CHAPTER 6

6. Comparisons Between Monotonic and Cyclic Tests

6.1 Introduction

Currently, one-directional (monotonic) shear wall tests are used to determine the capacity used for the design of shear walls. However, a shear wall will experience a dynamic, cyclic loading in a seismic event. For this reason, results of the monotonic and cyclic tests need to be compared. Values of load and drift at capacities as well as the values obtained from the equivalent elastic-plastic curve analysis for the monotonic and cyclic tests are compared in this chapter. Qualitative wall comparisons of monotonic and cyclic test specimens are also discussed.

6.2 Test Parameters

Test parameters found by the equivalent elastic-plastic curve analysis as well as wall load-deflection behavior is discussed in this section. These parameters are discussed for monotonic and for cyclic loading in Chapters 4 and 5 respectively.

6.2.1 Capacity and Drift

Capacity and corresponding drift are important parameters to compare between monotonic and cyclic tests. Capacity is the most interesting comparison for the designer since current design is based on values obtained from monotonic tests of shear walls. Values of strength and drift at capacity, as well as the ratio of cyclic to monotonic strength and deflection for the initial and stabilized cycles are presented in Table 6.1. Initial cyclic values are the values that quantify the behavior of the wall for a one-time peak load. Stabilized cyclic values are the values that quantify the behavior of the wall for sustained cyclic loading such as an earthquake or repetitive motion.

Table 6.1 – Values of Strength and Deflection at Capacity for Initial and Stabilized Cyclic and Monotonic Load Cases.

	Wall A	Wall B	Wall C	Wall D
F_{max} initial (lb)	2550	2550	4300	6650
F_{max} stabilized	2050	2000	3500	5500
F_{max} monotonic	2700	2650	4450	7050
Init/mono	0.94	0.96	0.97	0.94
Stab/mono	0.76	0.75	0.79	0.78
Δ_{max} initial (in)	0.75	0.63	0.88	0.52
Δ_{max} stabilized	0.54	0.54	0.69	0.51
Δ_{max} monotonic	0.98	0.79	1.08	0.68
Init/mono	0.77	0.80	0.81	0.76
Stab/mono	0.55	0.68	0.64	0.75

Initial cyclic values of capacity range from 94% to 97% the capacity for the monotonic tests. As shown in Figure 6.1, this difference is negligible. The same results, or slightly conservative results, would be obtained by testing SIPS cyclically and taking the initial cyclic values when a monotonic result for capacity is desired. Ratios of stabilized to monotonic load capacities are lower because of the fact that stabilized cyclic values are lower than initial cyclic values, as discussed in Chapter 5. Stabilized cyclic values of load at capacity range from 75% to 79% of that for capacity for monotonic tests. This suggests that a monotonic test overestimates the strength of a shear wall under cyclic loading. The stabilized cycle capacity of the sequential phased displacement procedure is a measure of the amount of resistance of structures to repeated cyclic loading. The loss in strength at a prescribed drift is the result of drywall screws damaging the Fiberboard and OSB or due to fatigue of the drywall screws from the numerous loading cycles. Nail fatigue has not been noticed in earthquakes, and for this reason, the large differences between stabilized cyclic and monotonic capacities may not be a significant finding.

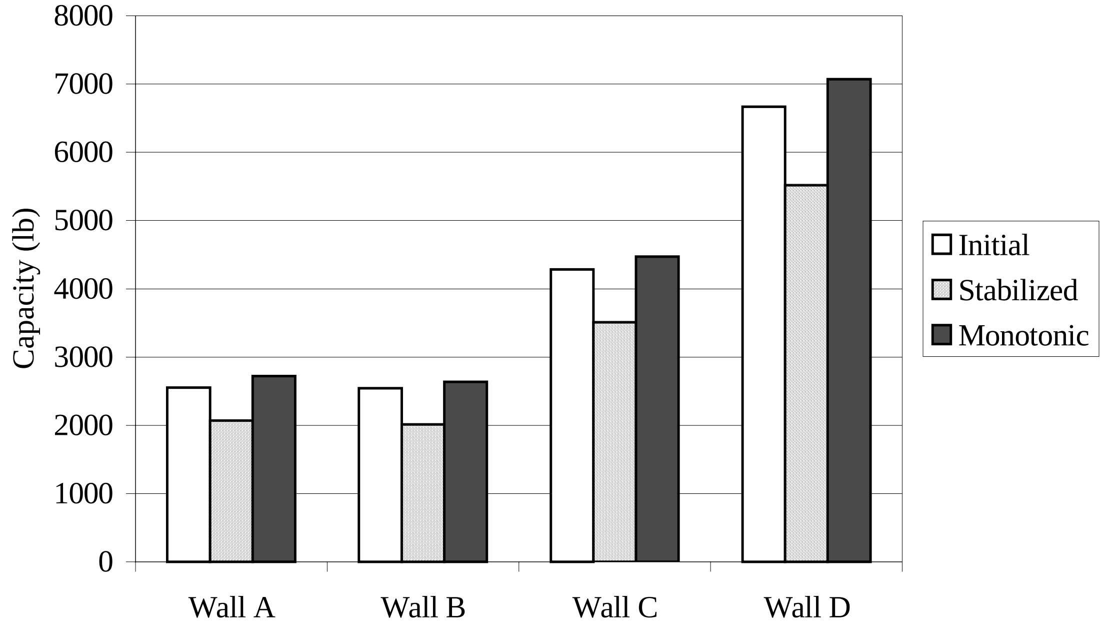

Figure 6.1 – Comparison of Capacities for Initial and Stabilized Cyclic and Monotonic Testing Procedures.

Values of drift at capacity are higher for the monotonic tests than for both the initial and stabilized cyclic responses. Values of drift at maximum load resistance for initial cyclic data range from 76% to 81% of the values of drift for monotonic tests. This may be due to base material degradation and the loss in ability to carry load near failure. This suggests that the drywall screws would exhibit low ductility. Values of stabilized cyclic drift at capacity range from a lower 55% to 75% monotonic drift.

6.2.2 Elastic Stiffness

The elastic stiffness, k_e, of a wall is important because it indicates how much the wall will deflect under load. Values of elastic stiffness from the monotonic tests as well as the initial and stabilized cycles of the cyclic tests are presented in Table 6.2.

Table 6.2 – Values of Elastic Stiffness for Initial and Stabilized Cyclic and Monotonic Load Cases.

	Wall A	Wall B	Wall C	Wall D
K_e initial (lb/in)	10200	11300	17200	21900
K_e stabilized	10000	10800	16600	23000
K_e monotonic	7990	13300	12400	28600
Init/mono	1.27	0.85	1.39	0.77
Stab/mono	1.25	0.81	1.34	0.80

There seems to be no correlation between the monotonic stiffness and the cyclic stiffness values. For Walls A and C, the stiffness values for cyclic tests are higher than the values of elastic stiffness obtained from monotonic tests. For Walls B and D, the values of stiffness for cyclic tests are lower than the values of elastic stiffness obtained from monotonic tests. Other researchers (Johnson, 1997; Heine, 1997) have also noticed higher values of elastic stiffness for cyclic tests when compared with monotonic tests. It would be reasonable to say that since no reasonable trends exist, variability of testing procedure and materials would account for this difference in stiffness.

6.2.3 Ductility

Values of ductility for the initial and stabilized cyclic and monotonic tests are compared in Table 6.3 along with the ratios of cyclic ductility to monotonic ductility. As shown in Figure 6.2, the values of ductility ratio are less for the cyclic tests than they are for the monotonic tests. This indicates that a wall subjected to cyclic loads would be more brittle, and the wall will fail at a lower ratio of failure to yield drift. To understand why the ductility ratios differ, cyclic and monotonic values of drift at yield and failure are presented in Table 6.4. Initial cyclic ductility ratios range from 67% to 97% of the monotonic ductility ratios. Stabilized ductility ratios range from 73% to 97% of the monotonic ductility ratios.

Table 6.3 – Values of Ductility Ratio for Initial and Stabilized Cyclic and Monotonic Load Cases.

	Wall A	Wall B	Wall C	Wall D
D, initial	3.6	3.8	4.0	2.2
D, stabilized	3.6	4.1	4.1	2.4
D, monotonic	3.7	4.9	4.6	3.3
Init/mono	0.97	0.77	0.90	0.67
Stab/mono	0.97	0.84	0.89	0.73

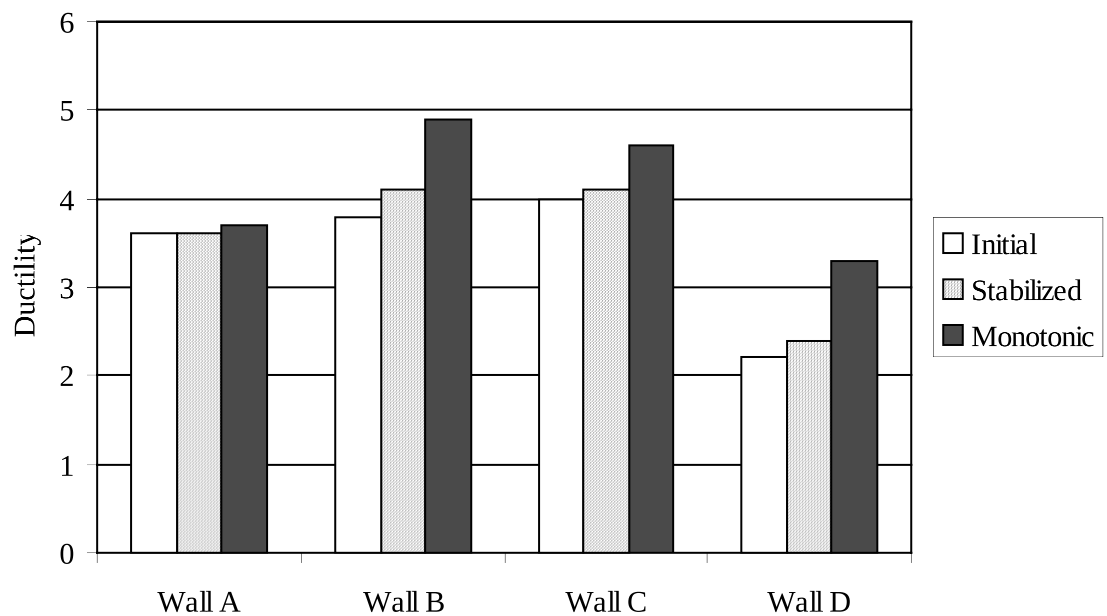

Figure 6.2 – Comparison of Ductility for Initial and Stabilized Cyclic and Monotonic Testing Procedures.

Table 6.4 – Values of Drift at Yield and Failure for Initial and Stabilized Cyclic and Monotonic Load Cases.

	Wall A	Wall B	Wall C	Wall D
Δ_{yield} initial (in)	0.24	0.19	0.21	0.27
Δ_{yield} stabilized	0.18	0.17	0.18	0.22
Δ_{yield} monotonic	0.29	0.18	0.30	0.20
Init/mono	0.83	1.09	0.70	1.33
Stab/mono	0.64	0.96	0.60	1.06
$\Delta_{failure}$ initial	0.85	0.72	0.87	0.60
$\Delta_{failure}$ stabilized	0.66	0.69	0.74	0.51
$\Delta_{failure}$ mono	1.02	0.79	1.36	0.68
Init/mono	0.83	0.91	0.64	0.88
Stab/mono	0.64	0.87	0.55	0.74

As can be seen in Table 6.4, values of drift at failure are consistently higher for the monotonic tests than they are for the cyclic tests. Values of drift at yield follow no pattern as to whether they are higher or lower for the monotonic tests when compared with the cyclic tests. This result for the values of drift at yield would be expected when the values of elastic stiffness are compared for the monotonic and cyclic load cases. Values of drift at failure are higher for the monotonic tests than for cyclic tests. This is probably due to fact that none of the monotonic elements experience repeated loading which would loosen the connections, by means such as the screws bearing into the wood, causing the connections to fail at a lower drift. Individual elements have no opportunity to fatigue in a monotonic test as may happen in the cyclic tests. This is why it would appear that the monotonic tests have more ductile failures.

As shown in Figure 6.2 and Table 6.3, the largest difference in ductility ratio obtained from monotonic and cyclic testing existed for Wall D. Initial cyclic ductility ratio is 67% and stabilized cyclic ductility ratio is 73% of the ductility ratio values obtained from the monotonic tests. In order to make the statement that this would be a general trend, more testing would need to be performed. The values of drift at yield are slightly higher, as seen by the lower values of elastic stiffness, and the values of drift at failure are slightly lower for cyclic tests than for monotonic tests for Wall D. These two factors combine to cause Wall D to have the largest difference in cyclic and monotonic ductility ratios.

6.3 Wall Behavior

Very little difference exists in the overall behavior of the SIPS shear walls under monotonic and cyclic loading. The same rigid body action of Walls A, B, and C were noticed both for monotonic and cyclic loading cases. The only difference was that the monotonic tests load the specimen in only one direction causing to failure to initiate on the load side of the wall in tension, whereas, failure could initiate on either side of the wall under cyclic loading. Wall D had the same racking behavior for both monotonic and cyclic loading cases. Failure modes recognized were practically the same for both monotonic and cyclic loading cases. Values of maximum uplift of the wall ends through failure seem to be on the same scale for both monotonic and cyclic tests.

6.4 Conclusions

The following conclusions can be drawn about the comparisons of the monotonic and cyclic data presented in this chapter.

- There is no practical difference in the capacity of the initial cycles of the cyclic test and the monotonic test for these wall configurations. A cyclic test could replace a monotonic test and yield the same results for capacity.
- This is no appreciable difference in the values of elastic stiffness obtained from the cyclic tests and the monotonic tests for these wall configurations.

- Because most shear wall test standards are only concerned with capacity and stiffness, it would be acceptable to replace a specified monotonic test with a cyclic test in order to obtain more information about the walls energy dissipating capabilities and not significantly change the results based on the initial values. This conclusion would be valid for these types of shear walls.
- The overall qualitative behavior of structurally insulated panel shear walls was the same for the SIPS walls under either monotonic or cyclic loading.

6.5 Summary

This chapter compares and contrasts the quantitative and qualitative behavior of the SIPS shear walls tested under monotonic and cyclic loading. Behavior of the walls under monotonic and cyclic loading is discussed in further detail separately in Chapters 4 and 5 respectively. Parameters of load and drift at failure, and the equivalent elastic-plastic curve values of elastic stiffness and ductility, as well as the qualitative behavior of the walls, are compared. A cyclic test of the SIPS walls would yield virtually the same information as well as many additional parameters to describe the behavior of the walls over a prescribed monotonic test.