3. TESTING PROGRAM

3.1 Introduction

The testing program for this thesis consisted of 11 wood shear wall test panels. The dimensions and specific construction details are listed in Table 3.1, and CAD drawings of each group of panels are shown in Appendix B. Table 3.1 demonstrates how the initial panels using standard construction practices were tested and then the remaining panels were sequentially modified to correct areas that were failing at the lowest applied displacements in the previous testing.

The testing program was set up to investigate how sequential modifications could be made to strengthen the shear panel. First, test panels were constructed with standard methods of construction. Panels 1, 2, 3, and 5 were tested in Group I. This configuration was tested to obtain a baseline force deformation relationship (hysteresis loop) under cyclical loading to determine design loads, elastic and inelastic stiffness, ductility, and overstrength factors and then to compare them to current published design values.
The next group of panels tested had sequential improvements made to the components that failed first during the testing of the Group I specimens. The first modification made to panel 4 was a light gauge metal strap from the hold-down anchor bolt to the end studs (see panel 4, Appendix B). The second modification was made to panel 6 that had blocking installed above the sill plate and fastened to the single sill plate, to allow for two rows of fasteners to be stapled along the base of the panel. This modification combined

Table 3.1 Test Specimen Specifications

Panel #	height	length (ft)	sill plate	top plate	end studs	sheathing	Staples**
Panel 1	8'	4	(1) 2x4	(1) 2x4	(2) 2x4	7/16 OSB	16 GA
Panel 2	8'	4	(1) 2x4	(1) 2x4	(2) 2x4	7/16 OSB	16 GA
Panel 3	8'	4	(1) 2x4	(1) 2x4	(2) 2x4	7/16 OSB	16 GA
Panel 4	8'	4	(1) 2x4	(1) 2x4	(2) 2x4	7/16 OSB	16 GA
Panel 5	8'	4	(1) 2x4	(1) 2x4	(2) 2x4	7/16 OSB	16 GA
Panel 6	8'	4	(1) 2x4 + blkg*	(1) 2x4	(2) 2x4	7/16 OSB	16 GA
Panel 7	8'	4	(2) 2x4	(2) 2x4	(2) 2x4	7/16 OSB	16 GA
Panel 8	8'	4	(2) 2x4	(2) 2x4	(2) 2x4	7/16 OSB	16 GA
Panel 9	8'	4	(2) 2x4	(2) 2x4	(2) 2x4	7/16 OSB	16 GA
Panel 10	8'	8	(1) 2x4 + blkg*	(1) 2x4 + blkg*	(2) 2x4	7/16 OSB	16 GA
Panel 11	8'	8	(1) 2x4 + blkg*	(1) 2x4 + blkg*	(2) 2x4	7/16 OSB	16 GA

Panel #	A-Bolts******	Hold-downs*** (1) ea end)	Date constructed	Time tested	notes:
Panel 1	(5) 5/8" w/ std washers	PHD 2A	Mar-99	6/14/2001 9:50	Panel was tested as a prelimary panel to
Panel 2	(5) 5/8" w/ std washers	PHD 2A	Mar-99	6/14/2001 9:50	First of three panels tested with no modifications to the framing system
Panel 3	(5) 5/8" w/ std washers	PHD 2A	Mar-99	6/14/2001 13:58	Second of three panels tested with no modifications to the framing system
Panel 4	(5) 5/8" w/ std washers	PHD 2A****	Jun-01	6/14/2001 17:14	First modified panel tested - one modification to the hold-down system
Panel 5	(5) 5/8" w/ std washers	PHD 2A	Jun-01	6/15/2001 10:40	Third of three panels tested with no modifications to the framing system
Panel 6	(5) 5/8" w/ sqr washers*****	PHD 2A****	Mar-99	6/15/2001 15:09	Second modified panel tested - two modifications to the framing system.
Panel 7	(5) 5/8" w/ sqr washers*****	PHD 2A****	Jun-01	6/15/2001 17:51	Third modified panel tested - four modifications to the framing system
Panel 8	(5) 5/8" w/ sqr washers*****	PHD 2A****	Jun-01	6/16/2001 10:37	Fourth modified panel tested - four modifications to the framing system
Panel 9	(5) 5/8" w/ sqr washers*****	PHD 2A****	Jun-01	6/16/2001 13:00	Fifth modified panel tested - four modifications to the framing system
Panel 10	(8) 5/8" w/ sqr washers*****	PHD 2A****	Mar-99	6/16/2001 17:07	First 8' panel with all four framing modifications
Panel 11	(8) 5/8" w/ sqr washers*****	PHD 2A****	Mar-99		First 8' panel with all four framing modifications

* on these panels blocking was installed between the studs at the top and sill plate levels so allow for (2) rows of staples.
All bolcking was face nailed to the plates below, or above, and the anchor bolts, and holds ran thru the blocking.
** All fasteners were 16 GA x 1/2" crown width x 2" in length. Spacing was 6" in the field, and 2 1/2" inches to all panel edges, w/ two rows to panel edges with double studs or plates.
*** PHD2A hold downs were provided by Simpson Strong Tie Inc. Ea hold down was fastened to end studs w/ (10) SDS 1/4 x 3 screws. End studs were face nailed together w/ 10d common nails, (0.148" Φx3") @ 6" o/c.
**** A ST6236 strap was added to the ends of the specimens by placing it over the hold down anchor and bending around the end of the wall. The strap was then nailed to the end studs on the out side.
***** square washers were 2"x2"x3/16" thk, between abolt nut and wood sill.
****** (1) of the 5/8" A-Bolts were used for each hold-down anchor typ.

with the first modification was made to panel 6. The last three 4′ panels (7, 8 & 9) were constructed with double sill plates, double top plates with the additional hold-down straps on each end and square washers.

The final group of panels were two 8′ x 8′ panels with blocking along top and bottom plates, a strap on each end and hold-downs at each end. Square washers were used at all anchor bolts (panels 10 & 11 Appendix B). All of the test elements were tested in accordance with AC130, ICBO's acceptance criteria for wood-framed shear walls. Hysteresis loops were recorded for all of the panels. These data will allow design loads, elastic stiffness, inelastic stiffness, yield loads, ultimate loads, ductility, and overstrength factors to be calculated for each configuration tested.

3.2 Test Procedures and Goals

The test panels were subjected to cyclical loads in accordance with AC130 and SEAOSC's *Standard Method of Cyclic (Reversed) Load Test for Shear Resistance of Framed Walls in Buildings*. The only deviation from SEAOSC's protocol was that the actuator was run at 2 Hz instead of the maximum 1 Hz specified in SEAOSC. This decision was made based on running the test at 2 Hz and determining that the actuator used was capable of running at this high frequency with acceptable inertial affects. The test criterion was based on a percentage of the first major event (FME). The FME is the yield point of the panels and the assumed yield displacement of the 4′ panels was 1″. This assumption was based on previous tests (Rose 1998) on 8′ wide panels and then extrapolating the yield point for 4′ wide panels. The actual test displacement programmed into the actuator for the tests is shown in Table 3.2.

Table 3.2 Structural Engineers Association of Southern California Test Protocol

Cycle No.	% of FME	Test displ. (inches)	Cycle No.	% of FME	Test displ. (inches)	Cycle No.	% of FME	Test displ. (inches)	Cycle No.	% of FME	Test displ. (inches)
0	0	0.000	17	125	1.250	38	200	2.000	59	350	3.500
1	25	0.250		-125	-1.250		-200	-2.000		-350	-3.500
	-25	-0.250		94	0.940		150	1.500		263	2.630
	25	0.250	18	-94	-0.940	39	-150	-1.500	60	-263	-2.630
2	-25	-0.250		63	0.630		100	1.000		175	1.750
	25	0.250	19	-63	-0.630	40	-100	-1.000	61	-175	-1.750
3	-25	-0.250		31	0.310		50	0.500		88	0.880
	50	0.500	20	-31	-0.310	41	-50	-0.500	62	-88	-0.880
4	-50	-0.500		125	1.250		200	2.000		350	3.500
	50	0.500	21	-125	-1.250	42	-200	-2.000	63	-350	-3.500
5	-50	-0.500		125	1.250		200	2.000		350	3.500
	50	0.500	22	-125	-1.250	43	-200	-2.000	64	-350	-3.500
6	-50	-0.500		125	1.250		200	2.000		350	3.500
	75	0.750	23	-125	-1.250	44	-200	-2.000	65	-350	-3.500
7	-75	-0.750		150	1.500		250	2.500		400	4.000
	75	0.750	24	-150	-1.500	45	-250	-2.500	66	-400	-4.000
8	-75	-0.750		113	1.130		188	1.880		300	3.000
	75	0.750	25	-113	-1.130	46	-188	-1.880	67	-300	-3.000
9	-75	-0.750		75	0.750		125	1.250		200	2.000
	100	1.000	26	-75	-0.750	47	-125	-1.250	68	-200	-2.000
10	-100	-1.000		38	0.380		63	0.630		100	1.000
	75	0.750	27	-38	-0.380	48	-63	-0.630	69	-100	-1.000
11	-75	-0.750		150	1.500		250	2.500		400	4.000
	50	0.500	28	-150	-1.500	49	-250	-2.500	70	-400	-4.000
12	-50	-0.500		150	1.500		250	2.500		400	4.000
	25	0.250	29	-150	-1.500	50	-250	-2.500	71	-400	-4.000
13	-25	-0.250		150	1.500		250	2.500		400	4.000
	100	1.000	30	-150	-1.500	51	-250	-2.500	72	-400	-4.000
14	-100	-1.000		175	1.750		300	3.000			
	100	1.000	31	-175	-1.750	52	-300	-3.000			
15	-100	-1.000		131	1.310		225	2.250			
	100	1.000	32	-131	-1.310	53	-225	-2.250			
16	-100	-1.000		88	0.880		150	1.500			
			33	-88	-0.880	54	-150	-1.500			
				44	0.440		75	0.750			
			34	-44	-0.440	55	-75	-0.750			
				175	1.750		300	3.000			
			35	-175	-1.750	56	-300	-3.000			
				175	1.750		300	3.000			
			36	-175	-1.750	57	-300	-3.000			
				175	1.750		300	3.000			
			37	-175	-1.750	58	-300	-3.000			

The test setup is shown in Figure 3.1. The actuator applied the load directly to the end of the wall through the steel stops between the guide beams. This direct application allowed for a high frequency load to be applied to the wall without the mechanical linkage and the "play" that is associated with linkage. The steel support column and the steel support beam were part of the steel test frame. The steel test frame was an assembly of wide flange columns and beams that allowed equipment and test assemblies to be supported in a rigid position. The wood shear wall test panels were bolted to a concrete foundation wall that was cast on top of the lower steel beams in the frame. This foundation allowed the panels to be centered in the steel frame using threaded rods for anchor bolts and hold-down anchors in the concrete. With the base of the wall rigidly anchored to the concrete foundation, the top of the wall was positioned between the guide beams with stops at either end. The guided beams could swing in the plane of the wall from the ½″ diameter threaded rods that were suspended but could not move in the out-of-plane direction due to braces that held the guide beams in place. The system was restrained from out-of-plane displacements using a system of column and cantilevered braces. Appendix C shows photographs of the setup. Displacement measured by the actuator was verified with separate measurements taken by a displacement-transducer (DT) measuring device.

In addition to the measurements recorded by the actuator, five other measuring devices were used. Two linear variable displacement transducers (LVDT) and three DTs were used. Figure 3.2 shows the location and numbers assigned to the instruments.

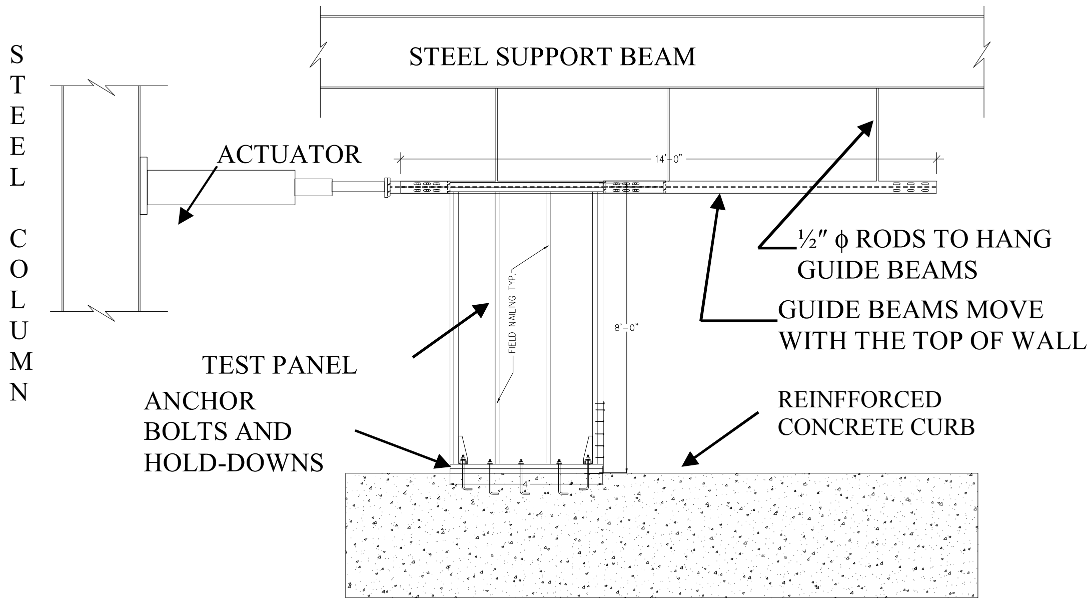

Figure 3.1 Test setup.

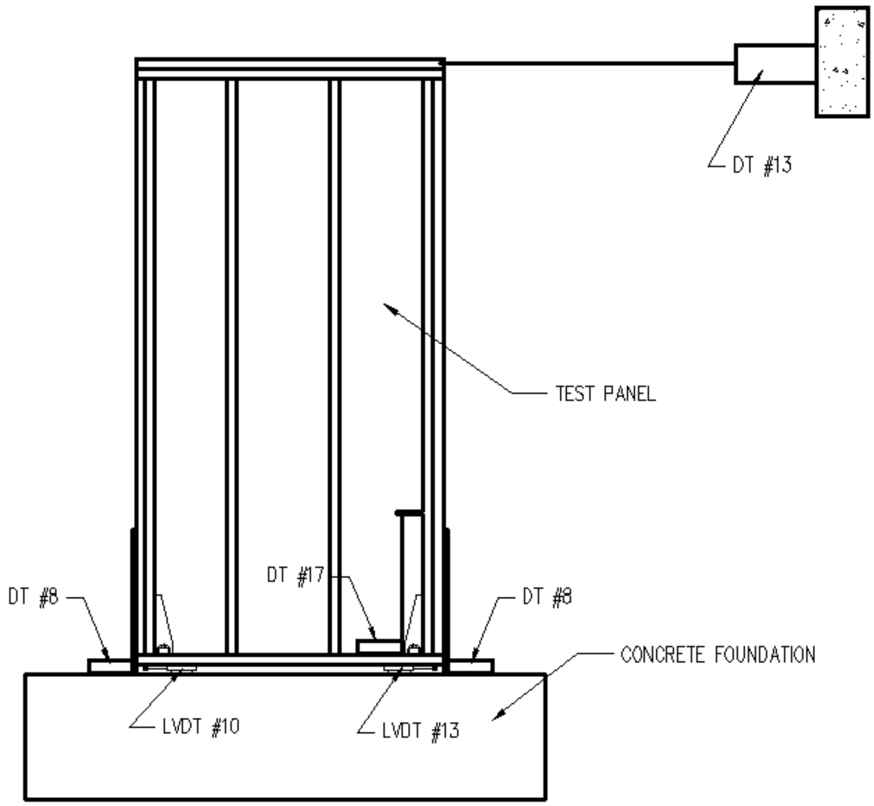

Figure 3.2. Data acquisition devices.

LVDTs 10 and 13 measured the base movement, DTs 8, 9 and 17 were used to measure end wall uplift and hold-down uplift and DT 13 measured the top of the wall displacement.

Data from the hydraulic actuator, the LVDTs, and DTs were recorded through a data acquisition system that stored the data in files that were converted into an Excel spreadsheet. The data were plotted and analyzed within the spreadsheet. The force displacement measurements that defined the hysteresis loops, were recorded in a separate system from the DT and LVDT data. In order to verify the force displacement recorded by the actuator, a plot of the actuator measured top plate displacement versus time and was overlaid with the top plate displacement versus time measured by DT 13. The curves that demonstrate the accuracy of the measurements taken through the actuator are virtually identical.

3.3 Results to Acquire

From the data acquisition described above, force displacement hysteresis curves for each test assembly were constructed by plotting the actuator data using Excel spreadsheets. The hysteresis curves were analyzed to determine the yield load and ultimate loads of the panels. Using protocol from AC130, design values from the test results were proposed. These values were compared with the code allowable values and the other panels that were tested in this research. Displacements of the new design values were also calculated.

In accordance with AC130, the first step to determining acceptable design values was to determine the YLS, SLS, and bilinear segments enveloping the force displacement hysteresis loop. The YLS is defined by SEAOSC as, “the point in the force-displacement relationship where the difference in the forces in the first and fourth cycle, at the same displacement, does not exceed 5%" (p. 2). The SLS is "the point in the force-displacement relationship corresponding to the maximum displacement for the peak force attained by the element" (p. 2). The bilinear segments are then drawn from the origin of the force displacement relationship to the YLS point and then to the SLS point (see Figure 3.3). For each set of two identical test specimens, the mean value of the YLS and SLS are determined and a single bilinear force displacement response is plotted for the two specimens. If the values from two specimens differ more than 10%, a third test is performed and the mean value from all three tests determined and used. The maximum shear strength is determined from the mean values of the SLS. This shear strength is defined as $S_{max} = P_{max} / L$ (P_{max} is the mean value). Shear stiffness is determined from the slope of the bilinear segments for each of the elastic and inelastic areas.

The shear modulus (*G'*) is equal to $P/\Delta \times H/L$. *P* is equal to the load at the YLS and SLS, respectively. Δ is equal to the displacement at the corresponding load *P*. *H* is equal to the wall height in feet, and *L* is equal to the wall length in feet. In order to determine the *G'* for each YLS and SLS for a test panel, *G'* is determined for each element in both positive and negative cycles. The mean value for each set is calculated from all values.

From the bilinear force displacement curve, the mean displacement at SLS (Δ_m), the elastic displacement (Δ_s), the force at Δ_s (*F*), and the allowable stress design loads from each set of data (panels 2, 3, 5, 7 & 9) were determined. The allowable design loads were calculated and associated values were discussed for each individual panel to compare each panel with current code values.

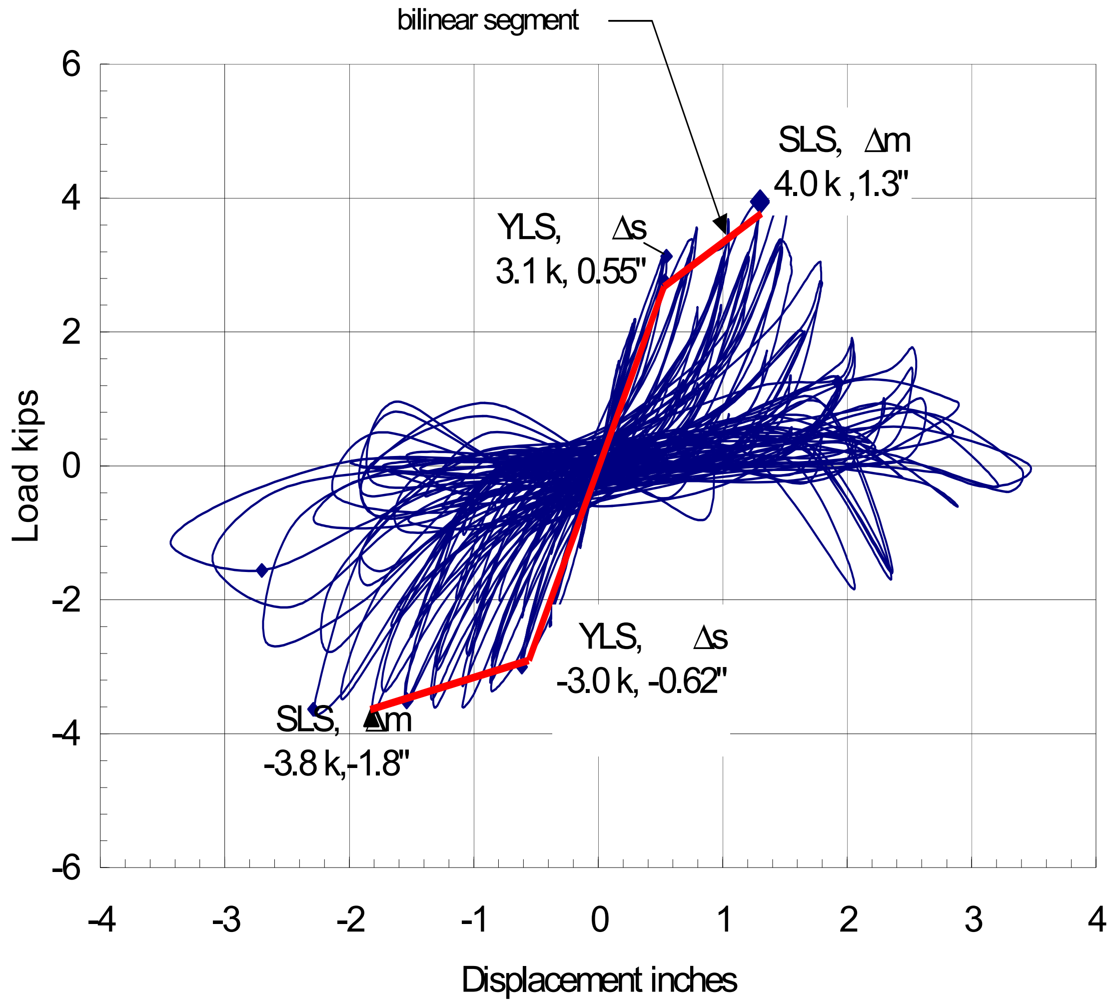

Figure 3.3 Hysteresis loops with bilinear segments.

Two overstrength factors were calculated: (1) a ratio of SLS capacities to AC130 allowable stress design loads; and (2) a ratio of the YLS capacities to AC130 allowable stress design loads. These factors will give a perspective on the overstrength factors, allowing a comparison with overstrength factors from previous tests.