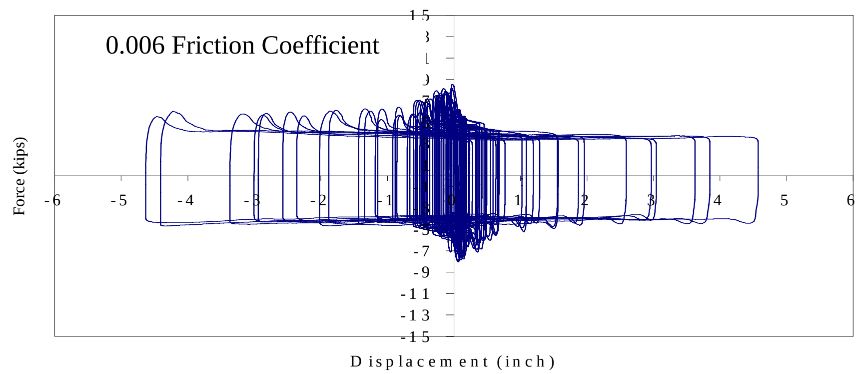

Figure 6 Force-displacement graph of Seismic Filter response to Mexico ’85 with 3500 psi confining pressure.

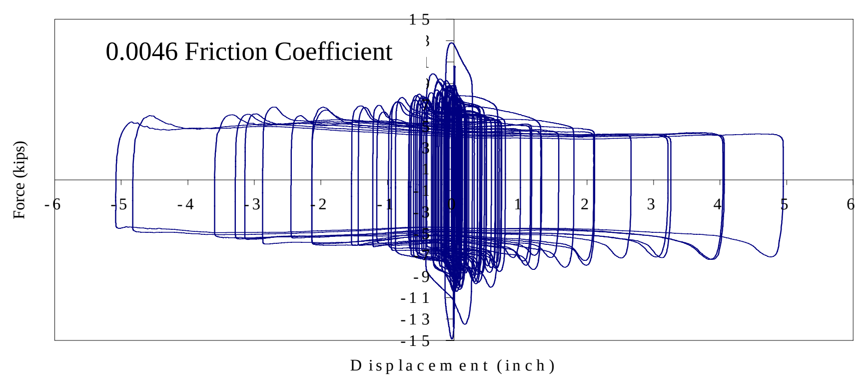

Figure 7 Force-displacement graph of Seismic Filter response to Mexico ’85 with 6000 psi confining pressure.

1.1 TESTS CONCLUSION

For the three confining pressures considered in the test, the behavior of the seismic filter is repeatable, stable and nearly identical in tension-compression (Filiatrault, 2001).

2 MATH MODELS

Using data from tests at UCSD, the following graphs were obtained showing the Seismic Filter's response. The reduction of energy to the structures is independent of the tremors' characteristics (Figures 8 and 9).

Figure 8 Math model of Seismic Filter response to Northridge '94.

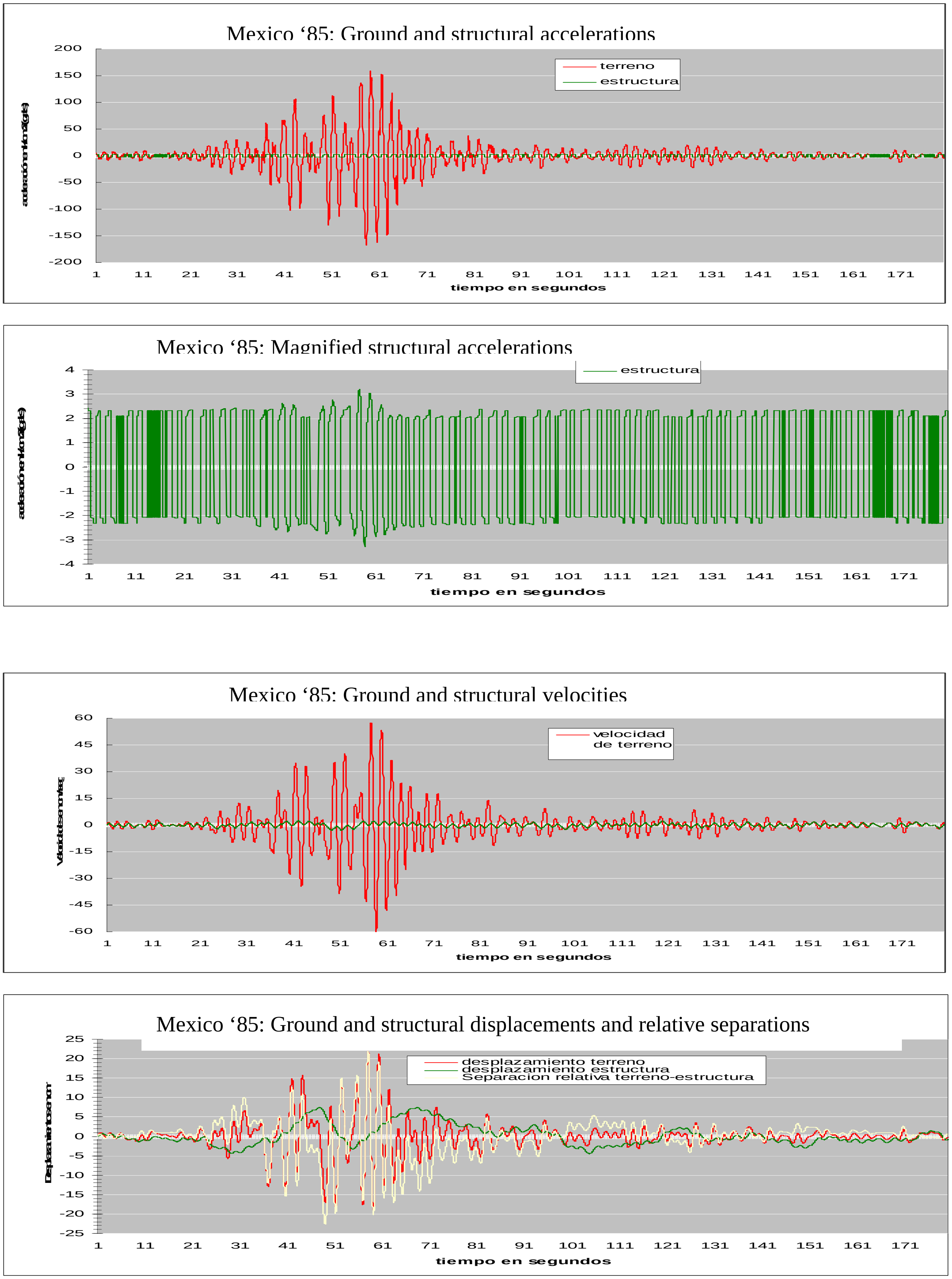

Figure 9 Math Model of Seismic Filter response to Mexico '85

3 SEISMIC FILTERS APPLIANCE ON A TEST BUILDING

Seismic simulations are being carried out of a $2.3 million prefab structure (Figure 10) involving a collaboration among UCSD, UCLA, the University of Arizona, and Lehigh University and being funded by the Precast/Prestressed Concrete Institute and its member companies and organizations, the National Science Foundation, the Charles Pankow Foundation, and the Network for Earthquake Engineering Simulation (NEES). At this time, the tests are proceeding at Englekirk shake table (UCSD) and the data thus obtained is being processed and will be shown in a later time.

Since the structure is wider then the shake table, the external sides are supported by four Seismic Filters that are acting as very low friction sliders (Figure 11).

Figure 10 Photographs of the prefab building tested on the Englekirk Shake Table.

Figure 11 Photograph of one external beam showing one supporting Seismic Filter.

4 CONCLUSIONS

The behavior of the seismic filter is repeatable, stable and nearly identical in tension-compression as has been demonstrated in all the tests realized. The energy transmitted to structures is independent of the earthquakes characteristics and practically insignificant and constant. All the information about the Seismic Filter can be consulted at http://www.seismicfilter.com.

REFERENCES

Filiatrault, A., Kenzel, K. A., Christopoulos, C. (2001). Dynamic Characterization of a Seismic Filter. Test Report. University of California, San Diego. USA.

HITEC. 1996. "Guidelines for the Testing of Seismic Isolation and Energy Dissipating Devices," Report Prepared by the Highway Innovative Technology Evaluation Center, Civil Engineering Research Foundation, CERF