Appendix E

Comparison between Experimental and Numerical Results

E.1 Introduction

In this appendix the complete set of results of the tests made at the Laboratory of Structural Dynamics of the Bristol University at Bristol, UK, are presented.

At first, the data concerning the input signals are displayed for both models. Besides, the sliding forces used in each numerical simulation are also shown. Next, the displacement time-histories are plotted (numerical and experimental results), as well as the hysteresis loops (experimental and numerical results).

E.2 SSMFD Input Data

Table E.2 summarizes the input signals used in the tests for the single-story model. These signals are plotted along with the displacement responses in Figs. E.1a, E.3a and E.5a. The sliding forces shown in Table E.2 are those used in the numerical simulation. Note that in the case of the sine-dwell signal it was necessary to use different values $F_{\max}$ and $F_{\min}$ (positive and negative, respectively) since equal minimum and maximum sliding forces did not reproduce accurately the experimental hysteresis loops in this case (see Fig. E.2).

Input	**Frequency (Hz)**	*PGA*	**Sampling period (s)**	**Total duration (s)**
Sine-dwell	4.0	$0.298g$	0.0025	12.5
Northridge Earthquake		$0.396g$	0.0050	15.0
San Fernado Earthquake		$0.452g$	0.0050	15.0

Table E.1 Inputs and sliding forces for the SSMFD

Input	Sliding force used in ALMA (N)	
	Minimum	Maximum
Sine-dwell	-1127.81	853.21
Northridge Earthquake	-686.49	686.49
San Fernado Earthquake	-686.49	686.49

Table E.2 Inputs and sliding forces for the SSMFD

Input	Frequency (Hz)	PGA	Sampling period (s)	Total duration (s)
Sine-dwell 1	4.0	$0.265g$	0.0050	12.5
Sine-dwell 2	2.0	$0.146g$	0.0050	22.5
Northridge Earthquake		$0.242g$	0.0050	15.0
San Fernado Earthquake		$0.347g$	0.0050	15.0
Artificial Earthquake		$0.159g$	0.00375	15.0

Table E.3 Inputs and sliding forces for the TSMFD

E.3 TSMFD Input data

Table E.4 shows the main characteristics for the input signals used in the tests for the two-story model. These signals are plotted along with the displacement responses in Figs. E.7a, E.11a, E.15a, E.19a and E.23a. The artificial acceleration was obtained by using the spectrum obtained in [67]. The sliding forces shown in Table E.4 are those used in the numerical simulation. As in the case of the sine-dwell of the SSMFD, for the TSMFD the sine-dwell 2 and the artificial earthquake signals required different positive and negative values $F_{\max}$ and $F_{\min}$ to reproduce the experimental response more accurately (see Figs. E.12, E.14, E.24 and E.26).

E.4 Results

Figs. E.1 to E.26 show the comparison between displacement responses and hysteresis loops for the two tested rigs. The convention used for the latter is: positive values of friction forces

Input	Sliding force used in ALMA (N)			
	First floor		Second floor	
	Minimum	Maximum	Minimum	Maximum
Sine-dwell 1	-745.33	745.33	-882.63	882.63
Sine-dwell 2	-813.98	693.30	-657.07	460.93
Northridge Earthquake	-539.39	539.39	-735.53	735.53
San Fernado Earthquake	-470.74	470.74	-882.63	882.63
Artificial Earthquake	-264.79	559.00	-951.28	813.98

Table E.4 Inputs and sliding forces for the TSMFD

correspond to tension in the brace while negative ones mean compression in the brace. Both experimental and numerical results are displayed.

Regarding the displacement responses, the agreement is satisfactory. On the other hand, the hysteresis loops are sometimes quite similar, but some of them are not. Deeper considerations to be included in the sticking-sliding condition are mentioned in Chapter 5.

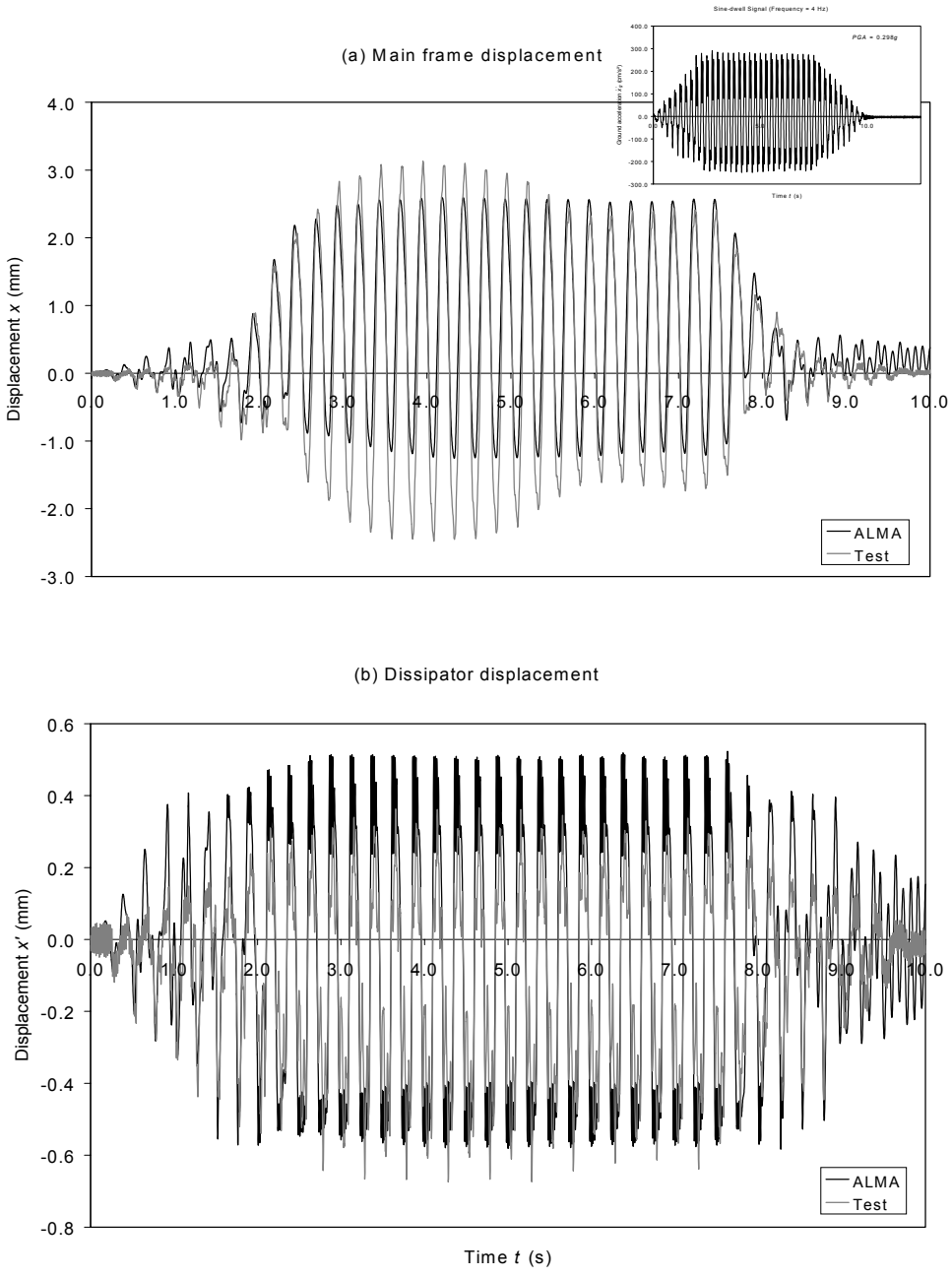

Figure E.1 Comparison between numerical (ALMA) and experimental displacements. Sine-dwell input (4 Hz)

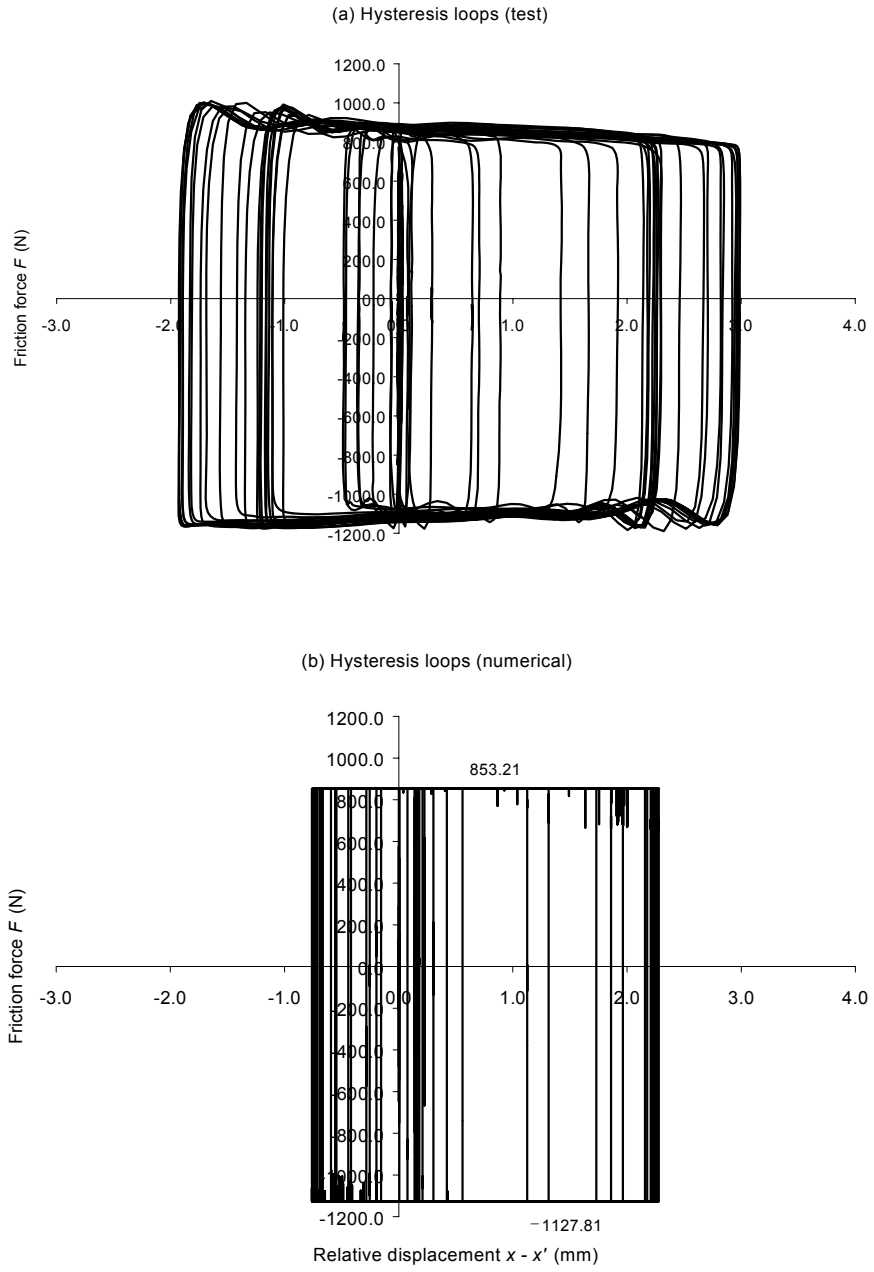

Figure E.2 Comparison between experimental and numerical (ALMA) hysteresis loops. Sine-dwell input (4 Hz)

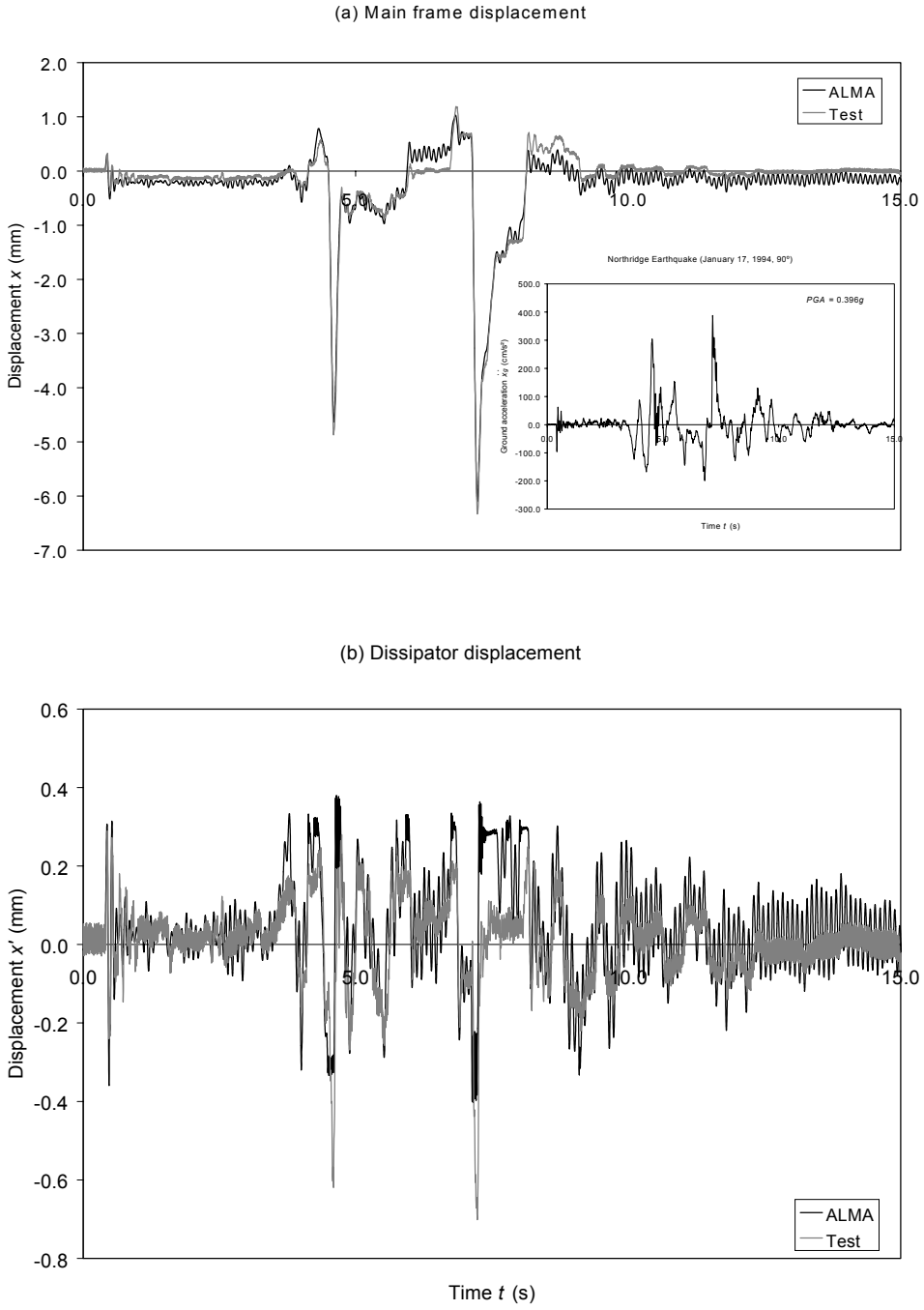

Figure E.3 Comparison between numerical (ALMA) and experimental displacements. Northridge earthquake

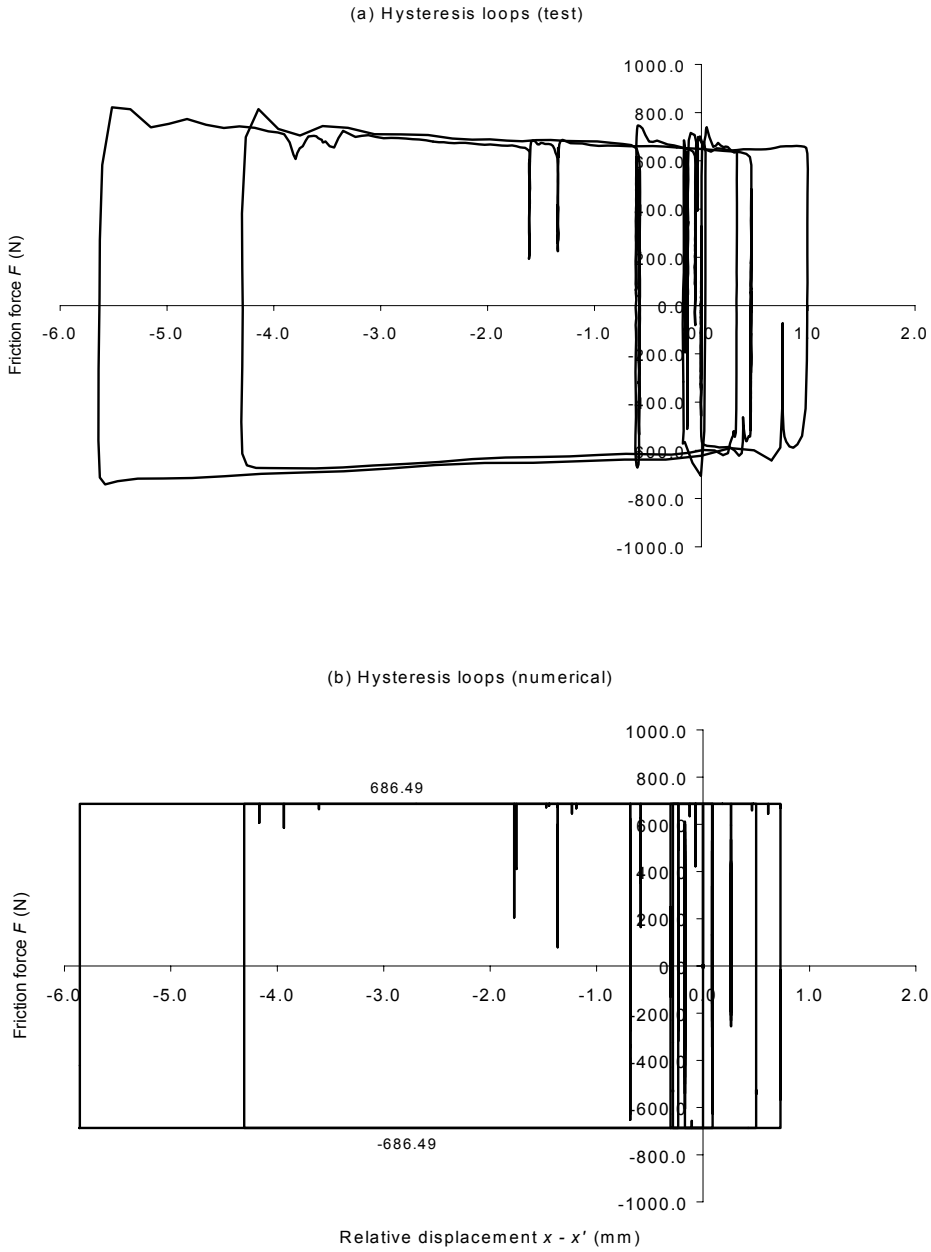

Figure E.4 Comparison between experimental and numerical (ALMA) hysteresis loops. Northridge earthquake

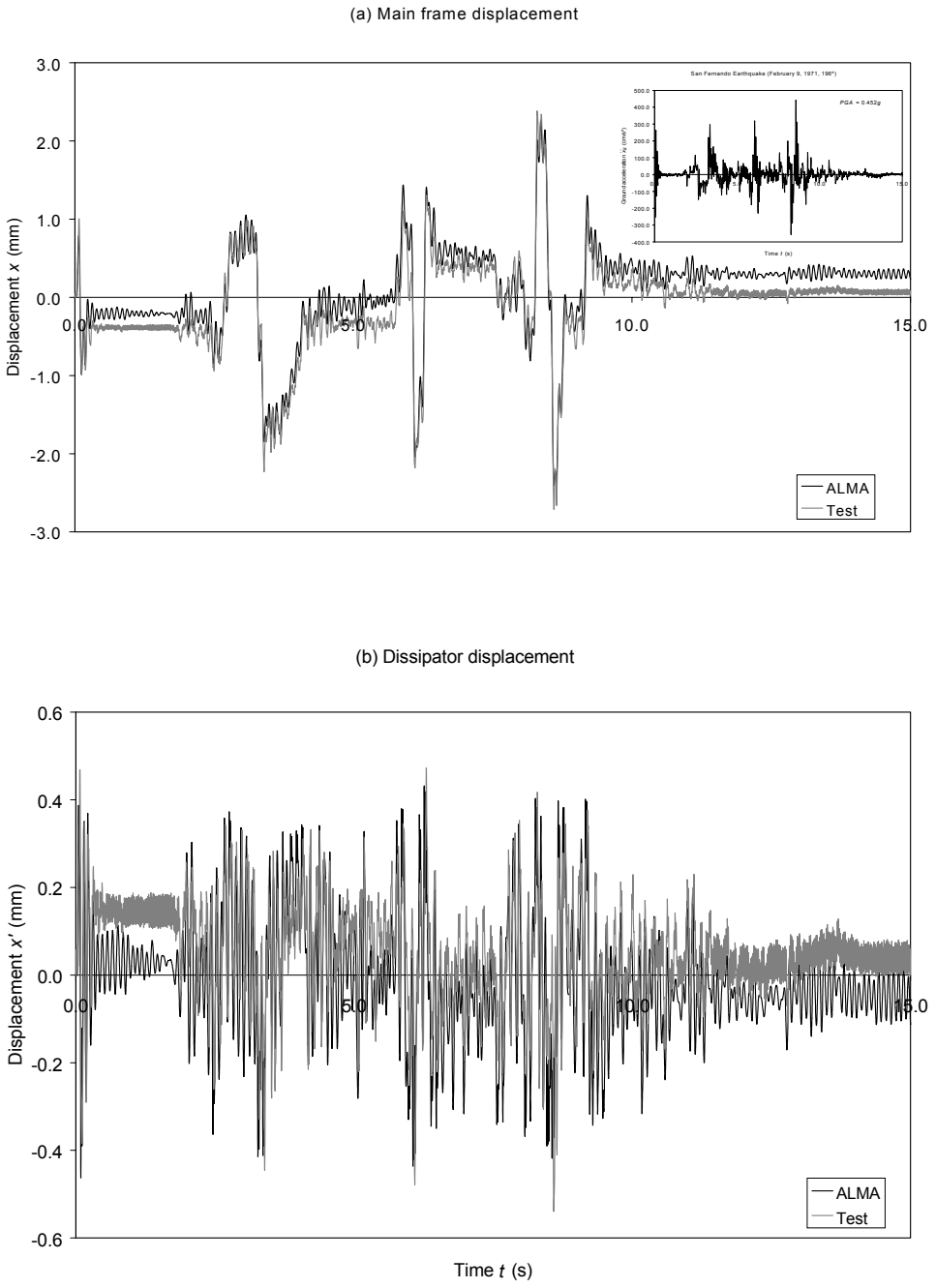

Figure E.5 Comparison between numerical (ALMA) and experimental displacements. San Fernando earthquake

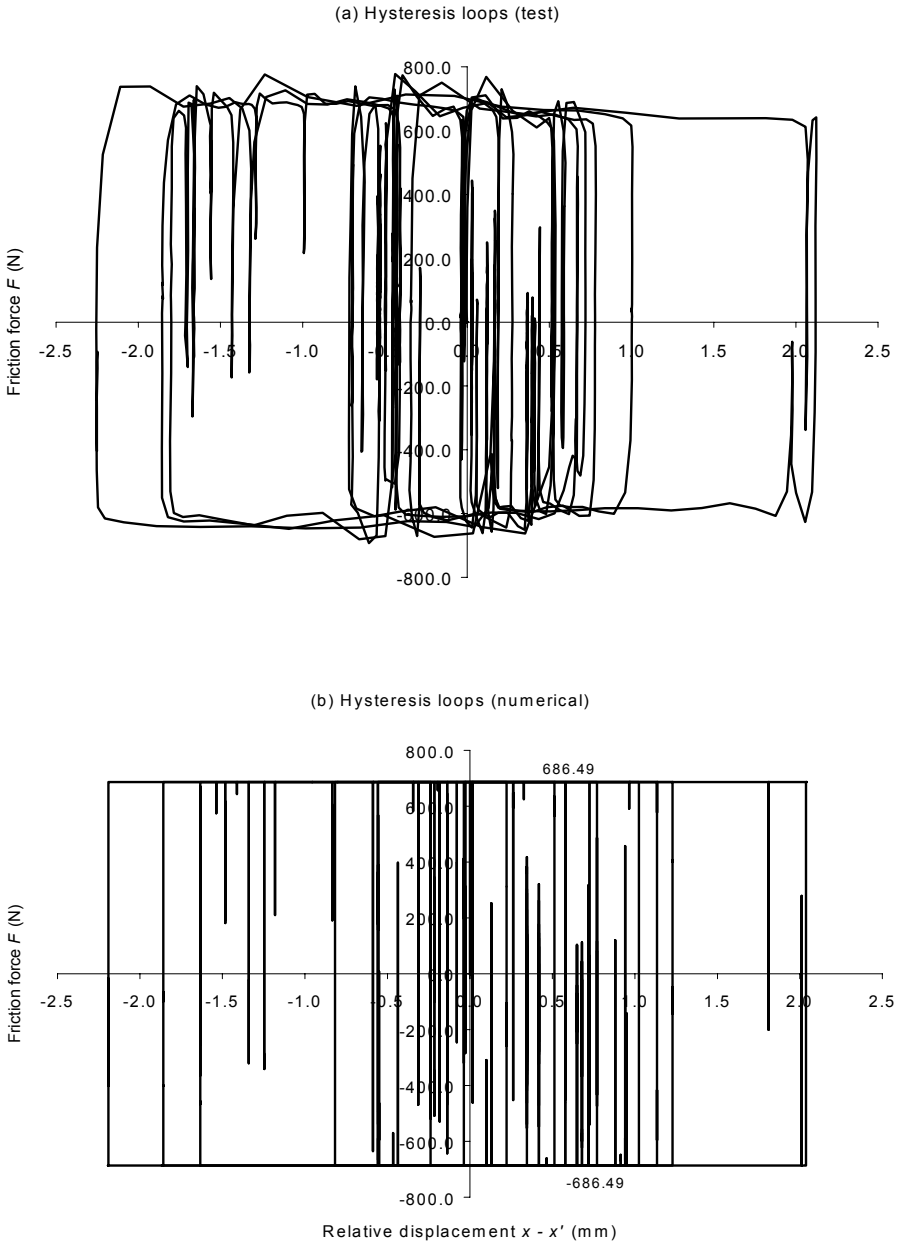

Figure E.6 Comparison between experimental and numerical (ALMA) hysteresis loops. San Fernando earthquake

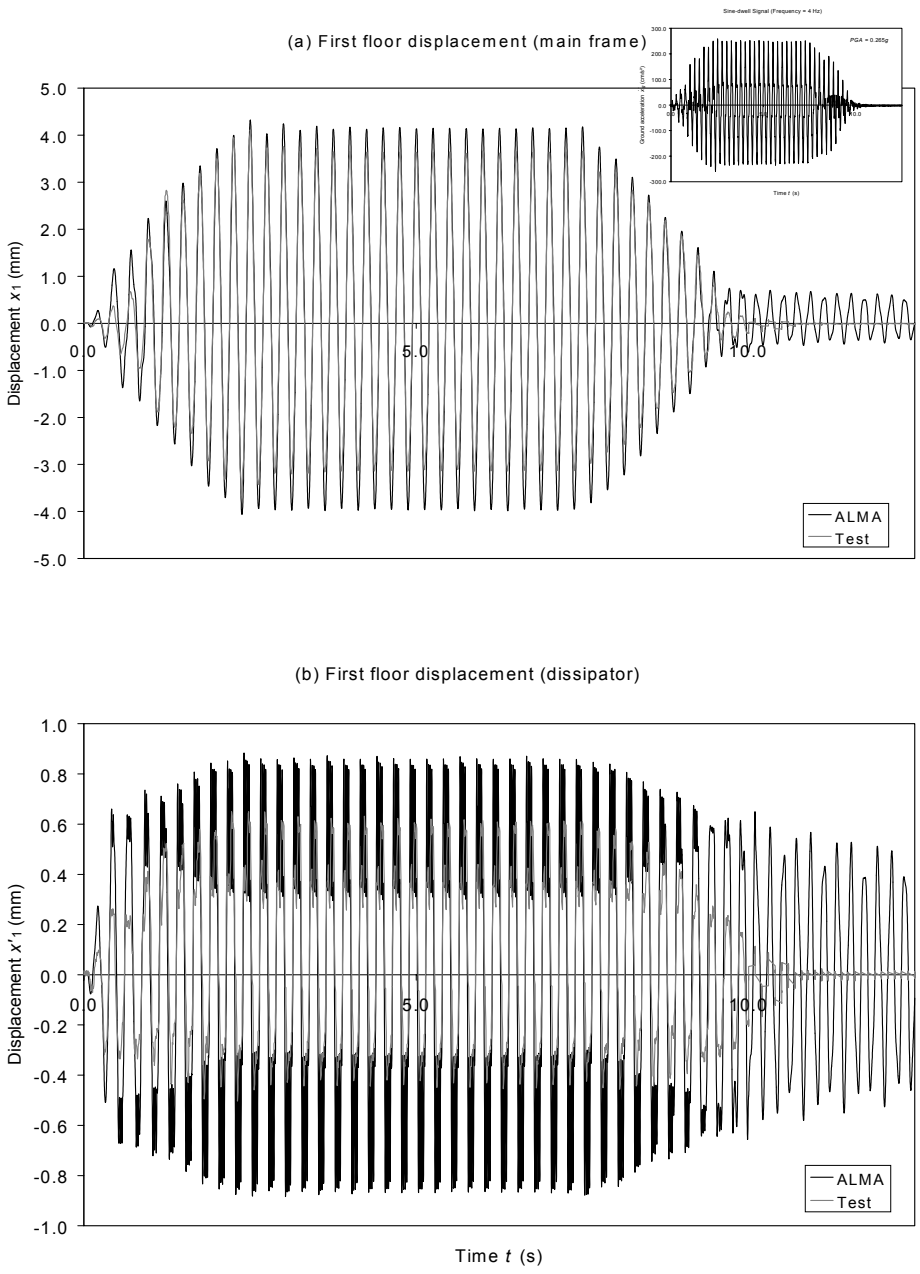

Figure E.7 Comparison between numerical (ALMA) and experimental first floor displacements. Sine-dwell (4 Hz)

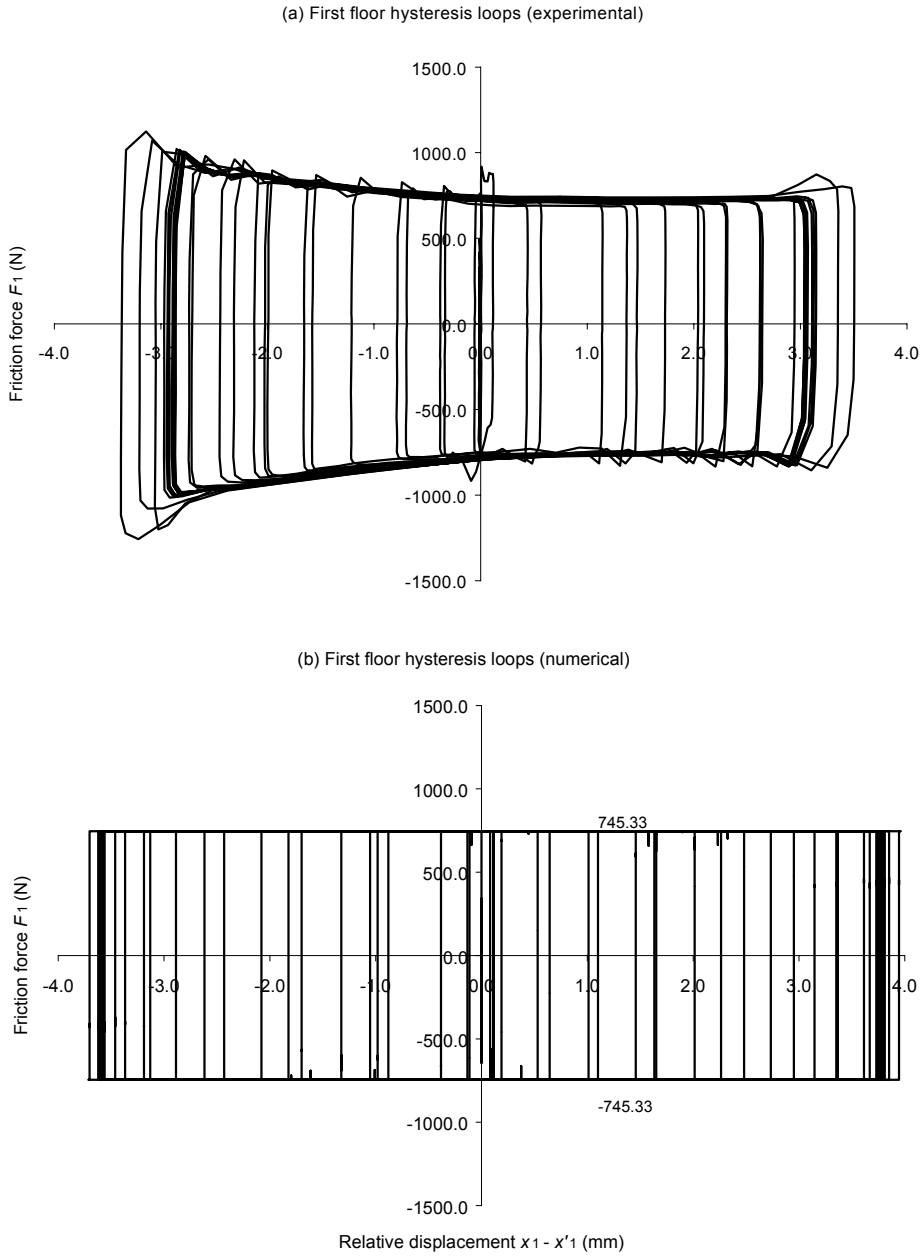

Figure E.8 Comparison between experimental and numerical (ALMA) first floor hysteresis loops. Sine-dwell (4 Hz)

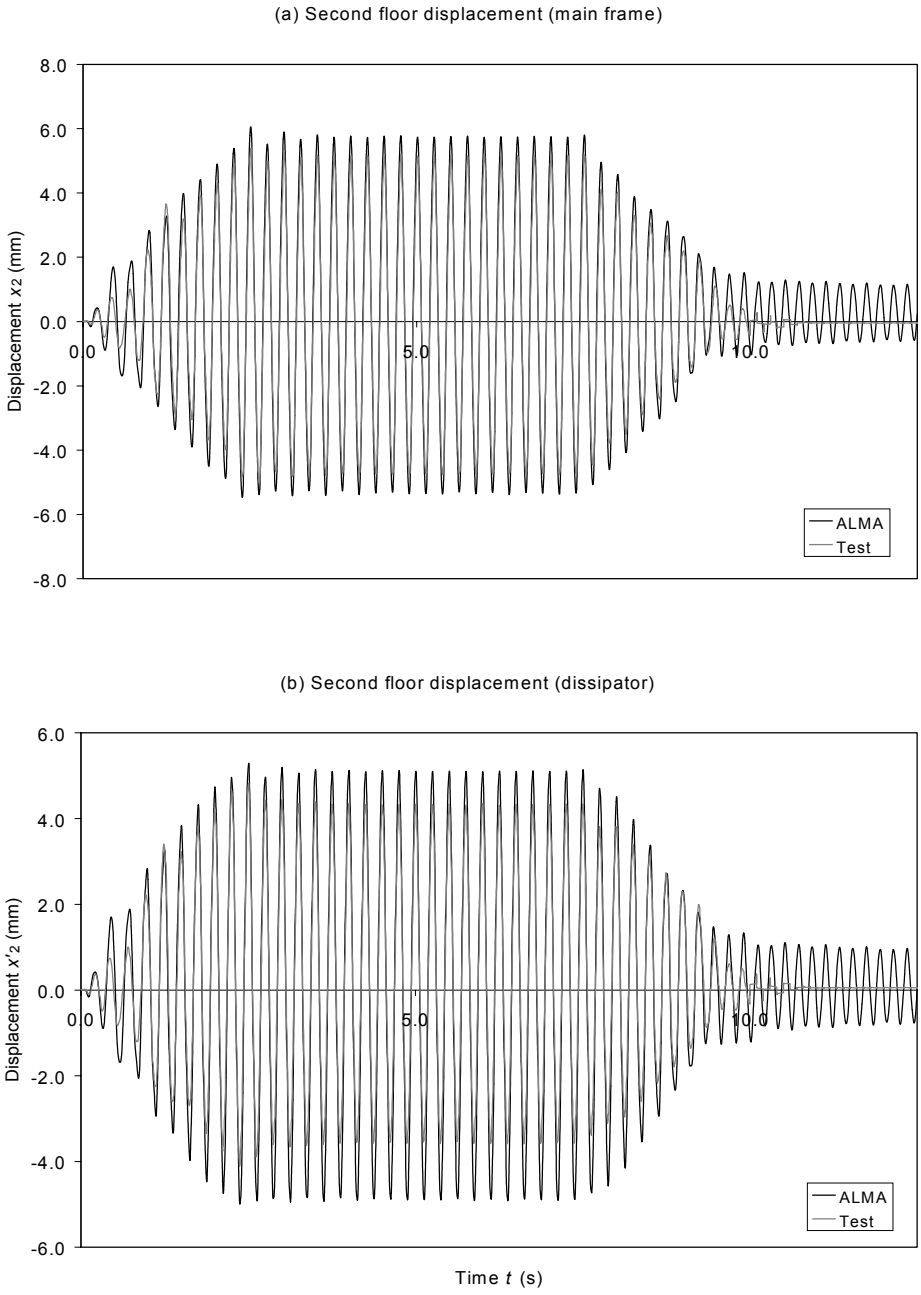

Figure E.9 Comparison between numerical (ALMA) and experimental second floor displacements. Sine-dwell (4 Hz)

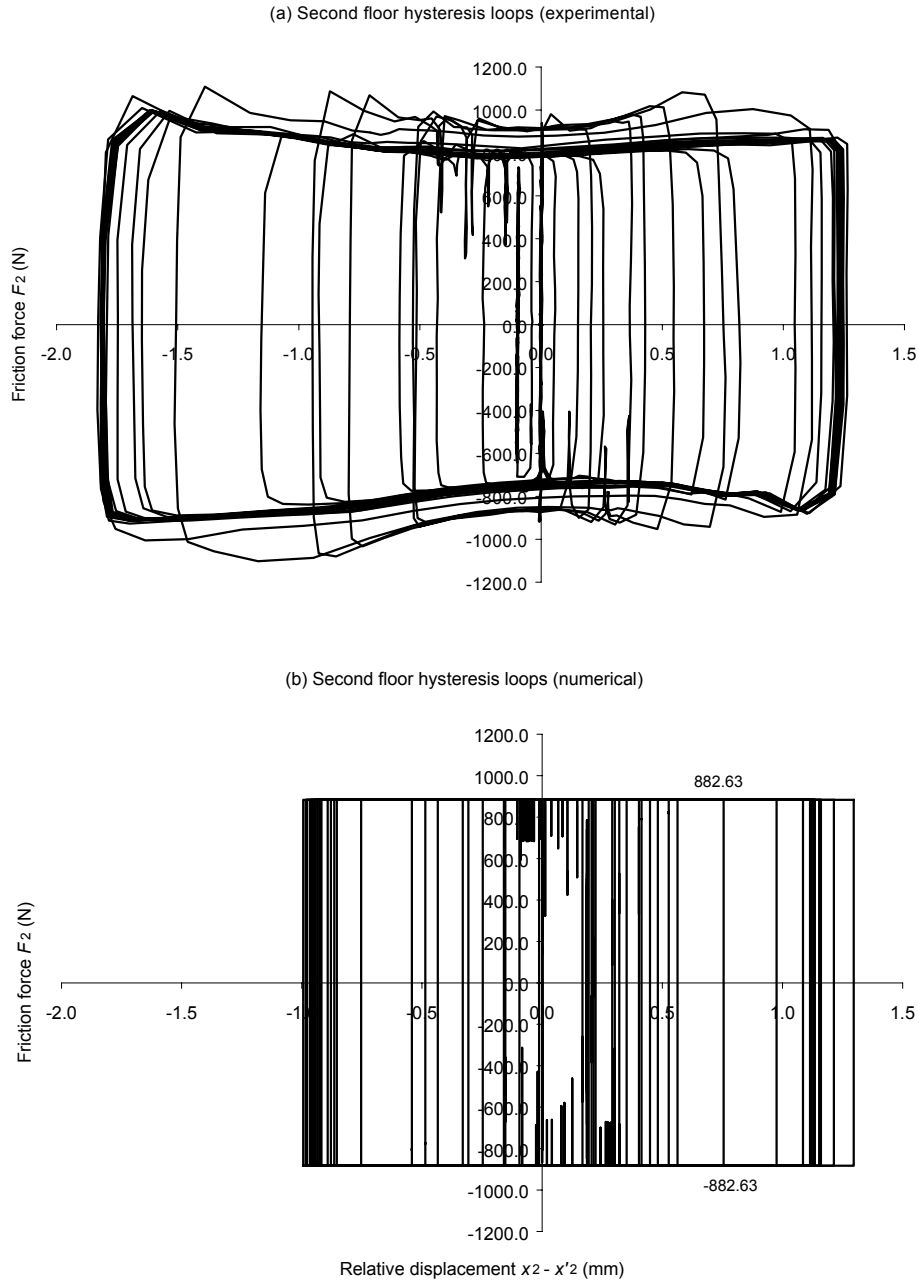

Figure E.10 Comparison between experimental and numerical (ALMA) second floor hysteresis loops. Sine-dwell (4 Hz)

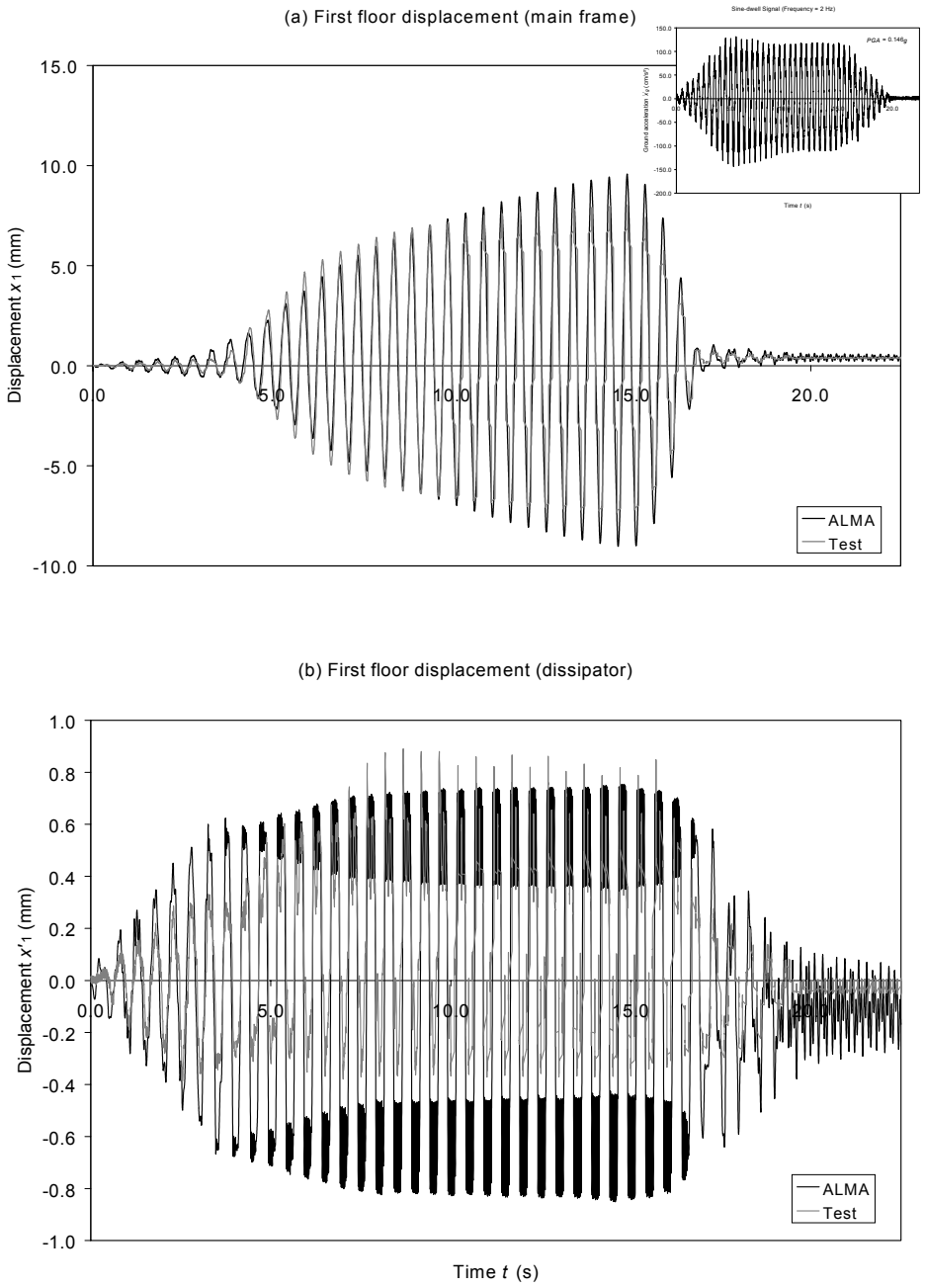

Figure E.11 Comparison between numerical (ALMA) and experimental first floor displacements. Sine-dwell (2 Hz)

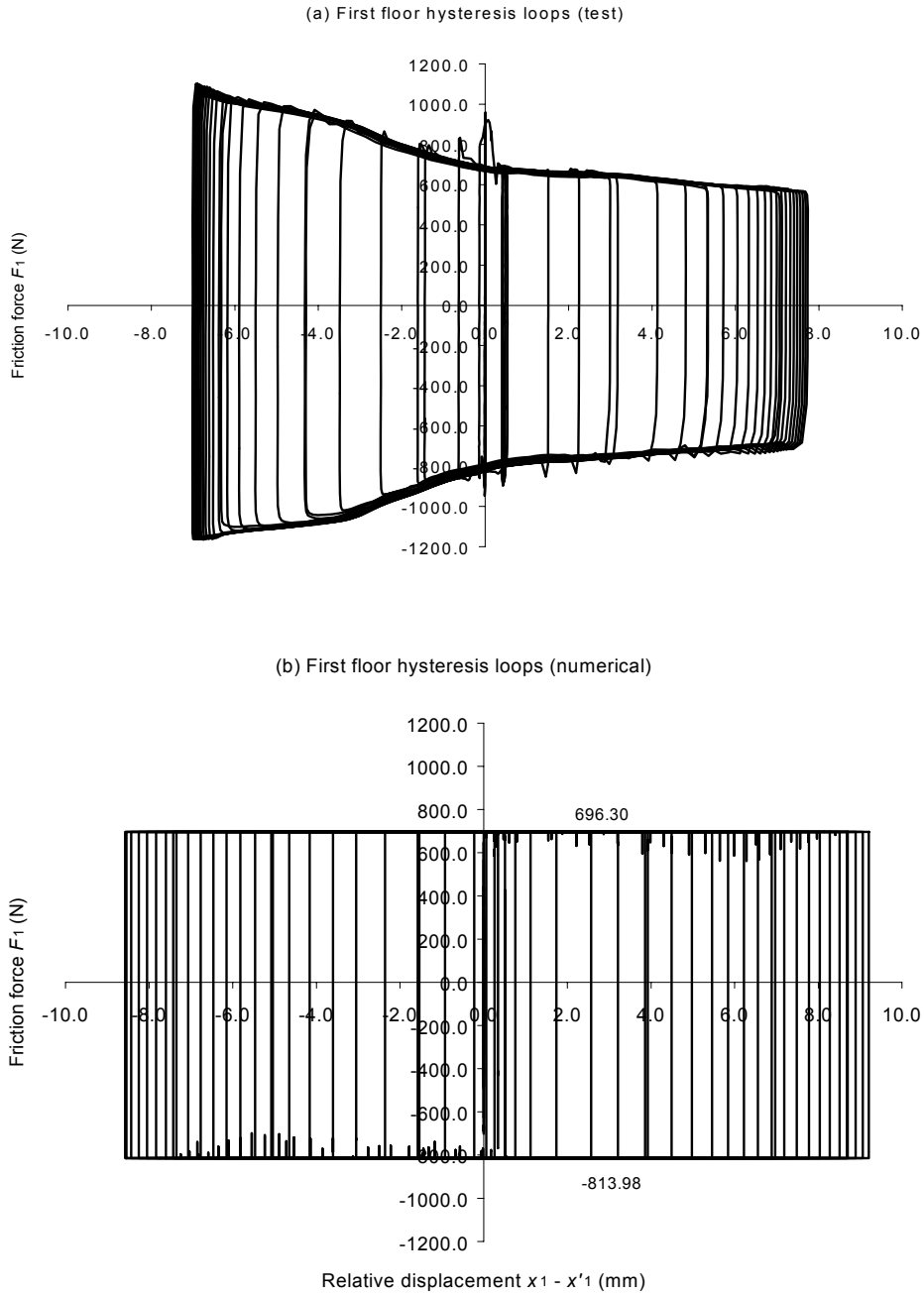

Figure E.12 Comparison between experimental and numerical (ALMA) first floor hysteresis loops. Sine-dwell (2 Hz)

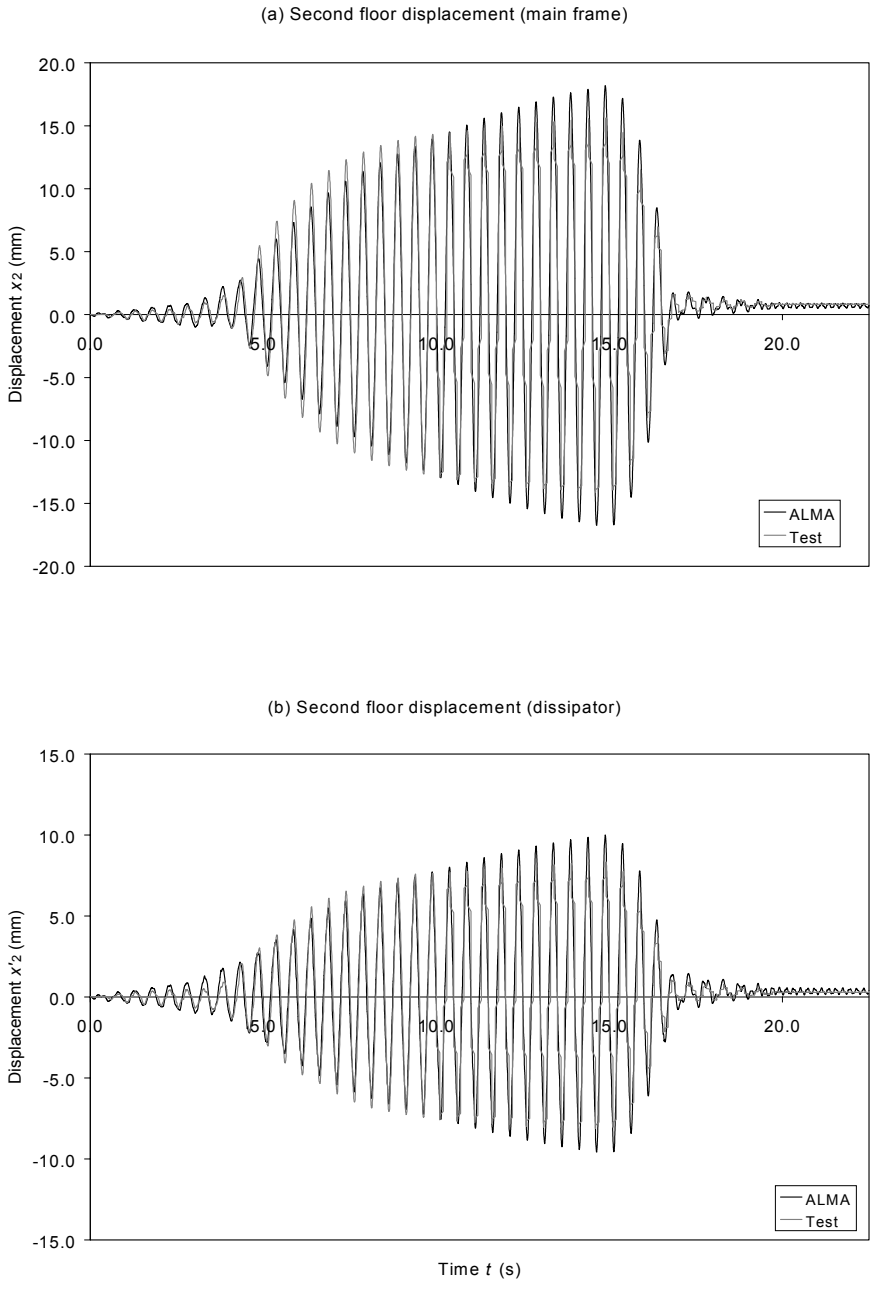

Figure E.13 Comparison between numerical (ALMA) and experimental second floor displacements. Sine-dwell (2 Hz)

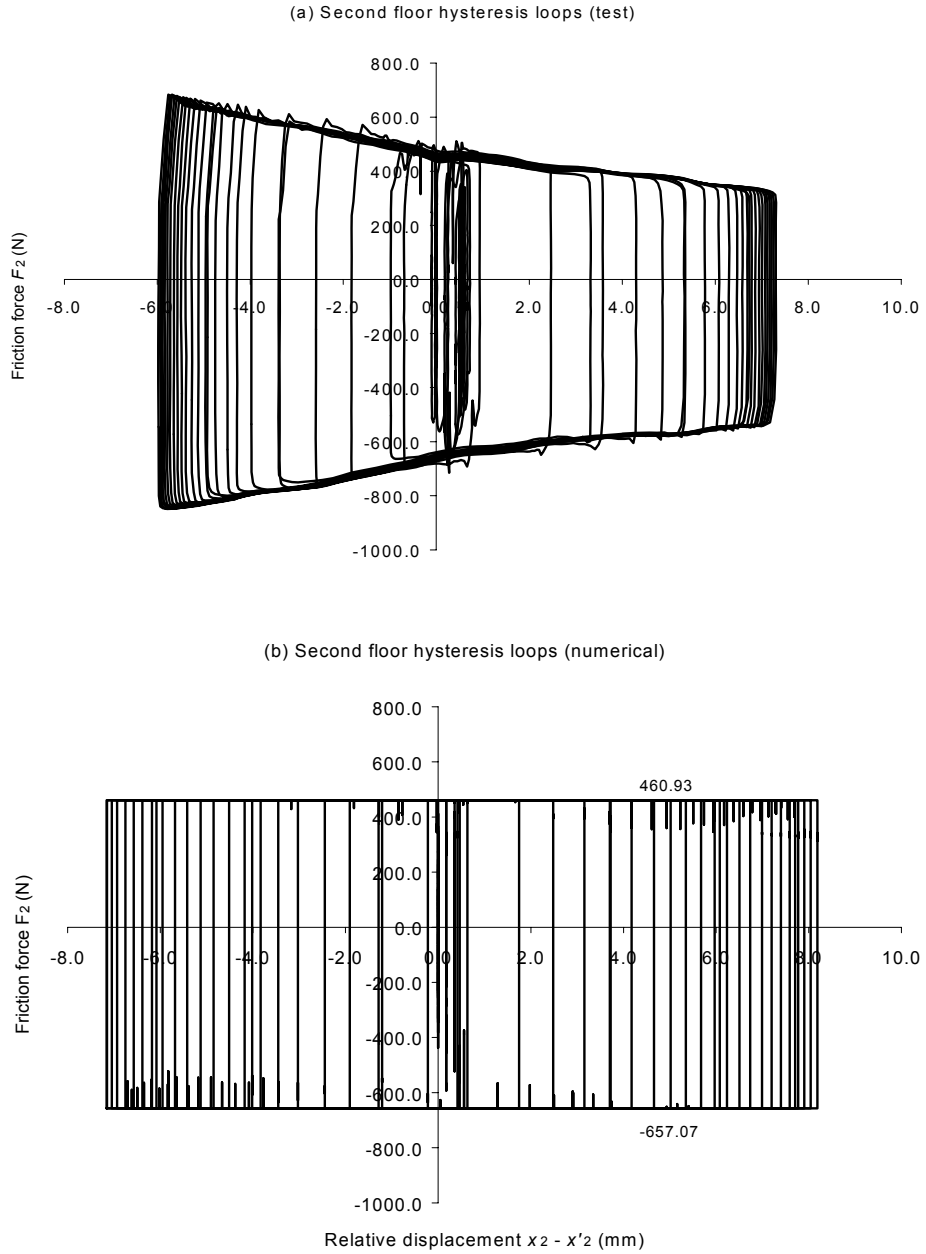

Figure E.14 Comparison between experimental and numerical (ALMA) second floor hysteresis loops. Sine-dwell (2 Hz)

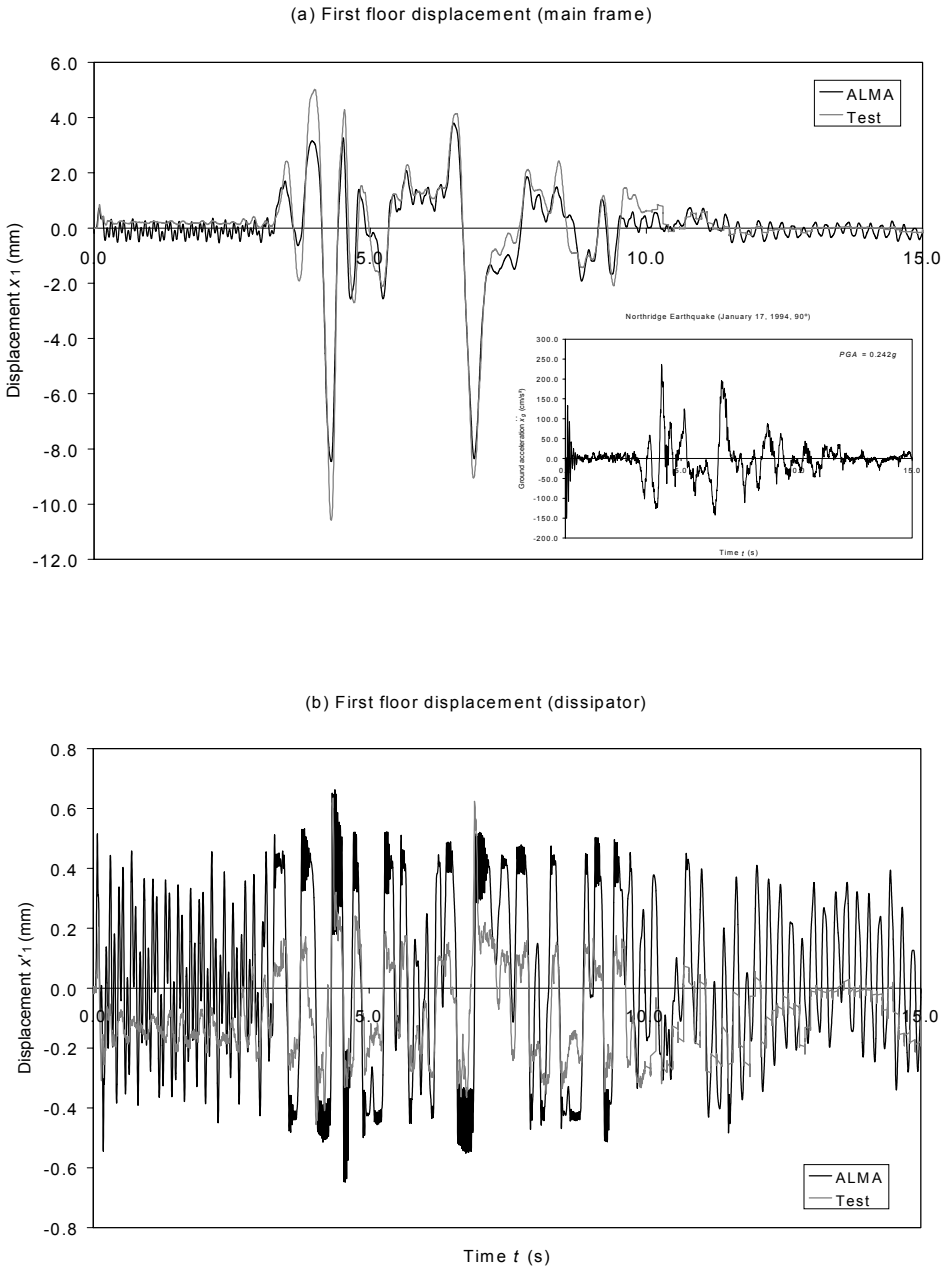

Figure E.15 Comparison between numerical (ALMA) and experimental first floor displacements. Norhridge earthquake

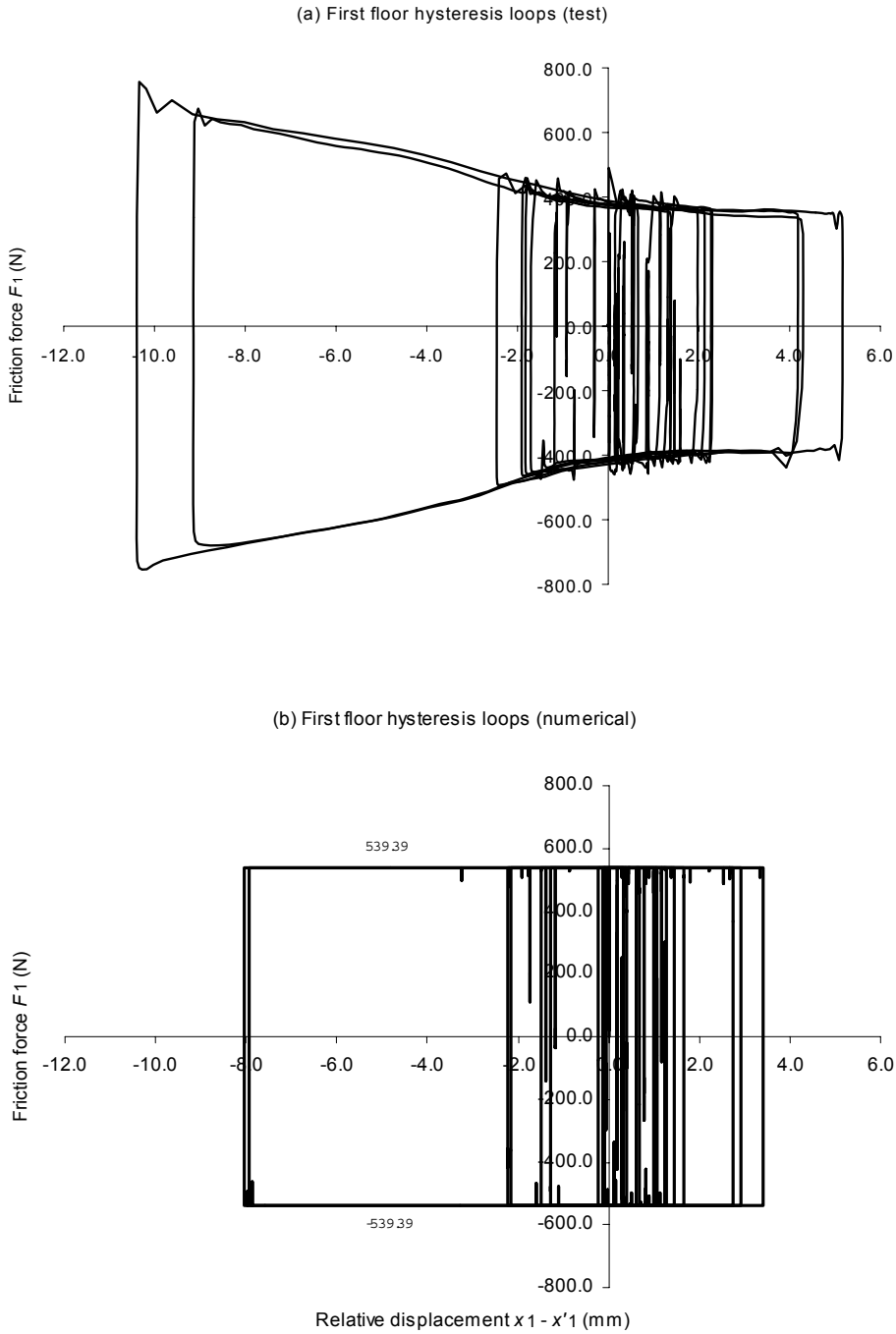

Figure E.16 Comparison between experimental and numerical (ALMA) first floor hysteresis loops. Norhridge earthquake

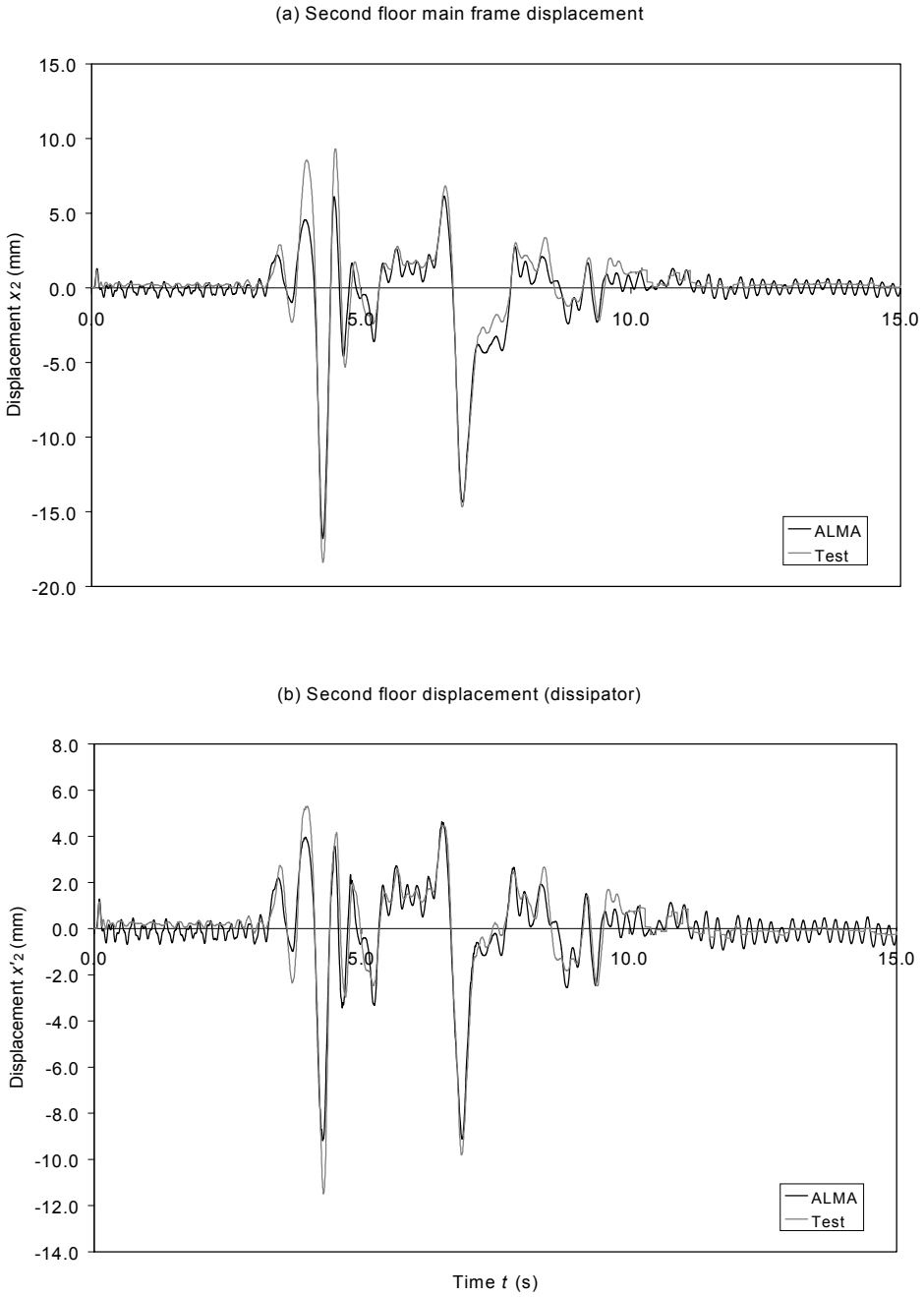

Figure E.17 Comparison between numerical (ALMA) and experimental second floor displacements. Norhridge earthquake

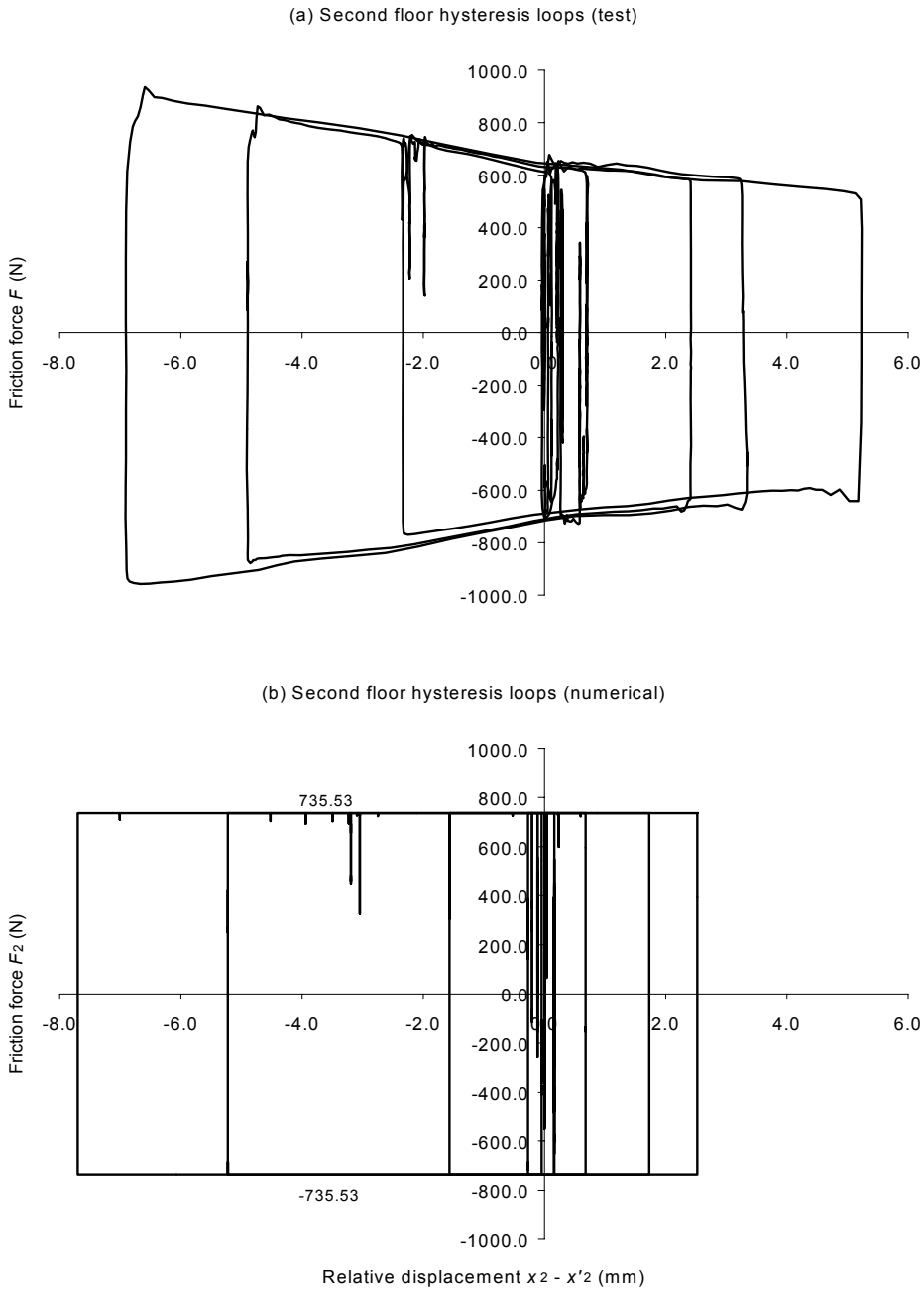

Figure E.18 Comparison between experimental and numerical (ALMA) second floor hysteresis loops. Norhridge earthquake

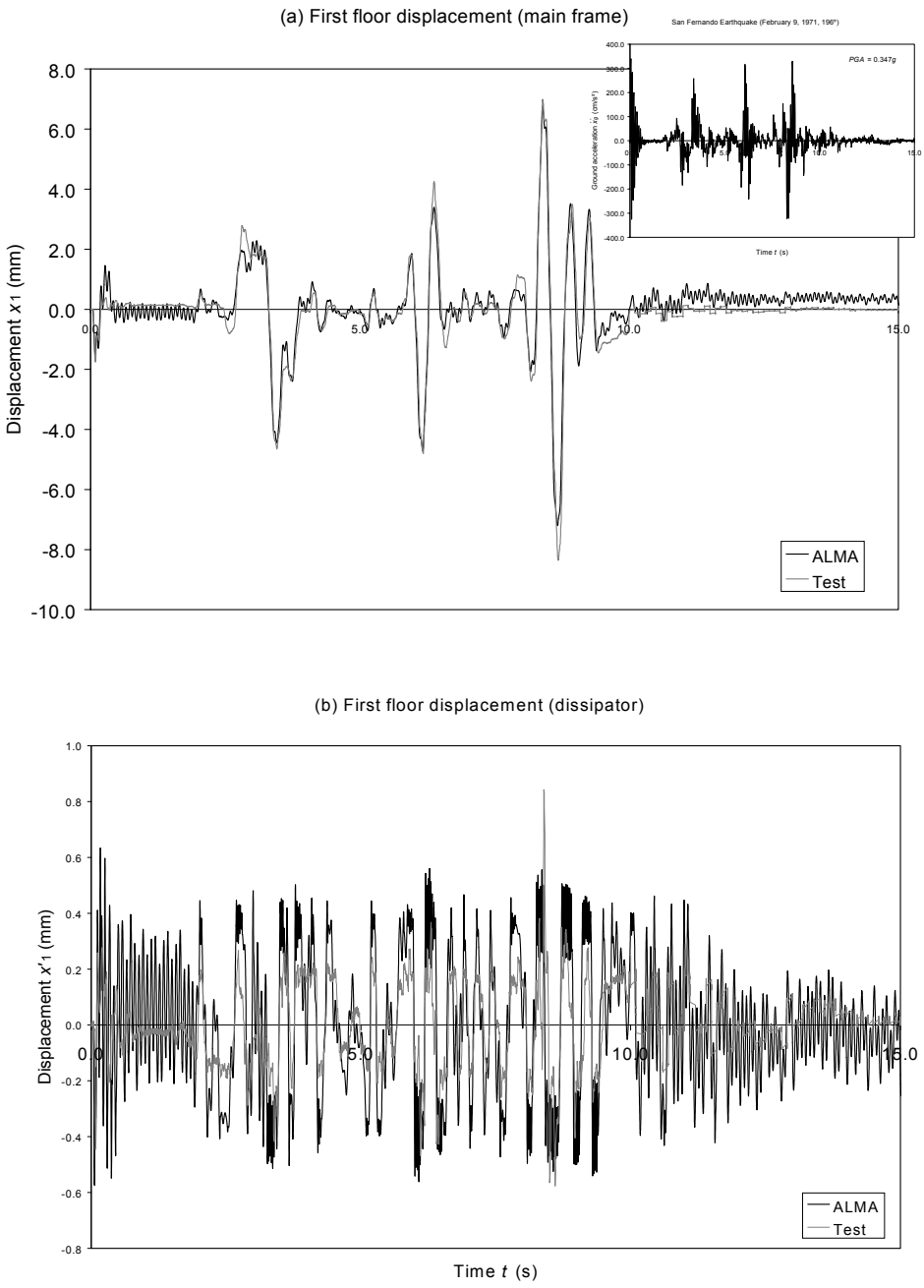

Figure E.19 Comparison between numerical (ALMA) and experimental first floor displacements. San Fernando earthquake

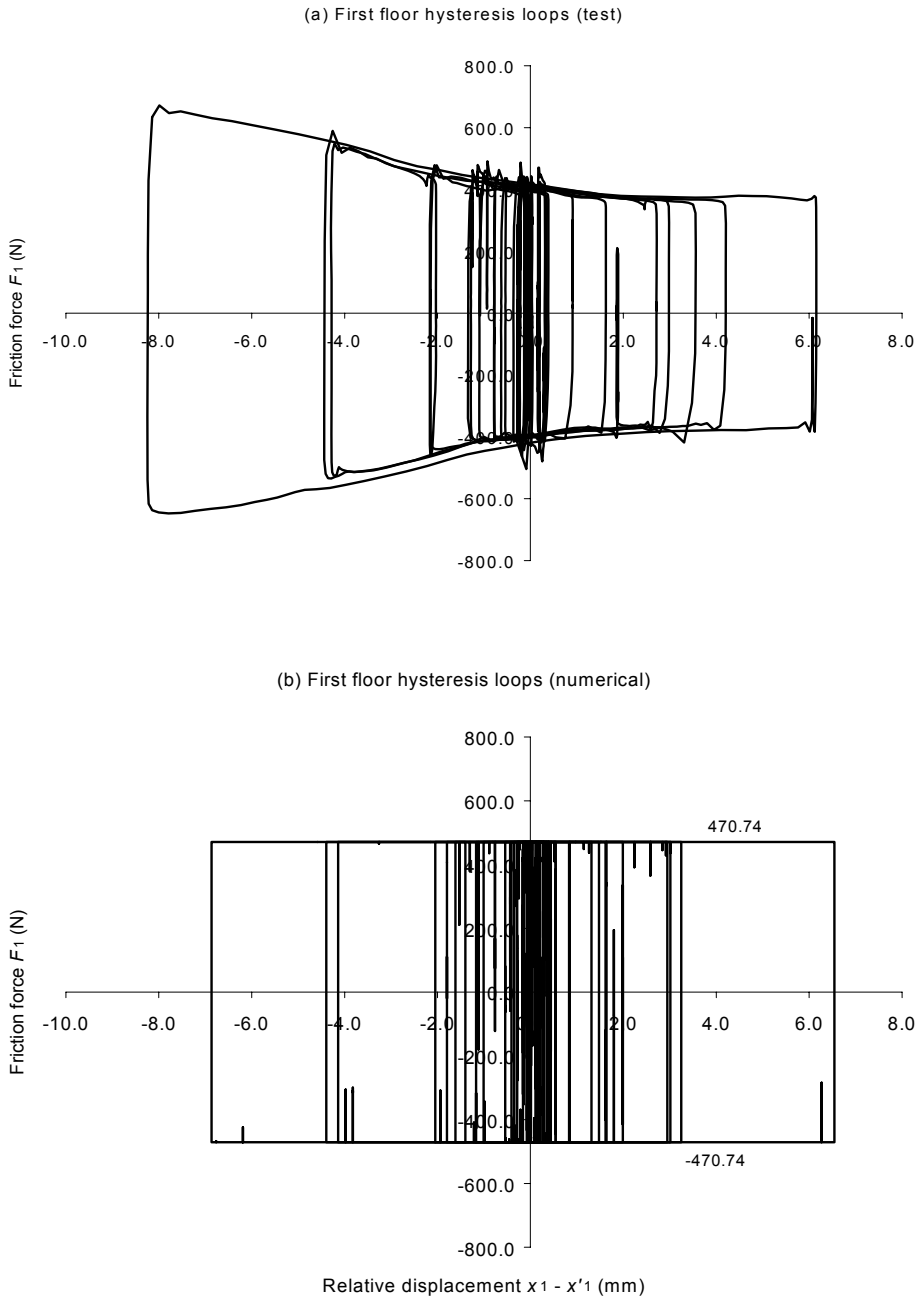

Figure E.20 Comparison between experimental and numerical (ALMA) first floor hysteresis loops. San Fernando earthquake

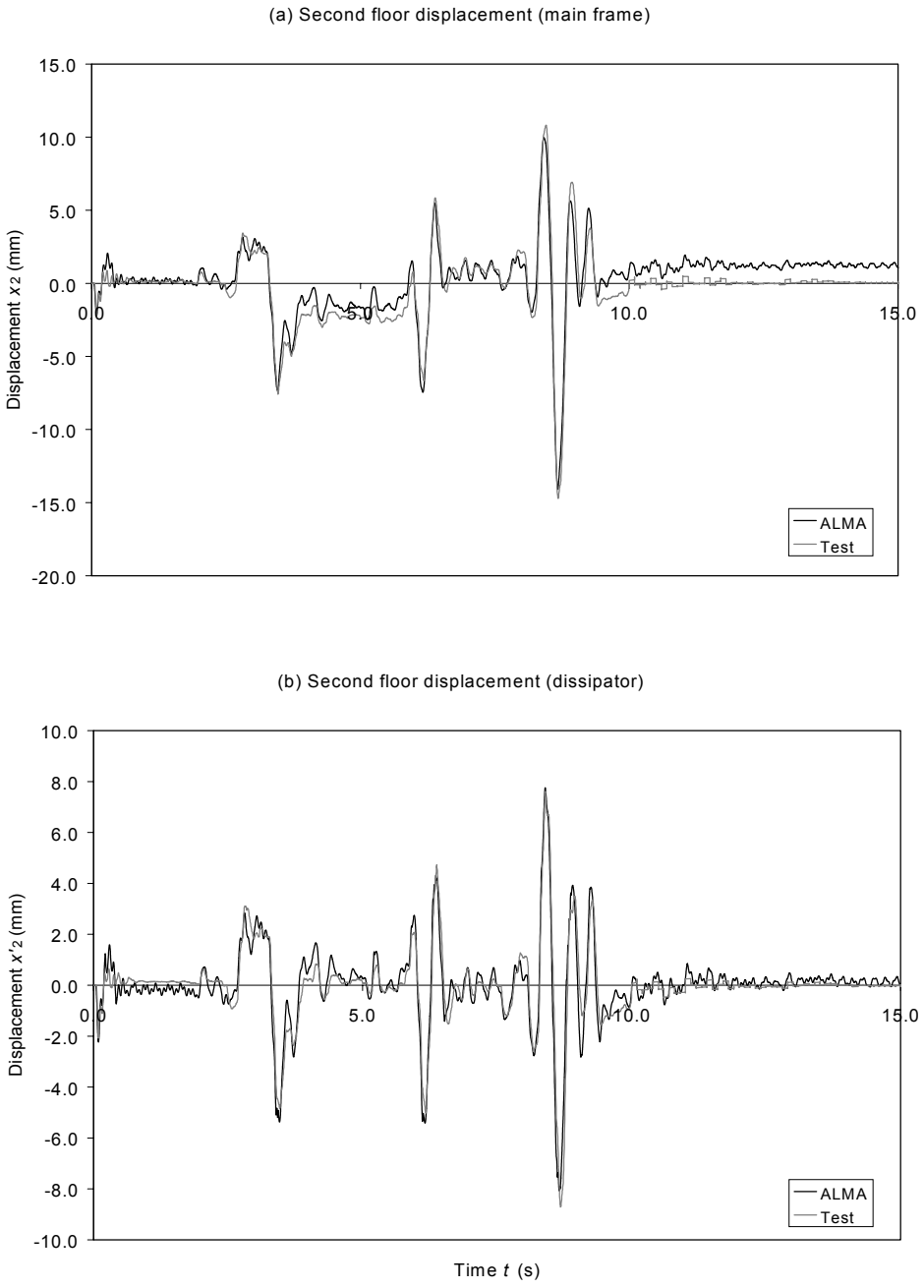

Figure E.21 Comparison between numerical (ALMA) and experimental second floor displacements. San Fernando earthquake

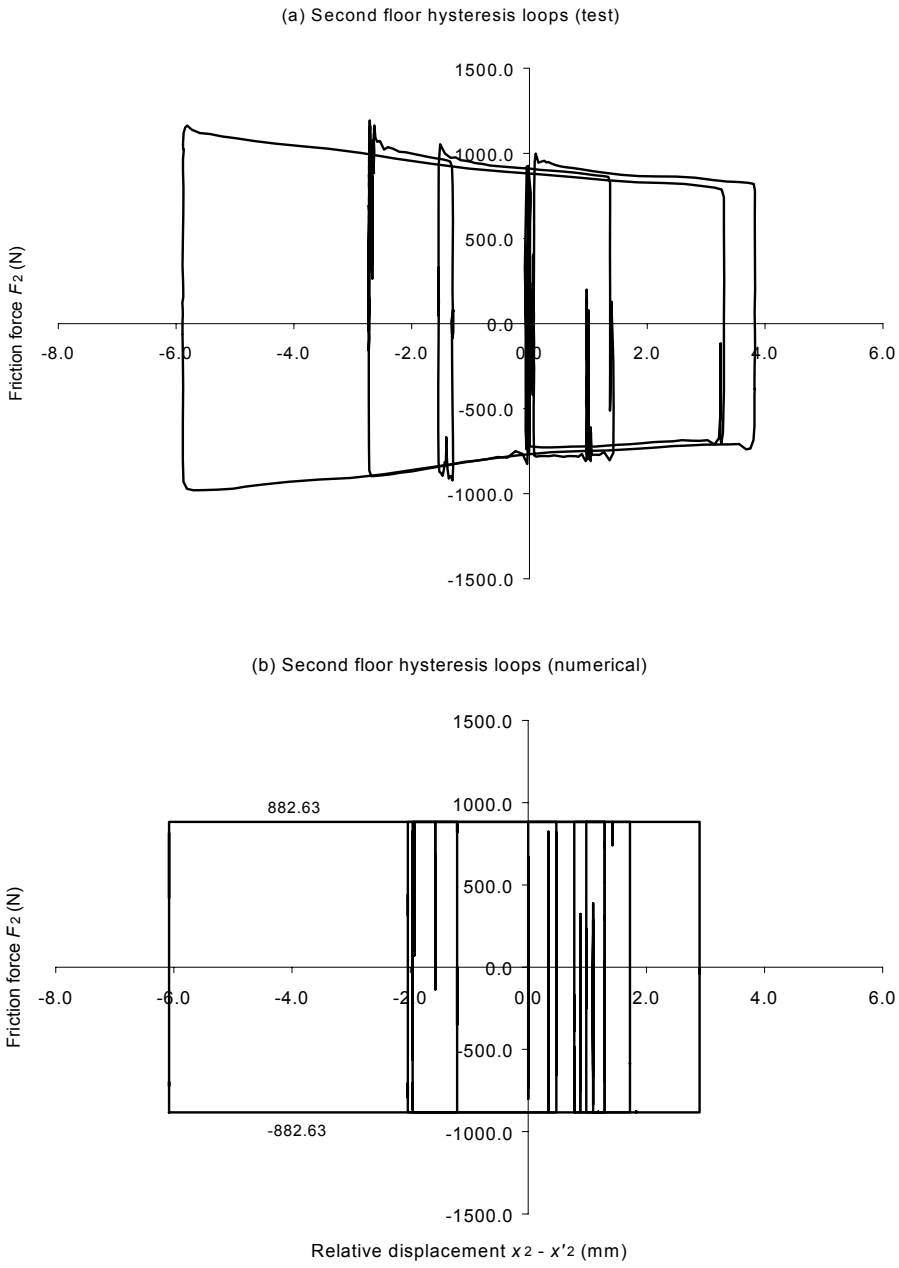

Figure E.22 Comparison between experimental and numerical (ALMA) second floor hysteresis loops. San Fernando earthquake

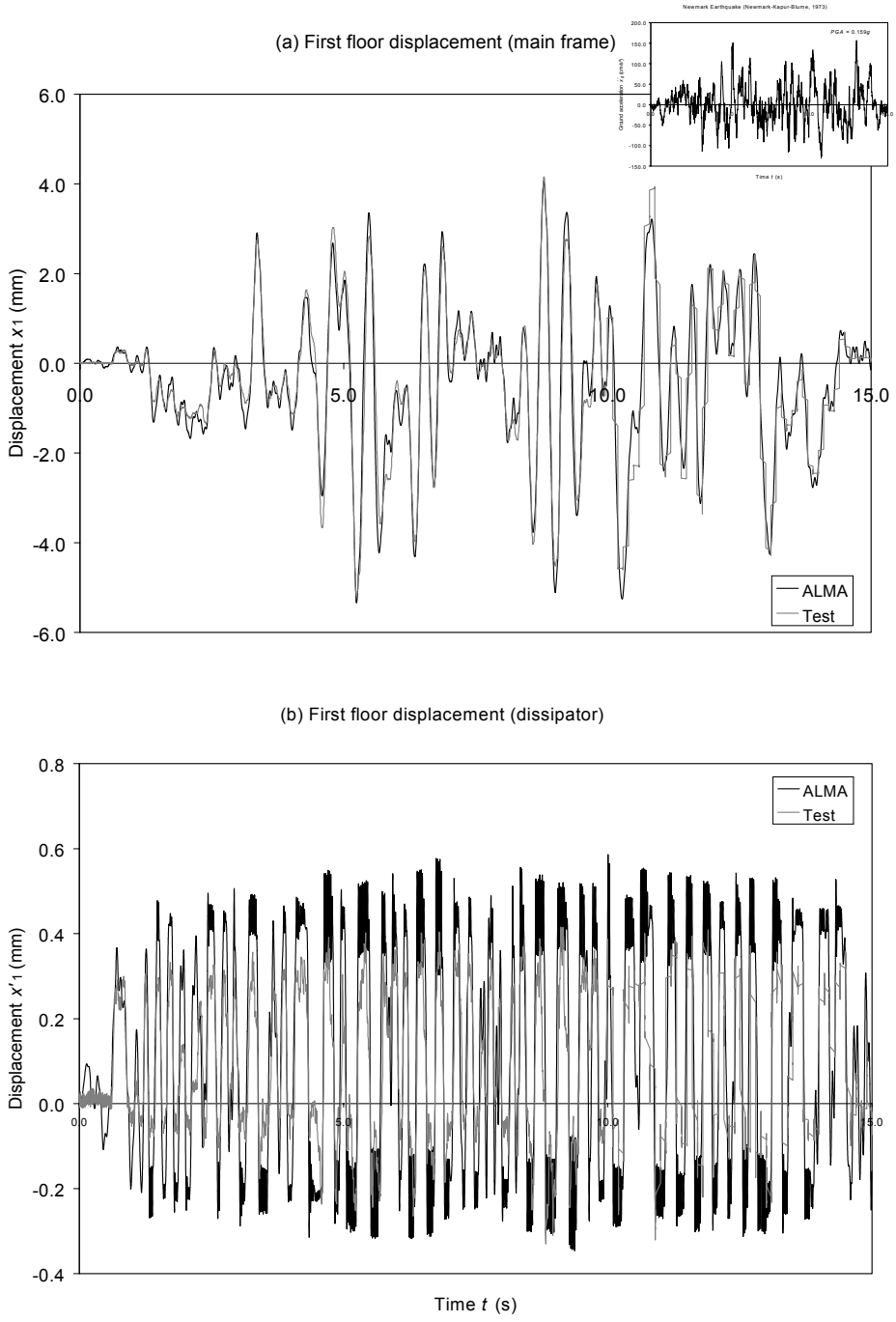

Figure E.23 Comparison between numerical (ALMA) and experimental first floor displacements. Artificial accelerogram

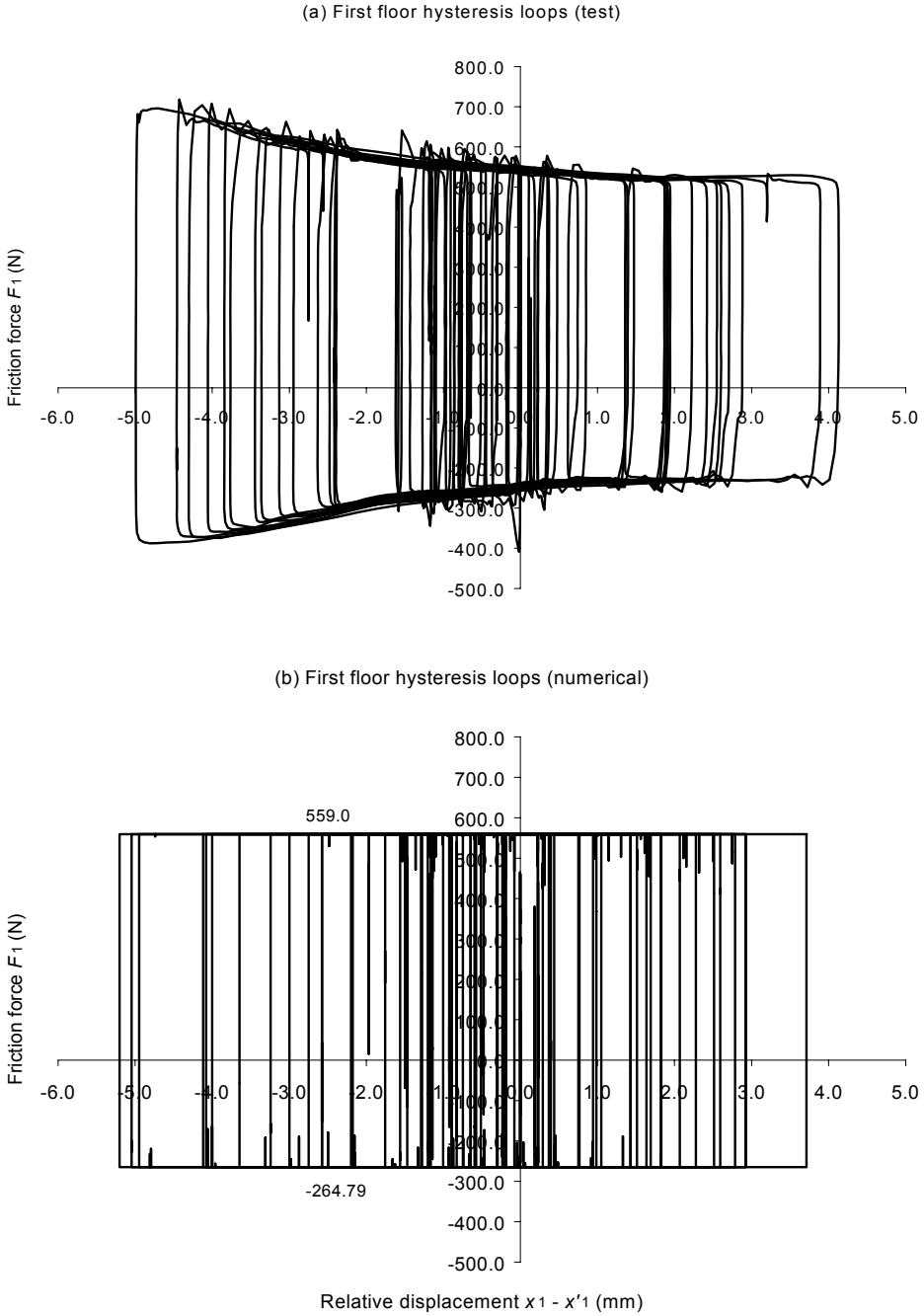

Figure E.24 Comparison between experimental and numerical (ALMA) first floor hysteresis loops. Artificial accelerogram

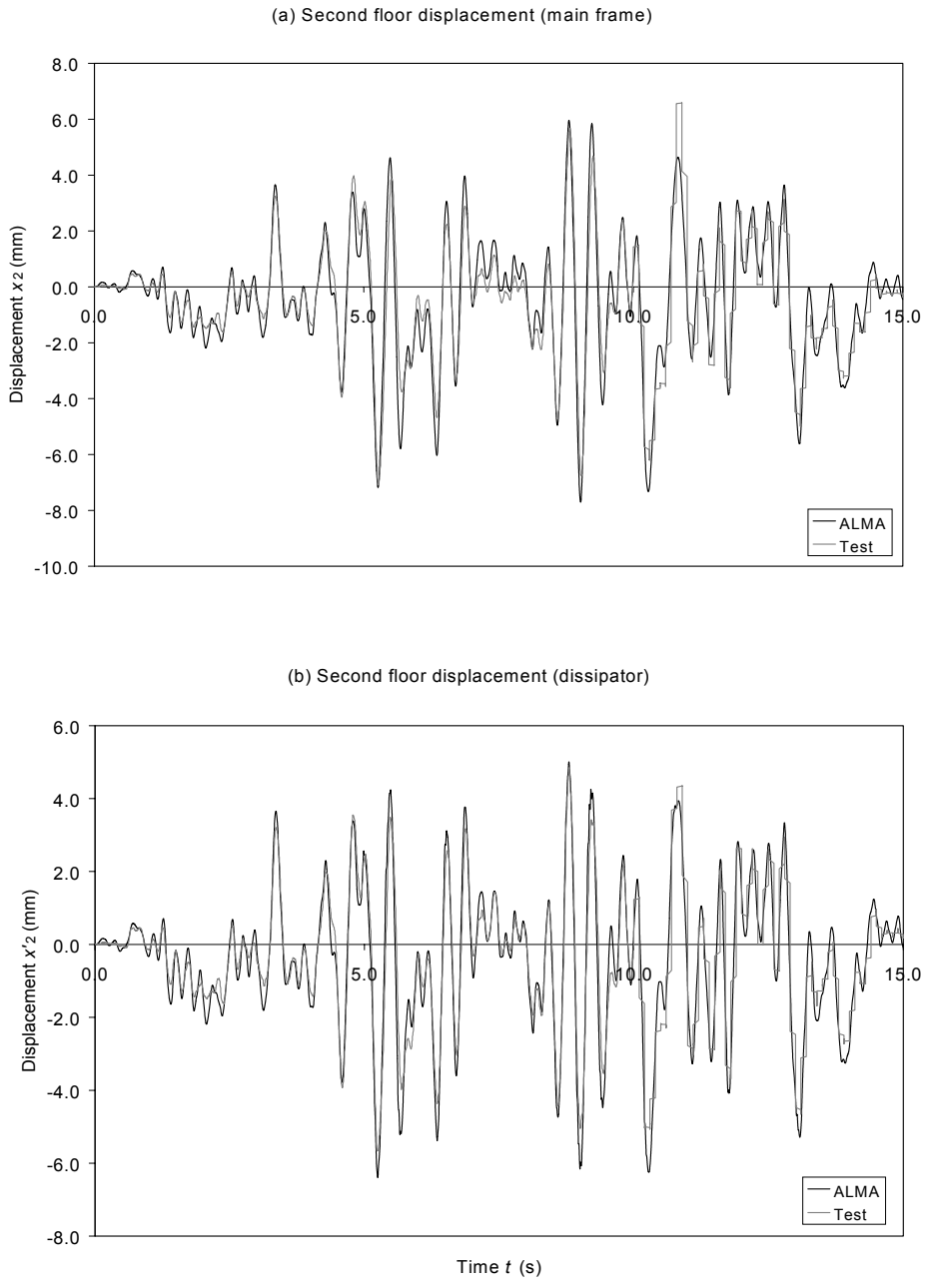

Figure E.25 Comparison between numerical (ALMA) and experimental second floor displacements. Artificial accelerogram

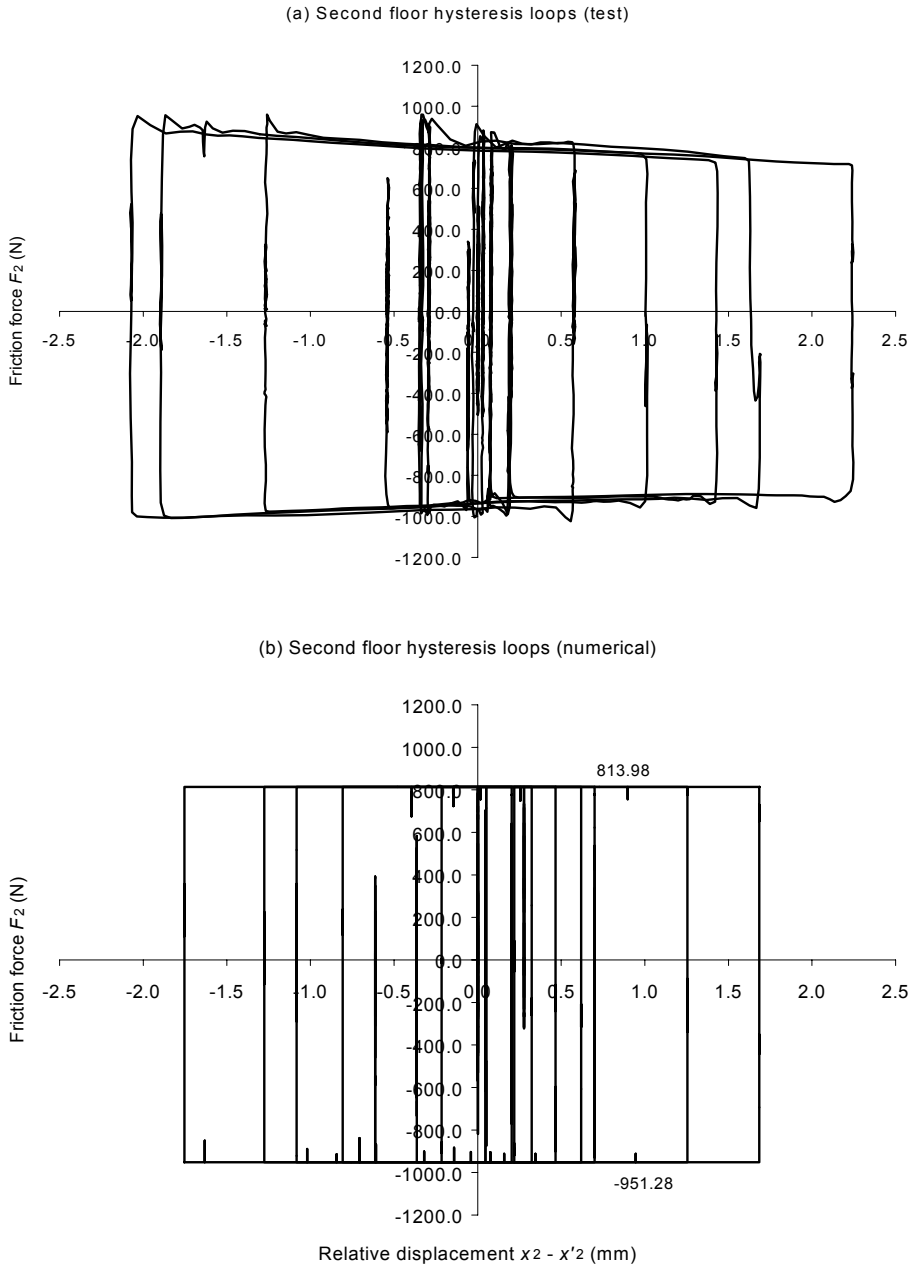

Figure E.26 Comparison between experimental and numerical (ALMA) second floor hysteresis loops. Artificial accelerogram