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## Cold-formed Steel Framing Seismic Design Optimization Phase 1a: Seismic Equivalency Parameter Evaluation

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# research report

## **Cold-Formed Steel Framing Seismic Design Optimization Phase 1a: Seismic Equivalency Parameter Evaluation**

**RESEARCH REPORT RP10-4**

**2010**



**American Iron and Steel Institute**



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## PREFACE

Currently, both wood structural panel and steel sheet sheathed, cold-formed steel framed and wood structural panel sheathed wood framed shear walls qualify for an R=6.5 in bearing wall systems and an R=7.0 in building frame systems (ASCE 7-10). Recent work done in support of the development of ICC-ES AC322 and an update to AC154 has questioned whether both materials should qualify for the same seismic design parameters.

A multi-phase research project has been undertaken to address the seismic design of cold-formed steel light frame construction from a holistic standpoint by focusing on the optimization of the entire system. The subject of this report, designated Phase 1a, includes an initial evaluation of seismic equivalency parameters for cold-formed steel framed shear walls with wood structural panel and steel sheet sheathing – an effort that parallels the AC322 Advisory Group effort for wood-framed shear walls. Also included is guidance on the next steps of the multi-phase project, which will help the AISI Seismic Code Team as those additional phases are implemented.

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Don Allen	Steel Stud Manufacturers Association
Bonnie Manley	American Iron and Steel Institute
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Steve Tipping	Tipping Mar + associates

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**AISI Cold-Formed Steel Framing Seismic  
Design Optimization Project,**

**Phase 1a: Seismic Equivalency  
Parameter Evaluation**

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# **AISI Cold-Formed Steel Framing Seismic Design Optimization Project**

## **Phase 1a: Seismic Equivalency Parameter Evaluation**

### **Introduction**

AISI has undertaken the Cold-Formed Steel (CFS) Framing Seismic Design Optimization Project as an initiative to take a holistic view of seismic design of cold-formed steel light-frame construction, with the objective of optimizing CFS shear wall systems. This report relates to Phase 1a of AISI's optimization project. Phase 1a includes the evaluation of seismic equivalency parameters for cold-formed steel framed shear walls with wood structural panel and steel sheet sheathing, in an effort parallel to the AC322 Advisory Group effort for wood-framed shear walls. Also included is discussion of several related topics.

### **1. Seismic Equivalency Parameters**

On 31 July 2007, the AC322 Seismic Equivalency Task Group presented to International Code Council Evaluation Services (ICC-ES) Acceptance Criteria Committee a methodology for seismic coefficient equivalency. This methodology was based on evaluation of test data for wood-framed wood structural panel (WSP) sheathed shear walls. The basis of establishing equivalency was the identification of a benchmark system to which critical performance parameters could be compared. Characteristics and parameters considered included indicators of component overstrength, ductility, energy dissipation, and deformation compatibility. The report "Methodology for Seismic Coefficient Equivalency," and the tabulated wood-framed shear wall test data used are included in Appendix A of this report. The parameters recommended by the task group are detailed in Appendix A of the task group report.

This report presents findings from evaluation of seismic equivalency parameters for cold-formed steel shear walls. Existing test data for cold-formed steel shear walls sheathed with either wood structural panel or steel sheet sheathing has been evaluated and parameters identified, consistent with the parameters adopted by the AC322 Advisory Group. Included in the test data are Type I and Type II walls, sheathed with plywood, OSB, or steel sheet. Available testing used either CUREE or SPD types of displacement histories (loading protocols). A total of 116 CSF framed shear walls are included in this data set; a listing of references for the test data is presented in Appendix B. Data has been obtained either directly from electronic testing data or from data plots. Parameter values from the positive and negative quadrants of the load-deflection plots have been averaged. ASD capacities have been determined in accordance with AISI S213-07, using the tabulated values for use in the *United States* and *Mexico*, where available; where not available, ASD capacities per the *Canada* tabulated values have been used.

### ***Evaluation of AC322 Recommended Parameters***

Appendix C provides seismic equivalency parameter values for the entire set of cold-formed steel shear walls listed in Appendix B. This Appendix C set of data will be referred to as the "all walls" data set, and includes data without any data conversion (i.e. for loading protocol). Each of the seismic equivalency parameters recommended for use by the AC322 task group is discussed below.

***Ratio of Peak Load Capacity to ASD Load Capacity***

The ratio of peak load capacity to ASD load capacity serves as an indicator of the component overstrength. The lower bound is relied on by the building codes to help achieve intended performance in design level and maximum considered earthquakes. The upper bound is used to cap demands made on boundary members and the balance of the seismic load path. Appendix A to the AC322 report requires that the peak load capacity,  $V_p$ , be not less than 2.5 times the ASD capacity,  $V_{ASD}$ , and not more than 5 times the ASD capacity. Based on the 116 test records in the CFS Appendix C “all walls” set and the 49 test record wood “All Data” set, these requirements are compared in Table 1.

***Table 1. Ratio of peak capacity ( $V_p$ ) to capacity at ASD ( $V_{ASD}$ )***

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Quantity Less Than 2.5x	Quantity Greater Than 5x
CFS all walls	7.06	1.70	3.47	33%	4.63	1.16	10 of 116	18 of 116
Wood	5.4	2.3	3.1	26%	3.9	2.3	3 of 49	3 of 49

The CFS shear walls have a minimum ratio that is smaller than the minimum for wood framed walls, and a greater number falling below the lower bound of 2.5. The primary contributors to ratios less than 2.5 are the steel sheet shear walls. Out of the 116 tests in the all walls data set, 23 are steel sheet sheathed. The overstrength implied by the steel shear walls is consistently less than the wood structural panel shear walls. It is recommended that a separate set of parameters be explored for the steel sheet shear walls. These walls are discussed further in Section 2 of this report.

The CFS shear walls have a maximum ratio that is larger than for wood framed walls, and a larger number of walls falling above the upper limit of 5. For the CFS shear walls, the primary contributors to ratios greater than 5 are the Type II (perforated) shear walls and the shear walls with 4:1 aspect ratios. In both of these wall types, there is overstrength in excess of what is recommended by the AC322 task group parameters. Out of the 116 tests in the all walls data set, 8 are Type II and 24 have 4:1 aspect ratios.

***Ratio of Post Peak Displacement to ASD Displacement***

The setting of a lower bound on the ratio of displacement at post peak capacity to displacement at ASD capacity serves to ensure that the shear wall is capable of maintaining load resistance when pushed past peak capacity and further serves as one measure of deformation capacity relative to other code-recognized shear wall systems. Ratios higher than the lower bound are viewed as better than required. Appendix A to the AC322 report requires that the ratio of displacement at 0.80 post peak load,  $\Delta_{0.8VP}$ , to ASD displacement be not less than 11, and the ratio of displacement at 0.65 post peak load,  $\Delta_{0.65VP}$ , to ASD displacement be not less than 14. The displacement at 0.80 post peak load is measured on the first cycle backbone curve where the load has peaked and then dropped to 80% of peak load. The displacement at 0.65 post peak load is measured similarly.

The 0.80 post peak ratio criterion is compared to the wood-framed shear wall data in Table 2. Here it can be seen that the choice of 11 as the criterion for wood shear walls corresponds approximately to the average minus one standard deviation for the wood-framed shear wall set. The variability of the CFS framed walls appears significantly higher, with the average minus one standard deviation coming out to 1.98. This value is so low as to be inappropriate to specify as an evaluation parameter. Further, if the

value of 11 were used, 31 percent of the shear walls would fail this criterion as opposed to 10 percent of the wood-framed walls. This criterion is explored further using sub sets of the CFS “all walls” data later in this report.

**Table 2. Ratio of displacement at  $0.80V_P$  ( $\Delta_{0.8VP}$ ) to displacement at ASD ( $\Delta_{ASD}$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 11
CFS all walls	85.86	3.50	17.52	89%	33.07	1.98	31 of 99
Wood	43.4	6.4	20.30	45%	29.4	11.2	5 of 49

The 0.65 post peak ratio criterion is shown in Table 3. Note that this data was not derived for the wood test data set, so only cold-formed steel data is presented. Again, the variability of the CFS framed walls appears high, with the average minus one standard deviation coming out to 3.50. This value is again so low as to be inappropriate to specify as an evaluation parameter, and if the value of 14 were used, more than half of the shear walls would fail this criterion as opposed to 10 percent of the wood-framed walls. Again, this criterion is explored further using sub sets of the “all walls” data later in this report.

**Table 3. Ratio of displacement at  $0.65V_P$  ( $\Delta_{0.65VP}$ ) to displacement at ASD ( $\Delta_{ASD}$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 14
CFS all walls	80.54	3.87	18.51	81%	33.52	3.50	49 of 94

**Drift Ratio at Post Peak Load Capacity**

The setting of a lower bound on the drift ratio at post peak load capacity serves as another check on the shear wall’s ability to accommodate post peak deformation and to maintain load resistance at post peak deformations. Ratios larger than the lower bound criteria are viewed as better than required. Appendix A to the AC322 report requires that the drift ratio at 0.80 post peak load capacity,  $0.80V_P$ , be not less than 2.8 percent of the wall height, and at 0.65 post peak load capacity,  $0.65V_P$ , be not less than 3.6 percent. Based on the 116 test records in the Appendix C “all walls” set, comparisons of these criteria between the cold-formed steel shear walls and the wood-framed shear walls are provided in Tables 4 and 5.

**Table 4. Drift ratio at 0.80 post peak load capacity ( $0.8V_P$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 2.8 percent
CFS all walls	4.38	1.55	2.53	23%	3.10	1.95	64 of 99
Wood	5.5	2.3	3.6	21.3%	4.3	2.8	6 of 49



**Table 5. Drift ratio at 0.65 post peak load capacity ( $0.65V_P$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 3.6 percent
CFS all walls	4.35	1.63	2.74	20%	3.30	2.18	86 of 94

The drift ratios adopted by the AC322 task group are clearly problematic for the CFS shear walls with the “all walls” data set, based on the number of walls not meeting the criteria. It is recommended that alternate ratios be explored for sub-sets of the data. This will be addressed in later sections of this report.

**Parameter Conversion Based on Test Loading Protocol**

During the CUREE-Caltech Woodframe Project, it was found that the loading protocol used for shear wall loading significantly affected the resulting load and displacement capacity for wood-framed shear walls (Gatto & Uang, 2002). Based on identical wood-framed shear wall assemblies tested with the CUREE and SPD protocols, recommendations were made by Gatto & Uang for conversion between results of CUREE and SPD protocols. Note that these conversions are based on a limited number of test specimens, with one wall configuration and two tests each for each protocol (four tests total). Appendix D provides data sets of the AC322 Task Group parameters for available testing comparing load protocol effects. The bottom portion of the table illustrates the conversion factors that were determined for wood-framed shear wall tests, based on Gatto & Uang Tests 2, 4, 6, and 8. These are summarized in the first row in Table 6. Using the Gatto & Uang tests, moderate differences in peak capacity and significant differences in peak and post peak drift ratios were identified.

For CFS shear walls, testing at McGill University allows comparison of similar parameters for conversion between SPD and CUREE protocol. Again, these ratios are based on a limited number of tests, including one wall configuration with plywood sheathing and three specimens tested with each protocol (six tests total). The derived ratios are given in the second row in Table 6.

Comparing the first and second rows of Table 6, it can be seen that there are significant differences between protocol conversion factors for wood-framed and CFS shear walls. For CFS walls, minor increases are suggested for  $\Delta_{ASD}$ ,  $V_P$  and  $\Delta_P$ . Minor decreases are suggested for  $\Delta_{0.80VP}$  and  $\Delta_{0.65VP}$ , and a significant increase is suggested for the equivalent viscous damping ratio. Conversion factors recommended by Gatto & Uang for evaluating loading protocol effects for CFS shear walls, based on the CUREE testing, are shown in the bottom row of Table 6.

**Table 6. Factors to convert SPD parameters to CUREE parameters for CFS walls**

	$\Delta_{ASD}$	$V_P$	$\Delta_P$	$\Delta_{0.80VP}$	$\Delta_{0.65VP}$	Equivalent Viscous Damping Ratio
Wood-framed Multiply SPD data by	0.92	1.25	1.75	1.63	1.65	1.15
CFS-framed Multiply SPD data by	1.07	1.17	1.25	0.89	0.86	2.07
Recommended CFS-framed Multiply SPD data by	1.07	1.17	1.25	1.00	1.00	2.0

A very significant implication of these conversion factors is that the deflections and drift ratios for 0.80 and 0.65 post peak will not be increased due to loading protocol conversions. Note that the data set used by the AC322 task group included only CUREE protocol tests, so conversion for protocol was not required for the wood-framed shear wall parameters.

**Converted Parameter Comparison to the Wood Shear Wall Data Base**

The following Tables 7 through 11 repeat Tables 1 through 5 using the recommended protocol conversions from the bottom row of Table 6 for all SPD protocol data. The converted CFS shear wall seismic equivalency parameters are taken from the “all walls” data set with conversion applied, included in Appendix E.

**Table 7. Ratio of peak capacity ( $V_P$ ) to capacity at ASD ( $V_{ASD}$ ) - Converted**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Quantity Less Than 2.5x	Quantity Greater Than 5x
CFS converted	8.26	1.74	3.70	35%	4.98	1.28	8 of 116	22 of 116
Wood	5.4	2.3	3.1	26%	3.9	2.3	3 of 49	3 of 49

Table 7 values are changed from Table 1 based on the 1.17 protocol adjustment to  $V_P$ . The factor of 1.17, used to increase  $V_P$  for SPD tests, slightly increases the ratio of  $V_P$  to  $V_{ASD}$ , but the number of walls failing the criteria of 2.5 and 5 is still significantly higher for CFS walls than wood-framed. This will be explored further with sub-sets of the data.

**Table 8. Ratio of displacement at  $0.80V_P$  ( $\Delta_{0.8VP}$ ) to displacement at ASD ( $\Delta_{ASD}$ ) - Converted**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 11
CFS converted	85.86	3.58	17.17	91%	32.77	1.57	36 of 99
Wood	43.4	6.4	20.30	45%	29.4	11.2	5 of 49

Table 8 values are changed from Table 2 based on the 1.07 protocol adjustment to  $\Delta_{ASD}$ . This is a minor change, which results in a few additional cold-formed steel walls failing the criterion of 11.

**Table 9. Ratio of displacement at  $0.65V_P$  ( $\Delta_{0.65VP}$ ) to displacement at ASD ( $\Delta_{ASD}$ ) - Converted**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 14
CFS converted	80.54	3.75	17.84	84%	32.85	2.90	50 of 94

Table 9 values are changed from Table 3 due to the 1.07 protocol adjustment to  $\Delta_{ASD}$ . This is a minor change, which results in one additional cold-formed steel wall failing the criterion of 14.

**Table 10. Drift ratio at 0.80 post peak load capacity ( $0.8V_P$ ) - Converted**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 2.8 percent
CFS	4.38	1.55	2.53	23%	3.10	1.95	64 of 99
Wood	5.5	2.3	3.6	21%	4.3	2.8	6 of 49

Table 10 values are unchanged from Table 4 because values were not affected by conversions.

**Table 11. Drift ratio at 0.65 post peak load capacity ( $0.65V_P$ ) - Converted**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 3.6 percent
CFS	4.53	1.63	2.74	20%	3.30	2.18	86 of 94

Table 11 values are unchanged from Table 5 because values were not affected by conversions.

Based on the very minor influence of the protocol conversions and the limited conversion data available, the data included in the balance of this report will not include protocol conversions.

## 2. Other Parameter Observations

Because the “all walls” data set in Appendix C includes wide-ranging shear wall types, several groups within the overall data set have been identified for further evaluation of their effect on parameters.

The first group identified as having notably different behavior is the Type II (perforated shear wall methodology) walls. The testing used an overall 40 foot long framed wall, with full height sheathing ranging from 30 to 70 percent of the 40 feet. A data set for Type II walls is provided in Appendix F, and information on parameters is provided in Table 12.

**Table 12. Type II Wall Parameters**

	$V_P / V_{ASD}$		$\Delta_{0.80P} / \Delta_{ASD}$		$\Delta_{0.65P} / \Delta_{ASD}$		Drift Ratio 0.80P		Drift Ratio 0.65P	
	Mean	COV	Mean	COV	Mean	COV	Mean	COV	Mean	COV
All Walls	3.47	33%	17.52	89%	18.51	81%	2.53	23%	2.74	20%
Type II Only	4.64	13%	16.55	19%	21.01	25%	2.18	17%	2.63	22%

One noticeable difference in Table 12 values is the large ratio of peak capacity to ASD capacity, indicating a large overstrength for these walls. The other noticeable aspect is the much smaller coefficient of variation for the Type II walls. Because the Type II walls are an alternate configuration, and because of the very high overstrength, Type II walls are deleted from the data set for the balance of parameter evaluation in this section of the report. An “all walls” Type I data set is provided in Appendix G and used in the remainder of Section 2 of this report.

A data set for wood structural panel (WSP) sheathed shear walls only is provided in Appendix H, and a comparison of parameters to the “all walls” Type I parameters is provided in Table 13.

**Table 13. Wood Structural Panel (WSP) Walls Only**

	$V_P / V_{ASD}$		$\Delta_{0.80P} / \Delta_{ASD}$		$\Delta_{0.65P} / \Delta_{ASD}$		Drift Ratio 0.80P		Drift Ratio 0.65P	
	Mean	COV	Mean	COV	Mean	COV	Mean	COV	Mean	COV
All Walls (Type I)	3.41	34%	17.78	92%	18.48	85%	2.58	22%	2.77	20%
WSP Only	3.63	32%	20.17	84%	20.57	78%	2.61	23%	2.76	20.0%
Ratio All/WSP	0.94	1.06	0.78	1.10	0.77	0.90	0.99	0.96	1.00	1.00

Ratios are only moderately different for WSP only, except the ratios of  $\Delta_{0.80P} / \Delta_{ASD}$  and  $\Delta_{0.65P} / \Delta_{ASD}$ , which have more notable changes.

**Table 14. Wood Structural Panel (WSP) Walls Only Without Canadian Softwood Plywood (CSP)**

	$V_P / V_{ASD}$		$\Delta_{0.80P} / \Delta_{ASD}$		$\Delta_{0.65P} / \Delta_{ASD}$		Drift Ratio 0.80P		Drift Ratio 0.65P	
	Mean	COV	Mean	COV	Mean	COV	Mean	COV	Mean	COV
All Walls (Type I)	3.41	34%	17.78	92%	18.48	85%	2.58	22%	2.77	20%
WSP Only	3.63	32%	20.17	84%	20.57	78%	2.61	23%	2.76	20.0%
WSP w/o CSP	3.56	33%	21.69	91%	21.39	88%	2.51	27%	2.62	23%

Table 14 evaluates the effect of softer, lower-capacity Canadian Softwood Plywood (CSP) on the overall data group, based on Appendix I data for WSP shear walls without CSP for Appendix J for CSP only. Including or excluding the CSP group has a moderate impact.

To further explore the effect of the lower-capacity CSP sheathing, Vieira and Shafer (2009) conducted small scale fastener tests comparing fastener peak capacity and deformation for Canadian CSP and Canadian Douglas Fir Plywood (DFP) and U.S. Structural 1 plywood. Resulting data representing the average of five tests for each sheathing type and given in Table 15.

**Table 15. Wood Structural Panel (WSP) Walls Only Without Canadian Softwood Plywood (CSP)**

Specimen	Peak Test Capacity (lb)	Tabulated Nominal Capacity for 6"oc (plf)	Ratio of Nominal to Test	Deflection at Peak Test Capacity (in)
CAN-2-DFP	660	795	1.205	0.61
CAN-1-CSP	500	651	1.302	0.66
USA- STR I	630	780	1.413	0.55

Interestingly, the tabulated ratios of nominal capacity to test capacity show CSP to be between DFP and US STR I. There does not seem to be any performance-related reason to exclude these tests from the data used to derive seismic parameters. On the other hand, the CSP plywood is a product with very limited use in the US, and Table 14 has illustrated that their inclusion somewhat impacts parameters; as a result it is recommended that they be excluded from data sets used to derive parameters for US construction.

Because differences in steel sheet sheathed shear wall performance have been identified (see discussion of Table 1), Table 16 considers seismic parameters for steel sheet shear walls, based on Appendix K & L.

**Table 16. Steel Sheet Sheathing Only**

	$V_P / V_{ASD}$		$\Delta_{0.80P} / \Delta_{ASD}$		$\Delta_{0.65P} / \Delta_{ASD}$		Drift Ratio 0.80P		Drift Ratio 0.65P	
	Mean	COV	Mean	COV	Mean	COV	Mean	COV	Mean	COV
All Walls (Type I)	3.41	34%	17.78	92%	18.48	85%	2.58	22%	2.77	20%
Steel Sheet Only	2.60	18%	6.00	27%	7.22	31%	2.39	17%	2.83	18%
Steel Sheet Five (27 mil) Representative Tests	1.89	12%	4.75	37%	4.76	16%	2.22	9%	2.43	10%

There are two lines of data for the steel sheet shear walls. This is because only five of the 23 test specimens closely reflect configurations included in the AISI S213-07 nominal shear strength table. The five specimens reflected have 27 mil steel sheet sheathing. The other eighteen specimens have steel sheet of 30 or 33 mils, which do not currently have tabulated values. As such, attention needs to be focused on the five representative tests reflecting AISI S213-07 intent. Ratios of  $V_P$  to  $V_{ASD}$  are significantly lower for the five representative tests, and are clearly lower than the 2.5 minimum criterion proposed by the AC322 task group. This suggests that the overstrength of steel sheet sheathed walls needs to be recognized as being lower than wood structural panel sheathed walls, given current detailing requirements and design values.

Ratios between post peak deflection and ASD deflection are significantly lower for steel sheet sheathing than for the “all walls” Type I data set. The variation between all steel sheet walls and the five representative tests, however, is not significant. The low ratios appear to be driven by higher ASD deflections. The higher ASD deflections are reflective of lower initial stiffness of the steel sheet shear walls. An alternate way to evaluate post-peak deflection capacity is the ratio of post-peak deflection to deflection at peak capacity. Table 17 illustrates use of this comparison for the wood-frame shear walls and five representative steel sheet shear walls.

**Table 17. Steel Sheet Sheathing Only**

	$\Delta_{ASD}$ (inches)		$\Delta_P$ (inches)		$\Delta_{0.80P} / \Delta_P$		$\Delta_{0.65P} / \Delta_P$	
	Mean	COV	Mean	COV	Mean	COV	Mean	COV
Wood Framed	0.213	18%	2.69	16%	1.35	14%	--	--
Steel Sheet Five Representative Tests	0.504	28%	1.47	21%	1.54	17%	1.83	23%

Table 17 illustrates that the deflection at peak capacity appears to be more stable, making the ratios of post-peak deflections more stable. In addition it appears that the ratios of post-peak to peak deflections of steel sheet shear walls are reasonably in line with the wood-framed shear wall data set. It is recommended that ratios of post peak deflection to deflection at peak capacity be considered as an acceptable alternative to ratios of deflection at ASD capacity.

AISI Research Report RP07-3 (Yu, 2007) provides recommendations for nominal capacities for the 30 and 33 mil steel sheet sheathing. Table 18 provides AISI S213-07 values for 27 mil sheets, and RP07-3 values for 30 and 33 mil sheets together for comparison.

**Table 18. Steel Sheet Sheathing Nominal Capacities (plf)**

Source	Steel Sheet Framing Thickness (mils)	Max Aspect Ratio	Fastener Edge Spacing (inches)			
			6	4	3	2
S213-07-S1-09	27 / 43	4	-	1000	1085	1170
RP07-3	30 / 43	2	911	1014	1042	1070
RP07-3	33 / 43	2	1056	1169	1236	1304

Important to note is that the recommended nominal values for 30 mil steel sheet are very close to the values in AISI S213-07 for 27 mil. The values for a 33 mil thickness range from 11 to 17 percent more than the 27 mil, overall a minimal increase for the thicker sheet. Note that following this testing, further testing by University of North Texas has revisited and recommended revised nominal capacities for the 27 mil sheet sheathing (RP09-2, Yu, 2009), in addition to exploring variations in wall layout and detailing. Based on this additional information, Table 17, with the five 27 mil tests, best represents what is in AISI S213-07. Table 16, with all test values, better represents anticipated behavior if the University of North Texas recommendations for nominal capacities are followed.

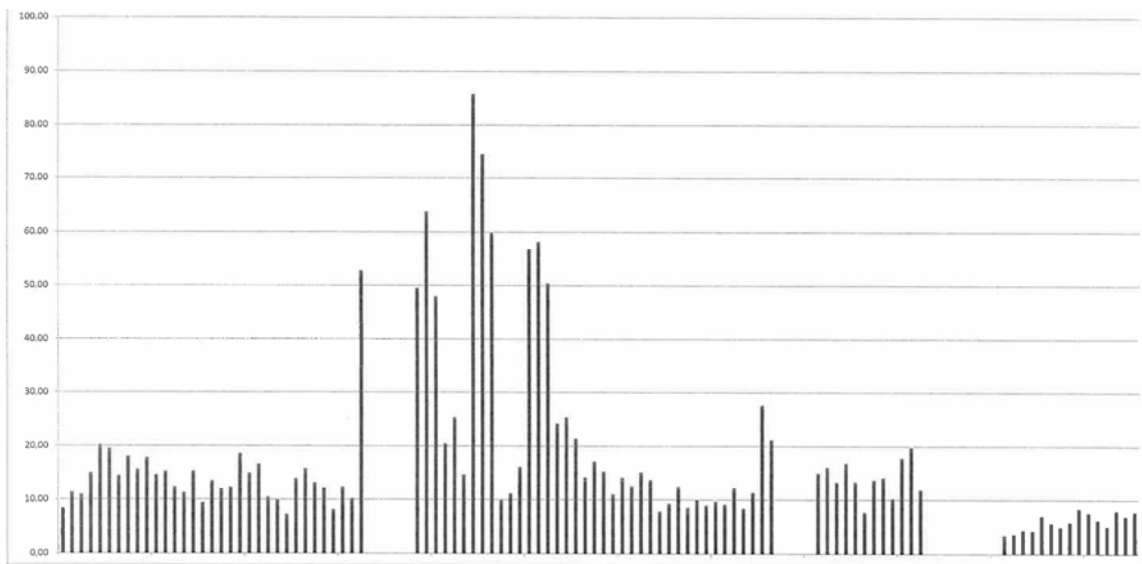
It has been clearly observed in many shear wall tests that the aspect ratio (ratio of wall sheathing height to width) of the shear wall effects drift, and to a lesser extent peak capacity. Shear walls with high aspect ratios have lower peak capacities and higher drifts. Adjustments are made to allowable shears in high aspect ratio shear walls that compensate for the capacity and drift effects. Table 19 illustrates the effect of excluding higher aspect ratio shear walls from both the wood and CFS data sets. Interestingly, with CFS the only parameter that is significantly affected by eliminating high aspect ratio shear wall data is the coefficient of variation for the ratio of peak to ASD load capacity. All other parameters are moderately affected.

**Table 19. Shear wall parameter variation with aspect ratios.**

	$V_P / V_{ASD}$		$\Delta_{0.80P} / \Delta_{ASD}$		$\Delta_{0.65P} / \Delta_{ASD}$		Drift Ratio 0.80P		Drift Ratio 0.65P	
	Mean	COV	Mean	COV	Mean	COV	Mean	COV	Mean	COV
Wood All Data	3.1	26%	20.30	45%	-	-	3.6	21%	-	-
Wood 2:1 Max Aspect	2.9	22%	12.8	27%	-	-	-	-	-	-
CFS All Walls (Type I)	3.41	34%	17.78	92%	18.48	85%	2.58	22%	2.77	20%
CFS 2:1 max aspect	3.01	12%	15.35	85%	16.66	79%	2.47	17%	2.67	17%

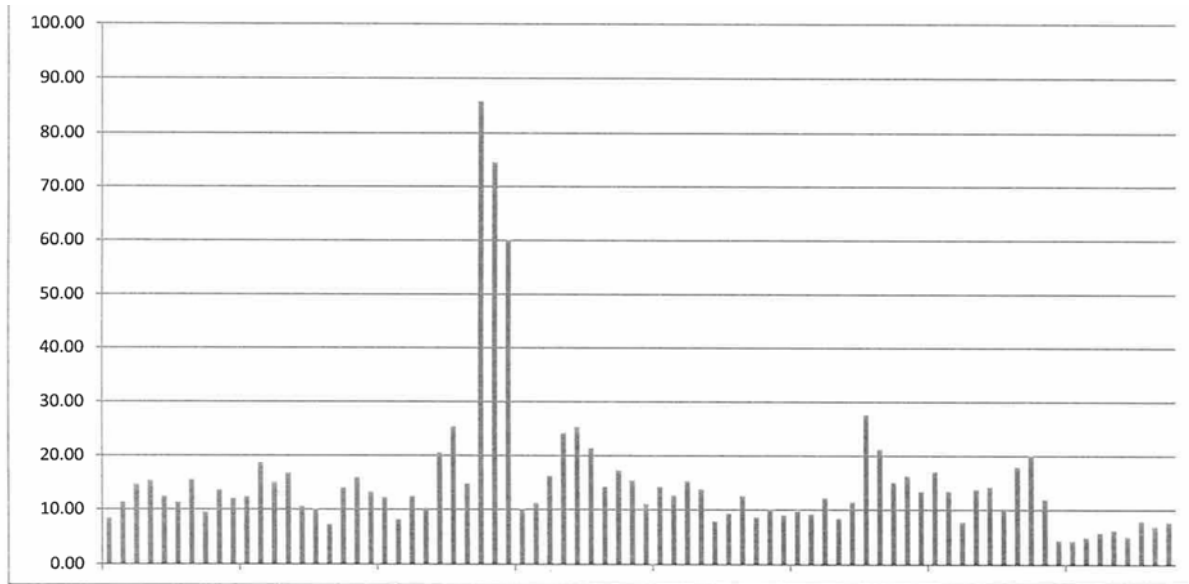
Of most concern in the effort to assign parameters for the CFS shear walls is the great variability in the ratios of 0.80 and 0.65 post peak deflection to ASD deflection. Bar charts shown in Figures 1 and 2 graphically show the variability in the 0.80 post peak ratio. Figure 1 includes all CFS Type I wall data. Ten tests show considerably more variability than the balance of the data; seven of these ten tests are 4:1 aspect ratios. The other three have 2:1 aspect ratios. The high ratios correspond to test numbers 33, 39, 40, 41, 45, 46, 4, 51, 52 and 53 in Appendix C. Parameter data for this figure is found in the third “CFS all walls” Type I line of Table 19.

Figure 2 shows the effect of removing the 24 shear walls with 4:1 aspect ratio shear walls. The fourth line in Table 18 provides parameter data for this group of walls. Three walls can be seen to still have much greater ratios than the balance.



**Figure 1.** Bar chart of ratios of 0.80 post peak drift to ASD drift for all walls. Note that ratios for ten walls are much higher than the others (vertical axis plots ratio in percent, horizontal axis plots one bar for each data point).





*Figure 2. Bar chart of ratios of 0.80 post peak drift to ASD drift for all walls with aspect ratio of 2:1 or less. Note that ratios for three walls are much higher than the others (vertical access plots ratio in percent, horizontal axis plots one bar for each data point)*

### 3. Recommended Parameters for Cold-Formed Steel Framed Shear Wall Seismic Equivalency

Based on the discussion in Sections 1 and 2 of this report, this section derives seismic equivalency parameters separately for CFS framed wood structural panel shear walls and CFS framed steel sheet shear walls, compares values to those used for the AC322 recommendations, and recommends equivalency parameters representative of these two groups of CFS framed shear walls. Evaluation is based on Type I walls only. The data used for comparison has not been adjusted for loading protocol.

#### **Recommended Parameters for Wood Structural Panel (WSP) Sheathed Shear Walls**

For derivation of parameters for wood structural panel sheathed CFS shear walls, the data group without Canadian softwood plywood (CSP) will be used, based on the assumption that the group without CSP is more representative of construction in the United States. Tables 20 through 24 explore the five seismic equivalency parameters with this data set, and compare to the AC322 wood-framed shear wall data set. Values are based on Appendix J.

**Table 20. Ratio of peak capacity ( $V_P$ ) to capacity at ASD ( $V_{ASD}$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Quantity Less Than 2.5	Quantity Greater Than 5
CFS WSP, no CSP	7.06	2.48	3.56	33%	4.73	2.39	1 of 62	10 of 62
Wood	5.4	2.3	3.1	63%	3.9	2.3	3 of 49	3 of 49

**Table 21. Ratio of displacement at  $0.80V_P$  ( $\Delta_{0.8VP}$ ) to displacement at ASD ( $\Delta_{ASD}$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 11
CFS WSP, no CSP	85	7.81	21.7	91%	41.4	1.97	12 of 58
Wood	43.4	6.4	20.30	45%	29.4	11.2	5 of 49

**Table 22. Ratio of displacement at  $0.65V_P$  ( $\Delta_{0.65VP}$ ) to displacement at ASD ( $\Delta_{ASD}$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 14
CFS WSP, no CSP	80	8.18	21.4	88%	40.1	2.65	22 of 56

**Table 23. Drift ratio at 0.80 post peak load capacity ( $0.8V_P$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 2.8 percent
CFS WSP, no CSP	4.38	1.55	2.51	27%	3.18	1.84	38 of 58
Wood	5.5	2.3	3.6	21%	4.3	2.8	6 of 49

**Table 24. Drift ratio at 0.65 post peak load capacity ( $0.65V_P$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 3.6 percent
CFS WSP, no CSP	4.35	1.63	2.62	23%	3.23	2.01	43 of 56

**Table 25. Ratio of displacement at  $0.80V_P$  ( $\Delta_{0.8VP}$ ) to displacement at Peak ( $\Delta_P$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation
CFS WSP, no CSP	1.46	1.06	1.24	9%	1.35	1.13

**Table 26. Ratio of displacement at  $0.65V_P$  ( $\Delta_{0.65VP}$ ) to displacement at Peak ( $\Delta_P$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation
CFS WSP, no CSP	1.65	0.88	1.34	11%	1.48	1.19

Based on results in Tables 20 to 26, the following are recommended as seismic equivalency parameters for CFS shear walls with WSP sheathing:

- $V_P/V_{ASD}$ : 2.5 minimum, 5 maximum
- $\Delta_{0.80VP}/\Delta_P$  1.1 minimum
- $\Delta_{0.65VP}/\Delta_P$  not used
- Minimum drift ratio at  $0.80V_P$  1.8
- Minimum drift ratio at  $0.65V_P$  2.0

See Section 1 on Page 2 of this report for discussion of intended parameter use. Ratios of post-peak drift to drift at ASD capacity are not included because the COV is so large that the data is not providing reasonable targets. Instead the ratio of post-peak drift to drift at peak capacity is used. While providing a much less variable value, it should be noted that the post-peak deflection is very close to the deflection at peak capacity; further evaluation of whether this is a meaningful parameter for wood structural panel sheathed CFS walls is recommended.

### **Recommended Parameters for Steel Sheet Sheathed Shear Walls**

For derivation of parameters for steel sheet sheathed CFS shear walls, following Tables 27 through 31 explore the five seismic equivalency parameters with this data set, and compare to the AC322 data set.

Note that the ratio of post-peak deflection to deflection at peak capacity has been substituted for the ratio at ASD capacity, based on discussion in Section 2 of this report.

**Table 27. Ratio of peak capacity ( $V_P$ ) to capacity at ASD ( $V_{ASD}$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Quantity Less Than 2.5x	Quantity Greater Than 5x
Cold-formed Steel sheet Five Representative Tests	2.28	1.70	1.89	10.6%	2.10	1.69	5 of 5	0 of 5
Wood	5.4	2.3	3.1	1.94	3.9	2.3	3 of 49	3 of 49

**Table 28. Ratio of displacement at  $0.80V_P$  ( $\Delta_{0.8VP}$ ) to displacement at peak capacity ( $\Delta_P$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation
Cold-formed Steel sheet Five Representative Tests	1.84	1.27	1.54	15.5%	1.78	1.30
Wood	--	--	1.35	14.5%	1.55	1.16

**Table 29. Ratio of displacement at  $0.65V_P$  ( $\Delta_{0.65VP}$ ) to displacement at peak capacity ( $\Delta_P$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation
Cold-formed Steel sheet Five Representative Tests	2.24	1.40	1.82	18.8%	2.16	1.48

**Table 30. Drift ratio at 0.80 post peak load capacity ( $0.8V_P$ )**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 2.8 percent
Cold-formed Steel Sheet	2.52	1.99	2.31	8.1%	2.50	2.13	5 of 5

Five Representative Tests							
Wood	5.5	2.3	3.6	21.4%	4.3	2.8	6 of 49

**Table 31. Drift ratio at 0.65 post peak load capacity (0.65V<sub>P</sub>)**

Framing	Maximum Ratio	Minimum Ratio	Average Ratio	COV	Average Plus 1 Standard Deviation	Average Minus 1 Standard Deviation	Number Less Than 3.6 percent
Cold-formed Steel Sheet Five Representative Tests	2.80	2.30	2.53	8.2%	2.74	2.32	3 of 3

Based on results in Tables 27 to 31, the following are recommended as seismic equivalency parameters for cold-formed steel shear walls with steel sheet sheathing:

- $V_P/V_{ASD}$ : 1.7 minimum, 2.1 maximum
- $\Delta_{0.80VP}/\Delta_P$ : 1.3 minimum
- $\Delta_{0.65VP}/\Delta_P$ : 1.5 minimum
- Minimum drift ratio at 0.80V<sub>P</sub>: 2.1
- Minimum drift ratio at 0.65V<sub>P</sub>: 2.3

Further study is needed of the design implications of recommended seismic equivalency parameters that vary from those recommended by the AC322 task group.

#### 4. Related Discussions

The following are discussions related to the study of seismic equivalency parameters.

##### **Selection of Wood-framed Structure Parameters**

Test data used by the AC322 Advisory Group is included in Appendix A. It is understood that the primary criteria used for selecting shear wall tests for inclusion in the AC322 study were the availability of testing using the CUREE displacement protocol, and shear walls with aspect ratios of two or greater. The testing sources used include the following:

- Martin, Zeno, Thomas Skaggs, and Edward Keith, “Using Narrow Pieces of Wood Structural Panel Sheathing in Wood Shear Walls.”
- Martin, Zeno, “Wood Structural Panel Lateral and Shear Connections with Common, Galvanized Box, and Box Nails.”
- Martin, Zeno and Thomas Skaggs, “Shear Wall Lumber Framing: Double 2x’s vs. Single 3x’s at Adjoining Panel Edges.”
- Martin, Zeno, “Effect of Green Lumber on Wood Structural Panel Shear Wall performance.”
- Rosowsky, David, Lori Elkins, and Cameron Carroll, “Cyclic Tests of Engineered Shearwalls Considering Different Plate Washers.”
- Pardoen, G.C., A. Waltman, R.P. Kazanjy, E. Freund, and C.H. Hamilton, “Testing and Analysis of One-Story and Two-Story Shear Walls Under cyclic Loading.”

Several groups of recent wood structural panel shear wall tests that were not included should be explored to make sure results would be consistent.

First is testing conducted by Gatto & Uang (2002) using the CUREE protocol. This testing is included in the Appendix D Data Set for Protocol Conversion data set. Table 32 below compares the average of these two tests to the wood-framed shear wall parameters.

**Table 32. Comparison of average seismic equivalency parameters between AC322 data set and Gatto & Uang Testing**

	$V_P / V_{ASD}$	$\Delta_{0.80VP} / \Delta_{ASD}$	$\Delta_{0.65VP} / \Delta_{ASD}$	$\Delta_{0.80VP}$ Ratio (%)	$\Delta_{0.65VP}$ Ratio (%)	Equivalent Viscous Damping Ratio
AC322 Data Set Average	3.1	20.3	Not Available	3.6	Not Available	2.0
Gatto & Uang CUREE Protocol Average	3.26	15.7	17.5	4.9	5.4	2.0

The inclusion of this test data in the AC322 data set would tend to increase the recommended parameters, but only slightly based on there only being two additional test specimens.

Second is testing conducted by City of Los Angeles (CoLA) using the SPD protocol. While protocol conversion is needed, this testing was very thorough in exploring the range of code-permitted fastener sizes and spacngs for wood structural panel shear walls. In particular, higher capacity shear walls with close fastener spacing can be compared to the AC322 criteria. Table 33 below provides comparison for two example tests (9A and 9C), with and without the protocol conversions used for wood-framed shear walls per Table 6.

**Table 33. Comparison of average seismic equivalency parameters between AC322 data set and CoLA Testing**

	$V_P / V_{ASD}$	$\Delta_{0.80VP} / \Delta_{ASD}$	$\Delta_{0.65VP} / \Delta_{ASD}$	$\Delta_{0.80VP}$ Ratio (%)	$\Delta_{0.65VP}$ Ratio (%)
AC322 Data Set Average	3.1	20.3	Not Available	3.6	Not Available
CoLA Without Protocol Conversion	2.62	12.5	13.6	2.87	3.10
CoLA With Protocol Conversion	3.28	22.1	24.4	4.68	5.11

For these tests, the protocol converted values for  $V_P / V_{ASD}$ ,  $\Delta_{0.80VP} / \Delta_{ASD}$ , and  $\Delta_{0.65VP} / \Delta_{ASD}$  appear to provide reasonable values which would tend to increase the target parameter values for the AC322 set somewhat, however the values for  $\Delta_{0.80VP}$  Ratio and  $\Delta_{0.65VP}$  Ratio are so large that they would be difficult to justify including. This is because they significantly exceed the drift ratios normally seen for wood

structural panel sheathed walls. This brings up the possibility that protocol conversions derived from the CUREE testing (Gatto & Uang, 2002) are not representative of the CoLA testing.

Review of this available information suggests that the seismic equivalency parameters derived by the AC322 Task Group might have been somewhat modified with additional data sets considered. There is no indication, however, that recommended seismic parameters would have changed significantly. In addition, use of some of the SDP protocol data sets is problematic.

### ***Potential Issues for Consideration in FEMA P695 Analysis***

The following comments are provided regarding considerations that could potentially impact results of FEMA P695 analysis, or have been brought up as being of interest for FEMA P695 analysis.

#### ***Finish materials***

There are a number of topics related to finish materials that should be considered. The first is whether or not finish materials should be included in the archetype buildings. Inclusion of finish materials for wood-framed shear walls was discussed at some length at the beginning of development of the FEMA P695 wood example application. Many issues were considered including some wood buildings that are constructed without interior finishes, the variation in type and amount of finish, and the fact that the finishes are not defined and regulated as part of the lateral force resisting system. This last issue was the prominent factor in deciding not to include finishes in the wood framed structure studies. In addition, recently available testing information from the NEESWood benchmark project reported minimal influence of finish materials installed on interior partition walls. For a short period during the development of the example, finishes were included; in the final version, however, with changes to scaling of ground motions, the finishes were not included in modeling. It would be appropriate to reconsider this discussion as part of CFS shear wall analysis. It is recommended that an analysis be conducted without finish materials, but it might make sense to conduct an additional analysis with these materials, to the extent that combinations of materials are codified.

Also of importance from this discussion is the difficulty in getting short-period structures to meet the margin of collapse criteria set by FEMA P695, discussed in Section 9.5.1 of the FEMA P695 report. Not considered in the wood framed structure analysis so far is the uplift and overturning behavior of the lateral force resisting system for short, stiff structures, which may reduce the very high force levels generated with fixed base modeling.

An additional important issue related to finish materials is whether the application of finish materials might significantly change the behavior of component tests. The significant out-of-plane buckling of the steel sheet sheathing suggests that component behavior might change with finishes installed. The steel sheet sheathing would normally have gypsum wallboard installed over the top, which would be anticipated to reduce buckling deformations. If this has not already been studied, it is suggested that it should be.

#### ***Quality rating for design requirements***

Section 3.4 of the FEMA P695 report discusses the quality rating based on design requirements. In this rating, predictable failure modes are given high ratings and unanticipated modes are given low ratings. While most CFS shear walls could likely qualify for the high rating, tests reporting repeated buckling failures of boundary members in steel sheet sheathed walls with fasteners at two inches on center suggest



that a low rating would be appropriate. It is recommended that detailing be identified to avoid this failure type.

#### ***Quality rating of test data***

Quality of the available test data is rated as high, medium or low in accordance with FEMA P695 Table 3-2. This is based on a series of important testing issues listed in Section 3.5.2, the identification of all important behaviors, and knowledge of behavior from material and fasteners to component to system. The available CFS shear wall testing should address the Section 3.5.2 criteria fairly well. A few potential areas of weakness include

- Gravity load effects - available research on gravity load effects needs to be reviewed to evaluate whether walls have stable post-peak behavior while supporting gravity loads. The 2006 McGill report addressing this issue (Hikita, 2006) is noted as available. With compression chords designed for gravity loads plus the nominal shear yield plus overstrength of the sheathing, the addition of gravity loads only slightly affected capacities and displacement, increasing them in positive loading and decreasing in them in negative loading. Review of this testing and especially the applicability of chord stud detailing is recommended.
- Finish material effects - finish materials are likely to reduce the deformation capacity of walls. It may be desirable to find out if deflections at peak capacity are significantly reduced with finish materials in place.
- Boundary conditions - shear walls with boundary members adequate for overstrength requirements for multi-story construction have not been tested to date. It may be desirable to conduct testing of these configurations.

#### ***Models for collapse simulation***

The modeling of the concrete and steel buildings for FEMA P695 examples included both very sophisticated non-linear analysis that took into account global component failure methods, and the addition by hand of other limit states that the analysis programs could not explicitly consider. For the wood-framed shear walls, only the analysis program results were relied on, based on the assumption that there were no additional limit states that were not captured by the analysis.

The analysis program chosen for use was SAWS, from the CUREE project. This program provides a detailed modeling of the hysteretic behavior of the walls with degrading stiffness and pinching of the hysteresis loops. The SAWS program, however, does not explicitly model overturning behavior. There are two methods by which input behavior can be developed for SAWS. One method is to use the CASHEW program, which models the wall sheathing, framing members and fasteners, and comes up with hysteretic parameters that describe the behavior of the sheathing and fastening (primarily shear behavior, not overturning). The second method is to derive hysteretic parameters from component testing; this automatically includes the overturning behavior that the component experienced during testing. For the FEMA P695 analysis, use of the CASHEW development of hysteretic parameters was used. This might have significantly under-predicted deformation due to overturning. The use of this software and this approach to hysteretic parameters should be revisited for CFS analysis to see if overturning and full building behavior can be better included. Ideally, the software would include overturning directly (NEESWood is working on this). Alternately component behavior could be used, but this is limited because testing representative of the bottom story of multi-story construction is not available.

One of the major judgments that needed to be made during the Incremental Dynamic Analysis (IDA) was the maximum drift that wood light-frame buildings could sustain prior to collapse. This is a very important parameter because results are based on determination of seismic demand at collapse. The only



data point we have for collapse of wood light-frame structures is one building collapsed on the Japan E-defense shake table. The last drift recorded prior to collapse was 7 percent. This number was used as the cut-off for the wood light-frame IDAs developed for FEMA P695. There will be a need to determine an acceptable collapse for CFS shear wall buildings, and to my knowledge no data exists. This issue should be discussed sooner rather than later, as it will be very important to the results. Some additional study of light-frame IDA development has occurred since; it is recommended that the researchers involved be contacted.

### ***Diaphragm behavior***

As published in FEMA P695, the evaluation of seismic parameters is based entirely on modeling of the vertical systems of the seismic-force-resisting system. The decision was made early on that torsional behavior would not be considered. The influence of the diaphragm on collapse margin ratio is currently on the wish list for the ATC 84 project, following up on the FEMA P695 methodology, but it is not clear if or to what extent it will be studied. The development of the archetype buildings will require that gravity weight and seismic mass be assigned to each archetype wall line, which will require that assumptions be made about diaphragm flexibility or tributary area to the wall line. Therefore, it is not clear at this time that AISI study of diaphragms is necessary to pursue FEMA P695 analysis. It may be considered in the future, but we have no indication of how this consideration might be included.

### ***Recommendations for Archetype Buildings for FEMA P695 Analysis***

In order for the performance of an FEMA P695 analysis of seismic parameters for cold-formed steel shear wall structures, defining of archetype buildings is required. Archetype buildings were defined for wood-framed structures using wood structural panel shear walls. These archetypes used planar structures varying from one to five stories high, based on common current construction methods and on construction trends. The process of developing the archetype buildings is described in Section 9.4.4 of the FEMA P695 report. It started with identification of common construction with wood-framed walls, considering building use, plan area, distance between shear wall lines, and number of stories. The same process should be conducted for CFS shear wall buildings. In addition, common wall pier lengths within the shear walls should be identified. Those that were considered for wood-framed construction ranged from very narrow walls to those with aspect ratios of one or less.

## **5. Conclusions**

The following are conclusions and observations based on the shear wall data reviewed for this report.

The variations of the CFS seismic equivalency parameters from those derived for wood suggest that seismic design parameters for CFS walls should be separately derived and different from those derived by the AC322 group for wood-framed walls. In addition, it appears that within the CFS framed shear walls, wood structural panel sheathed walls and steel sheet sheathed walls should be separated for the derivation of equivalency parameters. Recommendations are made in Section 3 of this report for wood structural panel sheathed walls and for steel sheet sheathed walls. To the extent that nominal capacities and detailing for steel sheet sheathed walls are under consideration, the recommended equivalency parameters may need to be revisited.

It was observed that improvements might be made in use of the CUREE protocol. First, it is important that post-peak behavior to larger displacements be captured. Second, the large increments in displacements currently used at the peak and post-peak capacities appear to be resulting in significant variation in the positive and negative quadrant capacities and deflections, and additionally appear to make

it more difficult to capture post-peak behavior. Very few post-peak cycles are captured because the displacement increment is so large. It appears that it would be beneficial to decrease the cycle to cycle increment of displacement at the post-peak portion of the test.

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## **Attachments**

APPENDIX A - Methodology for Seismic Coefficient Equivalency, Presented to ICCES July 31, 2007, From the “AC322 Seismic Equivalency Task Group.”

APPENDIX B - CFS Shear Wall Tests

APPENDIX C - Data Set for CFS “all walls”

APPENDIX D - Data Set for Protocol Conversion and Derived Conversions

APPENDIX E - Data Set for CFS “all walls” - Converted

APPENDIX F - Data Set for Type II Walls Only

APPENDIX G - Data Set for “all walls” Type I

APPENDIX H - Data Set for WSP Walls Only

APPENDIX I - Data Set for WSP Without CSP

APPENDIX J - Data Set for CSP Only

APPENDIX K - Data Set for Steel Sheet Walls Only

APPENDIX L - Data Set for Steel Sheet, Five Walls Only

# METHODOLOGY FOR SEISMIC COEFFICIENT EQUIVALENCY

Presented to ICC ES July 31, 2007

From the “AC322 Seismic Equivalency Task Group”

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## Executive Summary:

This document summarizes the recommendations of the “AC322 Seismic Equivalency Task Group.” The charge of the Task Group was to establish a methodology, characteristics and parameters by which equivalency to a seismic-force-resisting system not identified in the code may be determined.

ASCE 7-05 (§12.2.1) states “Seismic force resisting systems that are not contained in Table 12.2-1 are permitted if analytical and test data are submitted that establish the dynamic characteristics and demonstrate the lateral-force resistance and energy dissipation capacity to be equivalent to the structural system listed in Table 12.2-1 for equivalent response modification coefficient,  $R$ , system over-strength coefficient,  $\Omega_0$ , and deflection amplification factor,  $C_d$ , values.

As indicated herein, the task group has adopted a methodology that identifies characteristics with recommended parameters to identify whether the hysteretic behavior of a proprietary prefabricated shear panel (as a component of a seismic force resisting system) is sufficiently similar to the same characteristics of a given code-prescribed seismic system component.

Recommended numerical values of the parameters are based on the best available data for the code-prescribed system component (wood-structural panels nailed to wood-framing tested under the CUREE protocol). Alternative parameters (i.e., based on steel-stud framing for use in steel-framed buildings) will be developed at a later date. It is anticipated that this approach will serve as a compliment to the ATC-63 project.

## Background:

In recent years, the International Code Council Evaluation Service (ICC-ES) has been working to develop new acceptance criteria for cold-formed steel shear panels used in light-frame construction. Drafts of the proposed acceptance criteria, [AC322: Prefabricated, Cold-formed Steel Lateral Resisting Assemblies](#), have been the subject of considerable debate at development hearings. Much of the controversy has centered around two technical topics:

- How to evaluate the ability of a pre-fabricated panel to carry a combination of vertical and lateral load when the elements of the panel that carry the vertical load are degraded during a lateral load test.
- How to assign seismic design coefficients ( $R$ ,  $C_d$ ,  $\Omega_o$ ) to a proprietary shear panel product used as a component within a larger system.

A group of interested parties met in San Francisco on 9 May 2007 to discuss these issues at the offices of Simpson Gumpertz & Heger Inc. Representatives were present from various prefabricated shear panel manufacturers, related trade associations, consulting engineering firms, academia, government, the Structural Engineers Association of California (SEAOC) and ICC-ES. During the meeting, nearly all of the discussion centered about the assignment of seismic design coefficients. The first issue was not addressed.

With regard to the assignment of seismic coefficients, it was established that:

- Pre-fabricated shear panels are typically used as a component within a building containing a code-defined lateral force resisting system as well as other building elements, which though not considered in the structural design of the building's seismic resistance; do provide the building with stiffness, strength and energy dissipation capacity.
- The seismic design coefficients presently contained in the 2006 International Building Code (IBC) for defined systems cannot be directly calculated based upon cyclic shearwall test data. The reason for this is that code-defined seismic coefficients were developed over a period of many years by committee judgment based largely upon historical performance, limited test data, and comparison with other code-defined systems.

Given the current lack of a definitive mathematical methodology to analyze cyclic shearwall test data for a proprietary product and to assign seismic design coefficients that are both consistent and compatible with code-defined lateral force resistance systems, it was decided that seismic design coefficients for proprietary products could be assigned on an "equivalency" basis.

At the close of the May 9 meeting, a task group was formed out of interested parties to establish the methodology that should be employed to establish "equivalency" for the assignment of seismic design coefficients to proprietary products. The objective of this paper is to document the findings of the task group.

These recommendations to ICC-ES reflect the consensus of the task group discussions, but it should be noted that not all task group members are in agreement with all provisions. Areas where differences occurred are noted below, with discussion of the dissenter's opinion.

## **Basis for Establishing Equivalency:**

The task group objective was to provide a practical means by which to judge whether or not a proprietary wall performs in a manner consistent with a "benchmark" code-defined lateral force resisting system when subjected to high intensity, cyclic loading similar to that produced by earthquake shaking. If the cyclic test behavior of a proprietary panel is judged to be "equivalent" and consistent with the behavior of a lateral force resisting system defined in the IBC, then a proprietary pre-fabricated shearwall may be used as a component within that system and share the same seismic design coefficients.

The task group decided that the comparison should be made by comparing critical performance "parameters" from cyclic tests of the proprietary system against similar tests for the benchmark system defined by the code.

## **Benchmark Data Set:**

Given the large variation in performance expected even within a code-defined system, the committee judged that it was not appropriate for the proponent of a proprietary product to simply select test data for a single code-conforming wall panel to prove equivalency. The benchmark established by this single data point may or may not be representative of the level of performance commonly associated with the population of walls that conform to the code-defined system. The benchmark dataset should consist of all wall tests for the code-defined system that can be practically obtained and determined to be appropriate by a committee of interested parties. That review should consider the influence of:

- aspect ratios,
- boundary conditions,
- test protocol selected for the testing (i.e. CUREE, ISO, SPD, etc.)
- skew of the available data set relative to what exists in application, etc.

## **Characteristics and Parameters:**

Once the benchmark data set has been established, the next step in the process undertaken by the committee was to decide which cyclic test performance characteristics should be selected to make comparisons between the proprietary and benchmark systems and what parameter limits should be used for comparison. A large number of cyclic shearwall test parameters were available for consideration by the task group. The characteristics considered by the group included, but were not limited to:

- indicators of component overstrength:
  - the ratio of peak load to the code-defined LRFD design load
  - the ratio of peak load to the code-defined ASD design load

- indicators of ductility:
  - the ratio of displacement at a post-peak failure point to the LRFD design displacement
  - the ratio of displacement at a post-peak failure point to the ASD design displacement
  - the ratio of displacement at a post-peak failure point to a yield load with various definitions
  - the ratio of displacement at the peak load to the LRFD design displacement
  - the ratio of displacement at the peak load to the ASD design displacement
  - the ratio of displacement at the peak load to a yield load
- energy dissipation
- indicators of deformation compatibility:
  - the displacement at peak load expressed as a percentage of the wall height
  - the displacement at a post-peak failure point expressed as a percentage of the wall height
  - the secant stiffness at the ASD design load divided by the secant stiffness at the peak load

The task group focused on selecting a few, critical parameters that would both ensure that a proprietary panels provides performance that is reasonably compatible with the benchmark system but still allow room for product innovation. The following characteristics and parameters were selected:

1. An upper and lower bound on the ratio of peak strength to the assigned ASD design load. These boundaries were selected to ensure that the proprietary product performs with a component overstrength that is in general alignment with other components of the code-defined system. A lower bound is prescribed to ensure a minimum margin of safety. An upper bound is provided to ensure that elements like component anchorage and connections such as drag struts can be designed using traditional procedures for the code-defined system without the development of special design provisions. It was agreed that manufacturers of proprietary products should report the over strength inherent in their products as part of the evaluation report.
2. Lower bounds on the displacement at a “post peak” failure points (defined as points where the load drops off by more than 20% or 35% from the peak load). This parameter helps to ensure that the proprietary product has a drift capacity that is compatible with code-defined system. Since having additional drift capacity judged to be a benefit, an upper limit was not specified
3. Lower bounds on the ratio of the displacement at a “post peak” failure points (defined as points where the load drops off by more than 20% or



35% from the peak load) to the displacement at the assigned ASD design load. When coupled with parameters 1 and 2, this parameter was judged to provide an indication of the occurrence of yielding. It was selected to provide a consistent amount of yielding prior to reaching the peak without engaging in the controversy involved in selecting a consistent yield point from the nonlinear test data. Since having additional ductility was judged to be a benefit, an upper limit was not specified.

Taken alone, it is recognized that none of these three characteristics and their parameters provides sufficient assurance that the proprietary product performs in a manner consistent with the code-defined system. Taken together, their overlapping influences were judged to provide a reasonable measure of compatibility and equivalency.

### **Parameter Envelope Boundaries:**

Once the parameters had been selected, a consistent means must be used to establish upper and/or lower bounds, as appropriate. The task group recognized that:

- The cyclic shearwall test data sets available to serve as a benchmark for code-defined lateral force resisting systems are typically limited.
- The available data sets will not typically provide a comprehensive and statistically valid representation of all possible applications of the code-defined system.
- Even within the test data that are available for a code-defined system, there can be considerable variation in the parameters used to judge equivalence.

The task group discussed whether limits for the selected parameters should be based upon, the extremes of the benchmark data set, the average performance, or something else. In the end, it was decided that:

- Lower bounds for a parameter, where appropriate, shall be established based upon the average performance of the benchmark data set minus one standard deviation.
- Upper bounds for the ratio of peak strength to the assigned ASD design load was selected given the maximum strength reduction factor (multiplier) of 0.57 required by the code for 3.5:1 shear walls, one would anticipate that if the baseline ASD related safety factor for 2:1 aspect ratio walls and higher is 2.8, then for 3.5:1 walls it will be  $2.8/0.57 = 4.91$ , which the group rounded up to 5.0.

It was judged that establishing limits in this fashion should both ensure that a product performs within the expected range of the code-defined system and provides leeway for product innovation.

The task group intent is that for these boundaries to be compared against the average tested performance for each proprietary wall configuration tested in accordance with the methods outlined in AC322. It is not intended that each test replicate pass this criteria,

nor is it intended that some aggregate average of multiple panel configurations be compared against the performance benchmark.

### **Parameters Established by the Task Group:**

Throughout the task group discussion, test data from the lateral force resisting system defined in the 2006 IBC as light-frame wood-stud walls sheathed with wood structural panels served as an illustrative example. The benchmark data and parameters developed from it have been included as Appendix A.

The task group determined the following provisions should be part of the AC322 criteria:

1. Any approved testing protocol may be used for a product to be used in wood framed construction. The results, for the purposes of equivalency, shall be compared against CUREE characteristics and limits.
2. Any approved testing protocol may be used for a product to be used in light cold formed steel construction shall be compared against SPD or CUREE characteristics and limits.

The task group intent is that additional lateral force resisting systems be added as benchmark data becomes available.

## Appendix A: Equivalency Characteristics and Parameters for Proprietary Shearwalls Used in Wood Framed Construction

### Definitions:

$V_{asd}$  = allowable stress design capacity per code or as determined from an ICC ES acceptance criteria

$\Delta_{V_{asd}}$  = displacement at  $V_{asd}$

$V_P$  = peak capacity

$\Delta_{0.8VP}$  = displacement at  $0.80 \cdot V_P$

$\Delta_{0.65VP}$  = displacement at  $0.65 \cdot V_P$

### Characteristics and Parameters:

Ratio of Peak Load Capacity to ASD Design Capacity ( $V_P / V_{asd}$ )

- 1) Must be a minimum of 2.5 (see dissenting opinion in appendix B)
- 2) Maximum not exceed 5.0
- 3) Manufacturer must report and publish recorded over-strength

Ratio of Post Peak Load Displacement to ASD Design Capacity Displacement ( $\Delta_{0.80\% \text{ or } 0.65\%VP} / \Delta_{V_{asd}}$ )

- 1) 0.80 peak ratio must be a minimum of 11
- 2) 0.65 peak ratio must be a minimum of 14 (see justification in appendix C)

Minimum Displacements

- 1) Minimum displacement at 0.80 peak shall be 2.8%  $h_x$
- 2) Minimum displacement at 0.65 peak shall be 3.6%  $h_x$
- 3) Vertical capacity must be maintained at each of the displacements noted above

Table 1: CUREE Cyclic Wall Test Data to Benchmark the Performance of Wood Structural Panel Shearwalls (Revised 23 July 07)

Item	Source <sup>1</sup>	Source ID <sup>2</sup>	Wall Dimensions (h by l)	Sheathing	Openings	Fastener	Boundary Conditions	Fastener Spacing (edge/field)	Input Delta (CUREE)	0.4 Peak <sup>3</sup>		0.65 Peak <sup>3</sup>		0.8 Peak <sup>3</sup>		ASD Design <sup>4</sup>	
										Load (lbs.)	Disp. (in.)	Load (lbs.)	Disp. (in.)	Load (lbs.)	Disp. (in.)	Load (lbs.)	Disp. (in.)
1	A	24-1	8.5' by 4.5'	15/32" S1 OSB	none	10d com	Rigid Base	2"/12"	2.40	4,096	0.539	6,655	1.154	8,191	1.745	3,915	0.507
2	A	24-2	8.5' by 4.5'	15/32" S1 OSB	none	10d com	Rigid Base	2"/12"	2.40	4,185	0.556	6,800	1.112	8,369	1.586	3,915	0.516
3	B	1-8dc	8' by 8'	7/16" OSB	none	8d com	Rigid Base	4"/6"	2.40	2,992	0.139	4,862	0.380	5,984	0.745	2,800	0.124
4	B	2-8dgb	8' by 8'	7/16" OSB	none	8d galv box	Rigid Base	4"/6"	2.40	3,118	0.202	5,066	0.564	6,235	0.955	2,800	0.164
5	B	3-8db	8' by 8'	7/16" OSB	none	8d box	Rigid Base	4"/6"	2.40	3,282	0.178	5,333	0.510	6,564	0.978	2,400	0.106
7	C	2	8' by 8'	7/16" OSB	none	8d com	Rigid Base	4"/6"	2.40	2,807	0.132	4,562	0.342	5,615	0.628	2,800	0.132
8	C	3	8' by 8'	7/16" OSB	none	8d com	Rigid Base	4"/6"	2.40	2,786	0.151	4,527	0.406	5,572	0.762	2,800	0.152
9	C	4	8' by 8'	7/16" OSB	none	8d com	Rigid Base	4"/6"	2.40	2,681	0.137	4,356	0.369	5,361	0.715	2,800	0.149
10	C	5	8' by 8'	19/32" OSB	none	10d com	Rigid Base	2"/12"	2.40	6,379	0.206	10,365	0.581	12,757	1.065	6,960	0.245
11	C	6	8' by 8'	19/32" OSB	none	10d com	Rigid Base	2"/12"	2.40	6,381	0.239	10,369	0.606	12,762	1.096	6,960	0.282
12	C	7	8' by 8'	19/32" OSB	none	10d com	Rigid Base	2"/12"	2.40	7,142	0.295	11,606	0.736	14,285	1.288	6,960	0.281
13	C	8	8' by 8'	19/32" OSB	none	10d com	Rigid Base	2"/12"	2.40	6,969	0.280	11,324	0.694	13,937	1.283	6,960	0.279
14	D	1	8' by 8'	7/16" OSB	none	8d com	Rigid Base	4"/6"	1.80	2,873	0.410	4,669	0.851	5,747	1.224	2,800	0.387
15	D	3	8' by 8'	7/16" OSB	none	8d com	Rigid Base	4"/6"	1.80	2,931	0.464	4,845	0.890	5,963	1.213	2,800	0.429
16	D	5	8' by 8'	7/16" OSB	none	8d com	Rigid Base	4"/6"	1.80	2,762	0.230	4,489	0.613	5,525	1.000	2,800	0.237
17	D	6	8' by 8'	7/16" OSB	none	8d com	Rigid Base	4"/6"	1.80	2,854	0.248	4,639	0.649	5,709	1.038	2,800	0.240
18	D	7	8' by 8'	7/16" OSB	none	8d com	Rigid Base	4"/6"	1.80	3,052	0.107	4,960	0.277	6,105	0.475	2,800	0.094
19	D	8	8' by 8'	7/16" OSB	none	8d com	Rigid Base	4"/6"	1.80	2,991	0.106	4,860	0.271	5,982	0.467	2,800	0.096
20	E	A-1	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	2.40	4,083	0.321	6,635	0.666	8,167	1.088	3,920	0.303
21	E	A-2	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,245	0.205	6,899	0.587	8,491	1.177	3,920	0.180
22	E	A-3	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,460	0.279	7,248	0.699	8,921	1.228	3,920	0.220
23	E	B-1	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,351	0.233	7,070	0.578	8,702	1.021	3,920	0.205
24	E	B-2	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,622	0.208	7,510	0.568	9,243	1.025	3,920	0.165
25	E	B-3	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,558	0.209	7,407	0.616	9,117	1.109	3,920	0.163
26	E	C-1	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,381	0.386	7,119	0.854	8,762	1.409	3,920	0.321
27	E	C-2	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,230	0.266	6,873	0.639	8,459	1.049	3,920	0.233
28	E	C-3	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,462	0.306	7,251	0.695	8,925	1.156	3,920	0.257
29	E	D-1	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,345	0.212	7,061	0.620	8,690	1.097	3,920	0.191
30	E	D-2	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,308	0.201	7,001	0.629	8,617	1.174	3,920	0.183
31	E	D-3	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,106	0.307	6,673	0.738	8,212	1.223	3,920	0.282
32	E	E-1	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,318	0.226	7,016	0.599	8,636	1.017	3,920	0.205
33	E	E-2	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,369	0.228	7,100	0.543	8,739	0.939	3,920	0.204
34	E	E-3	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,368	0.215	7,098	0.527	8,736	0.913	3,920	0.193
35	E	F-1	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,045	0.217	6,574	0.504	8,091	0.855	3,920	0.211
36	E	F-2	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,333	0.215	7,040	0.512	8,665	0.878	3,920	0.195
37	E	F-3	8' by 8'	7/16" OSB	none	8d com	Rigid Base	3"/12"	3.30	4,432	0.229	7,201	0.541	8,863	0.900	3,920	0.203
38	F	4A	8' by 16'	3/8" OSB	none	8d box	Rigid Base	6"/12"	2.14	4,665	0.220	7,581	0.466	9,330	0.785	3,200	0.126
39	F	4B	8' by 16'	3/8" OSB	none	8d box	Rigid Base	6"/12"	2.14	4,772	0.162	7,754	0.403	9,543	0.659	3,200	0.087
40	F	6A	8' by 16'	3/8" OSB	pedestrian door	8d box	Rigid Base	6"/12"	3.05	4,545	0.178	7,386	0.414	9,090	0.591	2,600	0.101
41	F	6B	8' by 16'	3/8" OSB	pedestrian door	8d box	Rigid Base	6"/12"	3.05	4,032	0.184	6,553	0.454	8,065	0.708	2,600	0.113
42	F	8A	8' by 16'	3/8" OSB	garage door	8d box	Rigid Base	3"/12"	3.92	3,877	0.300	6,300	0.748	7,754	1.510	1,904	0.131
43	F	8B	8' by 16'	3/8" OSB	garage door	8d box	Rigid Base	3"/12"	3.92	4,082	0.271	6,633	0.708	8,164	1.370	1,904	0.134
44	F	10A	8' by 16'	3/8" OSB	garage door	8d com	Rigid Base	3"/12"	3.92	4,160	0.259	6,759	0.666	8,319	1.334	2,393	0.144
45	F	10B	8' by 16'	3/8" OSB	garage door	8d com	Rigid Base	3"/12"	3.92	4,058	0.249	6,594	0.638	8,116	1.182	2,393	0.145
46	F	11A	8' by 16'	3/8" OSB	none	1-3/8", 16ga stpl	Rigid Base	6"/12"	2.14	4,449	0.178	7,230	0.469	8,898	0.778	2,240	0.071
47	F	11B	8' by 16'	3/8" OSB	none	1-3/8", 16ga stpl	Rigid Base	6"/12"	2.14	4,651	0.168	7,558	0.478	9,302	0.830	2,240	0.058
48	F	26A	8' by 16'	3/8" OSB	pedestrian door	8d box	Rigid Base	6"/12"	3.05	3,683	0.265	5,985	0.705	7,366	1.309	2,600	0.156
49	F	26B	8' by 16'	3/8" OSB	pedestrian door	8d box	Rigid Base	6"/12"	3.05	3,321	0.259	5,397	0.599	6,642	1.017	2,600	0.179

Table 1: CUREE Cyclic Wall Test Data to Benchmark the Performance of Wood Structural Panel Shearwalls (Revised 23 July 07)

Item	LRFD Design <sup>5</sup>		EEEP Yield <sup>6</sup>		Peak <sup>7</sup>		Ultimate <sup>8</sup>		Area Under Backbone (in-lbs.)	Slack Loops? (Y/N)	Vertical Load Capacity Intact (Y/N)	Failure Mode	Normalized Parameter							
	Load (lbs.)	Disp. (in.)	Load (lbs.)	Disp. (in.)	Load (lbs.)	Disp. (in.)	Load (lbs.)	Disp. (in.)					Drift at Peak (%)	Drift at Ultimate (%)	Peak/ ASD Design Load	Ult. Drift/ ASD Drift	Drift at Peak/ Drift at ASD Design Disp.	Secant stiff. at ASD/ Secant stiff. at peak	Secant stiff. at ASD/ Secant stiff. at ult.	
1	5,481	0.804	9,047	1.191	10,239	3.314	9,748	4.147	32,132	N	Yes	Note 9	3.2%	4.1%	2.6	8.2	6.5	2.5	3.3	
2	5,481	0.771	9,125	1.213	10,461	3.224	8,369	3.422	25,688	N	Yes	Note 9	3.2%	3.4%	2.7	6.6	6.2	2.3	3.1	
3	3,920	0.218	6,646	0.308	7,480	2.316	5,984	3.223	20,397	N	Yes	Note 9	2.4%	3.4%	2.7	26.1	18.7	7.0	12.2	
4	3,920	0.330	6,856	0.444	7,794	2.259	6,235	3.319	21,233	N	Yes	Note 9	2.4%	3.5%	2.8	20.3	13.8	5.0	9.1	
5	3,360	0.186	7,315	0.397	8,205	2.245	6,564	3.646	25,219	N	Yes	Note 9	2.3%	3.8%	3.4	34.3	21.1	6.2	12.5	
7	3,920	0.224	6,209	0.293	7,019	1.614	5,615	2.372	13,818	N	Yes	Note 9	1.7%	2.5%	2.5	18.0	12.2	4.9	9.0	
8	3,920	0.305	6,303	0.341	6,965	2.322	5,572	3.585	21,520	N	Yes	Note 9	2.4%	3.7%	2.5	23.6	15.3	6.2	11.9	
9	3,920	0.293	6,099	0.313	6,701	2.316	5,361	3.697	21,595	N	Yes	Note 9	2.4%	3.9%	2.4	24.8	15.5	6.5	13.0	
10	9,744	0.507	14,185	0.458	15,947	3.203	12,757	3.380	44,702	N	Yes	Note 9	3.3%	3.5%	2.3	13.8	13.1	5.7	7.5	
11	9,744	0.525	14,035	0.525	15,953	2.305	12,762	3.431	44,465	N	Yes	End Post Tension	2.4%	3.6%	2.3	12.2	8.2	3.6	6.6	
12	9,744	0.515	15,793	0.652	17,856	3.326	15,107	4.380	64,018	N	Yes	Note 9	3.5%	4.6%	2.6	15.6	11.8	4.6	7.2	
13	9,744	0.508	15,393	0.618	17,421	3.398	14,537	4.380	62,663	N	Yes	Note 9	3.5%	4.6%	2.5	15.7	12.2	4.9	7.5	
14	3,920	0.625	6,229	0.889	7,184	2.573	5,747	2.751	14,369	N	Yes	Note 9	2.7%	2.9%	2.6	7.1	6.6	2.6	3.5	
15	3,920	0.643	6,618	1.029	7,454	2.533	5,963	2.758	14,844	N	Yes	Note 9	2.6%	2.9%	2.7	6.4	5.9	2.2	3.0	
16	3,920	0.463	6,071	0.505	6,906	2.557	5,525	2.977	16,541	N	Yes	Note 9	2.7%	3.1%	2.5	12.6	10.8	4.4	6.4	
17	3,920	0.463	6,217	0.540	7,136	2.548	5,709	2.874	16,191	N	Yes	Note 9	2.7%	3.0%	2.5	12.0	10.6	4.2	5.9	
18	3,920	0.166	6,867	0.242	7,631	1.700	6,105	2.251	14,626	N	Yes	Note 9	1.8%	2.3%	2.7	23.9	18.1	6.6	11.0	
19	3,920	0.174	6,760	0.238	7,478	1.160	6,309	2.270	14,537	N	Yes	Note 9	1.2%	2.4%	2.7	23.8	12.1	4.5	10.5	
20	5,488	0.479	9,273	0.729	10,208	3.373	10,208	3.373	27,894	N	Yes	Fastener Failure	3.5%	3.5%	2.6	11.1	11.1	4.3	4.3	
21	5,488	0.349	9,174	0.442	10,613	3.006	8,588	3.763	32,489	N	Yes	Fastener Failure	3.1%	3.9%	2.7	20.9	16.7	6.2	9.5	
22	5,488	0.416	9,754	0.610	11,151	2.980	9,268	3.690	33,010	N	Yes	Fastener Failure	3.1%	3.8%	2.8	16.8	13.5	4.8	7.1	
23	5,488	0.351	9,618	0.516	10,877	2.913	8,702	3.308	29,331	N	Yes	Fastener Failure	3.0%	3.4%	2.8	16.1	14.2	5.1	7.3	
24	5,488	0.276	10,209	0.459	11,554	2.987	9,243	3.747	35,906	N	Yes	Fastener Failure	3.1%	3.9%	2.9	22.7	18.1	6.1	9.6	
25	5,488	0.310	9,976	0.456	11,396	2.833	9,691	3.790	35,526	N	Yes	Fastener Failure	3.0%	3.9%	2.9	23.3	17.4	6.0	9.4	
26	5,488	0.543	9,240	0.815	10,952	2.743	10,952	2.743	21,577	N	Yes	Sill plate splitting	2.9%	2.9%	2.8	8.5	8.5	3.1	3.1	
27	5,488	0.430	9,387	0.590	10,574	2.784	8,775	3.763	32,548	N	Yes	Sill plate splitting	2.9%	3.9%	2.7	16.2	11.9	4.4	7.2	
28	5,488	0.432	9,756	0.668	11,156	2.835	8,925	3.032	26,315	N	Yes	Sill plate splitting	3.0%	3.2%	2.8	11.8	11.0	3.9	5.2	
29	5,488	0.353	9,583	0.467	10,863	2.840	9,815	3.831	34,473	N	Yes	Fastener Failure	3.0%	4.0%	2.8	20.1	14.9	5.4	8.0	
30	5,488	0.339	9,481	0.442	10,771	2.827	9,844	3.946	35,316	N	Yes	Fastener Failure	2.9%	4.1%	2.7	21.6	15.4	5.6	8.6	
31	5,488	0.507	9,179	0.686	10,265	2.833	9,441	4.044	33,973	N	Yes	Fastener Failure	3.0%	4.2%	2.6	14.3	10.0	3.8	6.0	
32	5,488	0.351	9,555	0.500	10,794	2.221	10,386	3.240	28,562	N	Yes	Fastener Failure	2.3%	3.4%	2.8	15.8	10.8	3.9	6.0	
33	5,488	0.308	9,744	0.508	10,923	2.256	10,068	3.278	29,468	N	Yes	Fastener Failure	2.4%	3.4%	2.8	16.1	11.1	4.0	6.3	
34	5,488	0.285	9,556	0.471	10,920	2.278	9,290	3.089	27,261	N	Yes	Fastener Failure	2.4%	3.2%	2.8	16.0	11.8	4.2	6.8	
35	5,488	0.329	8,828	0.474	10,113	2.246	8,083	2.916	23,642	N	Yes	Sill plate splitting	2.3%	3.0%	2.6	13.8	10.6	4.1	6.7	
36	5,488	0.287	9,635	0.479	10,831	2.318	9,838	3.203	28,549	N	Yes	Fastener Failure	2.4%	3.3%	2.8	16.4	11.9	4.3	6.5	
37	5,488	0.310	9,973	0.516	11,079	2.302	10,460	3.343	30,769	N	Yes	Fastener Failure	2.4%	3.5%	2.8	16.5	11.3	4.0	6.2	
38	4,480	0.207	10,523	0.496	11,663	1.944	10,183	2.776	26,600	N	Yes	Fastener Failure	2.0%	2.9%	3.6	22.0	15.4	4.2	6.9	
39	4,480	0.143	10,778	0.366	11,929	2.018	10,042	3.073	31,144	N	Yes	Fastener Failure	2.1%	3.2%	3.7	35.3	23.2	6.2	11.3	
40	3,640	0.141	10,156	0.398	11,363	1.895	9,090	2.505	23,425	N	Yes	Fastener Failure	2.0%	2.6%	4.4	24.8	18.8	4.3	7.1	
41	3,640	0.158	8,897	0.406	10,081	2.020	8,065	2.890	23,906	N	Yes	Fastener Failure	2.1%	3.0%	3.9	25.6	17.9	4.6	8.2	
42	2,666	0.182	8,675	0.670	9,692	3.740	9,222	5.311	43,167	N	Yes	Fastener Failure	3.9%	5.5%	5.1	40.5	28.5	5.6	8.4	
43	2,666	0.167	9,010	0.598	10,205	3.739	9,010	4.968	42,064	N	Yes	Fastener Failure	3.9%	5.2%	5.4	37.1	27.9	5.2	7.8	
44	3,350	0.201	9,166	0.571	10,399	3.736	8,813	4.907	42,365	N	Yes	Fastener Failure	3.9%	5.1%	4.3	34.1	25.9	6.0	9.3	
45	3,350	0.203	9,116	0.559	10,145	3.775	9,323	5.169	44,571	N	Yes	Fastener Failure	3.9%	5.4%	4.2	35.6	26.0	6.1	9.1	
46	3,136	0.100	9,639	0.385	11,123	1.402	8,898	2.383	21,116	N	Yes	Fastener Failure	1.5%	2.5%	5.0	33.6	19.7	4.0	8.4	
47	3,136	0.081	10,213	0.369	11,627	2.027	9,302	2.519	23,837	N	Yes	Fastener Failure	2.1%	2.6%	5.2	43.4	34.9	6.7	10.5	
48	3,640	0.255	7,721	0.556	9,208	2.007	7,367	3.356	23,761	N	Yes	Fastener Failure	2.1%	3.5%	3.5	21.5	12.9	3.6	7.6	
49	3,640	0.308	7,168	0.559	8,303	2.034	6,643	3.278	21,491	N	Yes	Fastener Failure	2.1%	3.4%	3.2	18.3	11.4	3.6	7.2	
													max	3.9%	5.5%	5.4	43.4	34.9	7.0	13.0
													min	1.2%	2.3%	2.3	6.4	5.9	2.2	3.0
												<b>All Data:</b>	Average	<b>2.7%</b>	<b>3.6%</b>	<b>3.1</b>	<b>20.3</b>	<b>14.8</b>	<b>4.7</b>	<b>7.7</b>
													COV	23.9%	21.3%	26.1%	44.9%	41.9%	25.6%	32.4%
													Average + 1 STD	3.3%	4.3%	3.9	29.4	21.0	5.9	10.2
													Average - 1 STD	2.0%	2.8%	2.3	11.2	8.6	3.5	5.2
												<b>1 to 1 Data:</b>	max	3.5%	4.6%	3.4	34.3	21.1	7.0	13.0
													min	1.2%	2.3%	2.3	6.4	5.9	2.2	3.0
													Average	<b>2.7%</b>	<b>3.5%</b>	<b>2.7</b>	<b>17.3</b>	<b>12.8</b>	<b>4.8</b>	<b>7.7</b>
													COV	19.3%	16.0%	7.7%	34.2%	26.8%	24.2%	33.9%
													Average + 1 STD	3.2%	4.0%	2.9	23.2	16.3	5.9	10.3
													Average - 1 STD	2.1%	2.9%	2.5	11.4	9.4	3.6	5.1
												<b>All Data below 2:1 aspect ratio:</b>	max	3.5%	4.6%	5.2	43.4	34.9	7.0	13.0
													min	1.2%	2.3%	2.3	6.4	5.9	2.2	3.0
													Average	<b>2.6%</b>	<b>3.4%</b>	<b>2.9</b>	<b>18.8</b>	<b>13.7</b>	<b>4.6</b>	<b>7.6</b>
													COV	21.2%	16.5%	21.7%	42.1%	37.7%	26.3%	33.9%
													Average + 1 STD	3.1%	4.0%	3.6	26.7	18.9	5.9	10.2
													Average - 1 STD	2.0%	2.8%	2.3	10.9	8.5	3.4	5.0

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**Appendix B**  
**CFS Shear Wall Testing**

**Appendix C Test No. 1-10**

Salenikovich, A.J. and Dolan, J.D., 1999, Revised 2007. *Monotonic and Cyclic Tests of Long Steel-Frame Shear Walls with Openings*, Research Report RP99-2, American Iron and Steel Institute, Washington, D.C.

Monotonic and cyclic (SEAOSC SPD) testing of one Type I shear wall configuration and four Type II shear wall configurations. Test specimens are overall 8 ft by 40 ft with 100%, 70%, 40% and 30% full height sheathing. Studs and track 33 mil, headers 43 or 54 mil, sheathing 7/16 OSB, sheathing fastening No.8 self-drilling bugle head screws at 6" edge, 12" field, 3/8 inch edge distance. Simpson HTT22 tie-down with 32 No. 8 self-drilling screws. Two cyclic tests each configuration.

**Appendix C Test No. 11-63**

Branston, Aaron E, Boudrealt, Felix A., and Chen, Chang Yi, 2004. *Light Gauge Steel Frame / Wood Panel Shear Wall Test Data: Summer 2003*, Department of Civil Engineering and Applied Mechanics, McGill University, Montreal, Quebec, Canada.

Monotonic and cyclic (SPD and CUREE) testing of Type I shear wall configurations, eight feet high and two, four and eight feet long. Related papers include:

- Branston, Aaron E., 2004. *Development of a Design Methodology and Steel Frame / Wood panel Shear Walls*.
- Chen, Chang Yi, 2004. *Testing and Performance of Steel Frame / Wood Panel Shear Walls*.
- Boudrealt, Felix-Antoine, 2005. *Seismic Analysis of Steel Frame / Wood Panel Shear Walls*.
- Blais, Caroline, 2006. *Testing and Analysis of Light Gauge Steel Frame / 9mm OSB Wood Panel Shear Walls*.
- Rokas, David, 2006. *Testing and Evaluation of Light Gauge Steel Frame / 9.5MM CSP Wood Panel Shear Walls*.

**Appendix C Test No. 64-71**

Serrette, R., Nguyen, H., and Hall, G., 1996. *Shear Wall Values for Light Weight Steel Framing*, Report No. LGSRG-3-96, Light Gauge Steel Research Group, Department of Civil Engineering, Santa Clara University, Santa Clara, CA.

**Appendix C Test No. 72-81**

Serrette, R., Encalada, J., Hall, G., Matchen, B., Nguyen, H., and Williams, A., 1997. *Additional Shear Wall Values for Light Weight Steel Framing*, Report No. LGSRG-1-97, Light Gauge Steel Research Group, Department of Civil Engineering, Santa Clara University, Santa Clara, CA.

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**Appendix B**  
**CFS Shear Wall Testing**

**Appendix C Test No. 82-93**

CoLA-UCI, 2001. *Report of a Testing Program of Light-Framed Walls with Wood-Sheathed Shear Panels, Final Report to the City of Los Angeles Department of Building and Safety*, Light Frame Test Committee, Subcommittee of Research Committee, Department of Civil and Environmental Engineering, University of California, Irvine, CA.

Cyclic (SEAOSC SPD) testing of six Type I shear wall configurations. Overall dimensions of 8 ft by 8 ft. Steel studs and tracks were 20 gauge (estimate 33mil). Sheathing included 15/32-inch Structural I plywood sheathing and 7/16 OSB rated sheathing. Sheathing fasteners were No. 8 by 1-inch bugle head screws. Fastener spacings were 2, 4, and 6 inches on center edge and 12 inches on center field. Tie-downs were custom fabricated of steel plate and tube section, connected to back-to-back studs with 18-No. 10 x 3/4-inch hex head self-tapping screws.

**Appendix C Test No. 94-116**

Yu, Cheng, Vora, Hitesh, Dainard, Tony, Tucker, Jimmy, and Veetvkuri, Pradeep, 2007. *Steel Sheet Sheathing Options for Cold-Formed Steel Framed Shear Wall Assemblies Providing Shear Resistance*, Research Report RP07-3, American Iron and Steel Institute, Washington, D.C.

Monotonic and cyclic (CUREE) testing of 15 Type I wall configurations. Overall dimensions of 4 ft by 8 ft and 2 ft by 8 ft. Studs and tracks, 33 and 43 mil, steel sheet sheathing 27, 30 and 33 mil, sheathing fastening No. 8 x 18 1/2" modified truss head self-drilling tapping screws. Fastener spacing 2, 4 and 6 inches edge, 12 inches field. Fastener edge distance not specified, but estimated as one inch based on photos. No abutting sheathing edges included. Simpson S/HD10S tie down installed with 15 No. 14x1" HWH self-drilling screws (no screws at stud punch-out). Two cyclic tests each configuration. Note that of the 15 wall configurations, only 2 are directly tabulated in the AISI S213.

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Appendix C

Test	Test No.	Source	Protocol	Wall Type	Height	Length	Sheathing	Fastener Spacing	Stud Thickness	% Full Height	Opening height Rat.	C <sub>a</sub>	Elastic Stiffness	Vasd	ΔVasd	Vp	ΔVp	Δ0.8Vp	Δ0.65Vp	Vp/ Vasd	Δ0.8Vp/ Δasd	Δ0.65Vp/ Δasd	Equivalent Viscous Damping Ratio
				I or II	ft	ft		in	mills				lb / in	p/ft	in	p/ft	in	in	in				
				Geometry								AISI 5213	From Table	=13"H3*700/2.5	=13/13	=X (lb)/F3	From Plot	From Plot	=O3/N3	=M3/O3	=P3/M3	From Data	
Acyc1	1	Salenikovich	SPD	I	8	40	7/16 in OSB	6	33					280	0.190	644	1.33	Min=2.69 in	Min=3.46 in	Min=2.5	Min=11	Min=14	Min = 0.150
Acyc2	2	Salenikovich	SPD	I	8	40	7/16 in OSB	6	33					280	0.150	686	1.02	1.71	1.74	2.30	8.47	9.16	
Bcyc1	3	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.703	0.833	0.69	33681	193	0.140	704	1.36	1.55	1.79	3.64	11.07	12.79	
Bcyc2	4	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.703	0.833	0.69	33687	193	0.130	757	1.42	1.96	2.23	3.92	15.08	17.15	
Ccyc1	5	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.406	0.833	0.53	24639	148	0.110	788	1.41	2.24	2.84	5.31	20.36	25.82	
Ccyc2	6	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.406	0.833	0.53	19150	148	0.130	800	1.69	2.55	3.52	5.39	19.62	27.08	
Dcyc1	7	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.403	0.833	0.53	16497	148	0.180	701	1.61	2.61	-	4.72	14.50	-	
Dcyc2	8	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.403	0.833	0.53	20539	148	0.130	732	1.38	2.36	3.11	4.93	18.15	23.92	
Ecyc1	9	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.3	1	0.42	9280	118	0.150	542	1.90	2.36	2.57	4.61	15.73	17.13	
Ecyc2	10	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.3	1	0.42	10320	118	0.100	542	1.40	1.79	2.32	4.61	17.90	23.20	
3A	11	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43					356	0.228	943	1.87	3.35	3.44	2.65	14.67	15.06	0.078
3B	12	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43					356	0.187	991	1.78	2.87	2.93	2.78	15.38	15.70	0.086
3C	13	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43					356	0.261	953	1.98	3.24	3.38	2.67	12.39	12.93	0.078
4A	14	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43					356	0.271	1056	2.40	3.07	-	2.96	11.32	-	0.170
4B	15	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43					356	0.185	1127	2.29	2.85	-	3.16	15.40	-	0.169
4C	16	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43					356	0.268	1200	2.36	2.54	2.88	3.37	9.49	10.76	0.163
6A	17	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	4	43					472	0.207	1461	2.31	2.82	3.21	3.10	13.59	15.47	
6B	18	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	4	43					472	0.231	1450	2.28	2.78	3.15	3.08	12.05	13.65	
6C	19	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	4	43					472	0.244	1440	2.31	3.02	3.31	3.05	12.35	13.54	
8A	20	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	6	43					260	0.143	784	1.96	2.66	2.92	3.01	18.66	20.49	
8B	21	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	6	43					260	0.161	789	1.97	2.42	2.75	3.03	14.99	17.04	
8C	22	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	6	43					260	0.175	760	1.95	2.91	3.11	2.92	16.65	17.79	
10A	23	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	3	43					532	0.274	1691	2.37	2.89	3.12	3.18	10.56	11.40	
10B	24	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	3	43					532	0.281	1734	2.38	2.83	3.02	3.26	10.08	10.76	
10C	25	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	3	43					532	0.353	1653	2.37	2.59	2.89	3.11	7.34	8.19	
12A	26	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	6	43					318	0.182	889	1.95	2.56	2.82	2.80	14.04	15.47	
12B	27	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	6	43					318	0.165	1041	2.02	2.62	2.87	3.27	15.84	17.36	
12C	28	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	6	43					318	0.176	967	2.03	2.32	2.61	3.04	13.21	14.86	
14A	29	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43					606	0.249	2025	2.65	3.05	3.23	3.34	12.24	12.96	
14B	30	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43					606	0.304	1812	2.17	2.51	2.86	2.99	8.26	9.41	
14C	31	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43					606	0.251	1966	2.70	3.12	3.29	3.25	12.44	13.12	
14D	32	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43					606	0.276	1894	2.56	2.84	3.06	3.13	10.31	11.10	
16A	33	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	6	43					130	0.069	758	2.82	3.66	3.60	5.82	52.82	51.95	
16B	34	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	6	43					130	0.078	745	3.75	-	-	5.72	-	-	
16C	35	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	6	43					130	0.304	719	3.73	-	-	5.52	-	-	
18A	36	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	4	43					178	0.213	1078	4.45	-	-	6.05	-	-	
18B	37	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	4	43					178	0.120	1109	3.95	-	-	6.22	-	-	
18C	38	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	4	43					178	0.089	1183	3.94	-	-	6.64	-	-	
20A	39	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43					136	0.081	755	3.22	4.04	4.18	5.56	49.57	51.29	
20B	40	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43					136	0.065	739	3.18	4.12	4.35	5.44	63.81	67.37	
20C	41	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43					136	0.072	720	2.76	3.46	3.74	5.31	48.02	51.91	
22A	42	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43					271	0.113	759	1.63	2.33	2.64	2.80	20.55	23.28	
22B	43	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43					271	0.094	780	1.64	2.39	2.70	2.87	25.40	28.69	
22C	44	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43					271	0.139	754	1.61	2.04	2.37	2.78	14.72	17.10	
24A	45	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43					400	0.028	1131	2.26	2.40	1.99	2.83	85.86	71.19	
24B	46	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43					400	0.030	1133	1.67	2.23	2.41	2.83	74.53	80.54	
24C	47	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43					400	0.031	1138	1.49	1.84	2.10	2.84	59.92	68.38	
26A	48	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43					507	0.198	1608	1.66	2.00	2.27	3.17	10.08	11.44	
26B	49	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43					507	0.170	1517	1.38	1.91	2.19	2.99	11.20	12.85	
26C	50	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43					507	0.145	1599	2.05	2.34	2.51	3.15	16.15	17.32	
28A	51	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43					200	0.077	1143	3.24	4.38	-	5.71	56.76	-	
28B	52	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43					200	0.072	1134	3.90	4.22	-	5.66	58.25	-	
28C	53	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43					200	0.073	1213	3.23	3.68	4.01	6.06	50.53	55.06	
30A	54	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	6	43					260	0.104	874	1.90	2.51	2.77	3.35	24.24	26.75	
30B	55	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	6	43					260	0.100	848	1.91	2.55	2.81	3.25	25.40	27.99	
30C	56	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	6	43					260	0.124	875	1.88	2.65	3.00	3.36	21.44	24.27	
32A	57	McGill University, Canada	CUREE																				



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Appendix C

PLY2	69	Reynaud Serette, 1996	SPD	I	8	4	PLY	6	33						312	0.248	970	2.30	2.50	2.65	3.11	10.08	10.69	0.105
PLY3	70	Reynaud Serette, 1996	SPD	I	8	4	PLY	4	33						396	0.275	1206	2.01	2.49	2.60	3.05	9.05	9.45	0.098
PLY4	71	Reynaud Serette, 1996	SPD	I	8	4	PLY	4	33						396	0.276	1420	2.46	2.69	2.86	3.59	9.75	10.36	0.087
B1	72	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	43						356	0.215	933	1.76	1.99	2.16	2.62	9.26	10.05	0.096
B2	73	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	43						356	0.203	1096	1.96	2.48	2.63	3.08	12.22	12.96	0.093
B3	74	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	54						356	0.197	1031	1.54	1.67	1.77	2.90	8.48	8.98	0.106
B4	75	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	54						356	0.179	1096	1.75	2.04	2.14	3.08	11.40	11.96	0.091
D1	76	Reynaud Serette, 1997	SPD	I	8	4	18 mil STL	6	33						156	0.092	444	1.74	2.55	2.81	2.85	27.72	30.54	0.111
D2	77	Reynaud Serette, 1997	SPD	I	8	4	18 mil STL	6	33						156	0.102	433	1.33	2.17	2.40	2.78	21.27	23.53	0.115
E1	78	Reynaud Serette, 1997	SPD	I	8	2	OSB	6	33						140	0.089	771	2.40	-	-	5.51	-	-	0.085
E2	79	Reynaud Serette, 1997	SPD	I	8	2	OSB	6	33						140	0.092	835	2.80	-	-	5.96	-	-	0.080
E3	80	Reynaud Serette, 1997	SPD	I	8	2	OSB	4	33						183	0.094	1188	2.84	-	-	6.49	-	-	0.077
E4	81	Reynaud Serette, 1997	SPD	I	8	2	OSB	4	33						183	0.092	1292	2.59	-	-	7.06	-	-	0.077
14A	82	CoLA / UCI	TCCMAR	I	8	8	PLY	6	33						312	0.123	937	1.45	1.85	2.00	3.00	15.04	16.26	0.109
14B	83	CoLA / UCI	TCCMAR	I	8	8	PLY	6	33						312	0.123	872	1.45	1.99	2.13	2.79	16.18	17.32	0.112
14C	84	CoLA / UCI	TCCMAR	I	8	8	PLY	6	33						312	0.175	863	1.75	2.34	2.48	2.77	13.37	14.17	0.097
15A	85	CoLA / UCI	TCCMAR	I	8	8	PLY	4	33						396	0.140	1251	1.68	2.37	2.53	3.16	16.93	18.07	0.098
15B	86	CoLA / UCI	TCCMAR	I	8	8	PLY	4	33						396	0.162	1192	1.72	2.18	2.25	3.01	13.46	13.89	0.099
15C	87	CoLA / UCI	TCCMAR	I	8	8	PLY	4	33						396	0.269	1222	1.71	2.10	2.20	3.09	7.81	8.18	0.096
17A	88	CoLA / UCI	TCCMAR	I	8	8	OSB	6	33						280	0.146	772	1.47	2.01	2.20	2.76	13.77	15.07	0.112
17B	89	CoLA / UCI	TCCMAR	I	8	8	OSB	6	33						280	0.129	716	1.29	1.83	2.00	2.56	14.19	15.50	0.117
17C	90	CoLA / UCI	TCCMAR	I	8	8	OSB	6	33						280	0.174	693	1.50	1.79	2.02	2.48	10.29	11.61	0.114
18A	91	CoLA / UCI	TCCMAR	I	8	8	OSB	4	33						366	0.107	1093	1.41	1.91	2.03	2.99	17.85	18.97	0.113
18B	92	CoLA / UCI	TCCMAR	I	8	8	OSB	4	33						366	0.093	1132	1.39	1.85	2.03	3.09	19.89	21.83	0.110
18C	93	CoLA / UCI	TCCMAR	I	8	8	OSB	4	33						366	0.130	968	1.31	1.55	1.63	2.64	11.92	12.54	0.120
2X8X43X30-2-C1	94	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	2	43						468	0.700	1200	3.33	-	-	2.56	-	-	
2X8X43X30-2-C2	95	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	2	43						468	0.700	1246	3.07	-	-	2.66	-	-	
2X8X43X30-4-C1	96	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	4	43						400	0.700	1065	3.31	-	-	2.66	-	-	
2X8X43X30-4-C2	97	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	4	43						400	0.600	1119	3.18	-	-	2.80	-	-	
2X8X43X33-2-C1	98	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	2	43						468	0.600	1450	3.10	-	-	3.10	-	-	
2X8X43X33-2-C2	99	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	2	43						468	0.700	1355	3.19	-	-	2.90	-	-	
2X8X43X33-4-C1	100	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	4	43						400	0.400	1257	3.19	-	-	3.14	-	-	
2X8X43X33-4-C2	101	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	4	43						400	0.500	1357	3.34	-	-	3.39	-	-	
4X8X33X27-2/12-C1	102	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	2	33						468	0.620	794	1.71	2.17	2.40	1.70	3.50	3.87	
4X8X33X27-2/12-C2	103	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	2	33						468	0.650	878	1.87	2.37	-	1.88	3.65	-	
4X8X33X27-4/12-C1	104	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	33						400	0.430	740	1.20	1.91	2.21	1.85	4.44	5.14	
4X8X33X27-4/12-C2	105	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	33						400	0.510	707	1.20	2.21	2.69	1.77	4.33	5.27	
4X8X43X30-2/12-C1	106	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	2	43						468	0.400	1079	1.99	2.85	3.30	2.31	7.13	8.25	
4X8X43X30-2/12-C2	107	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	2	43						468	0.450	1084	1.84	2.60	3.20	2.32	5.78	7.11	
4X8X43X30-4/12-C1	108	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	4	43						400	0.400	1073	2.01	2.01	2.70	2.68	5.03	6.75	
4X8X43X30-4/12-C2	109	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	4	43						400	0.500	1073	2.05	2.95	3.15	2.68	5.90	6.30	
4X8X43X33-2/12-C1	110	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	2	43						468	0.250	1401	1.91	2.10	3.15	2.99	8.40	12.60	
4X8X43X33-2/12-C2	111	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	2	43						468	0.300	1318	2.08	2.30	2.60	2.82	7.67	8.67	
4X8X43X33-4/12-C1	112	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	4	43						400	0.350	1225	1.89	2.20	2.30	3.06	6.29	6.57	
4X8X43X33-4/12-C2	113	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	4	43						400	0.350	1271	1.70	1.80	2.00	3.18	5.14	5.71	
A-3	114	AISI Steel Sheet Walls	CUREE	I	8	4.3	30 mil STL	2	43						468	0.400	1179	1.60	3.20	3.75	2.52	8.00	9.38	
A-5	115	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	2	43						468	0.400	1164	2.04	2.80	3.30	2.49	7.00	8.25	
A-6	116	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	43						400	0.310	913	1.38	2.42	-	2.28	7.81	-	

Test No.	Source(1)	Protocol	Wall Type	Height	Length	Sheating	Fastener Spacing	Stud Thickness	% Full Height	Opening height Rat.	C <sub>a</sub>	Elastic Stiffness	V <sub>asd</sub>	ΔV <sub>asd</sub>	V <sub>p</sub>	ΔV <sub>p</sub>	Δ0.8V <sub>p</sub>	Δ0.65V <sub>p</sub>	V <sub>p</sub> / V <sub>asd</sub>	Δ0.8V <sub>p</sub> / Δ <sub>asd</sub>	Δ0.65V <sub>p</sub> / Δ <sub>asd</sub>	Equivalent Viscous Damping Ratio
				ft	ft		in	mills				lb / in	plf	in	plf	in	Min=2.69 in	Min=3.46 in	Min=2.5	Min=11	Min=14	Min = 0.150
Mean													0.232	1094	2.161	2.526	2.736	3.474	17.52	18.51	0.106	
Standard Deviation													0.157	345	0.696	0.575	0.560	1.156	15.54	15.01		
Mean plus std dev													0.389		2.857	3.101	3.296	4.629	33.07	33.52		
Mean minus std dev													0.075		1.465	1.951	2.176	2.318	1.98	3.50		
COV													0.677		0.322	0.228	0.205	0.333	0.887	0.811		

AISI Optimization Project  
Appendix D  
Protocol Adjustments

Test No.	Source	Protocol	Wall Type	Height ft	Length ft	Sheathing	Fast Spacing in	Stud mills	Vasd plf	$\Delta$ Vasd in	Vp plf	$\Delta$ Vp in	$\Delta$ 0.8Vp	$\Delta$ 0.65Vp	Vp/Vasd	$\Delta$ 0.8Vp/ $\Delta$ asd	$\Delta$ 0.65Vp/ $\Delta$ asd	Equiv Visc Damp Ratio
			I or II	Geometry					$=13 \cdot H^3 \cdot 7007$	$=13/13$	$=X (lb)/F_3$	From Plot	From Plot	From Plot	$=L3/13$	$=N3/K3$	$=O3/K3$	From Data
															Min=2.5	Min=11	Min=14	Min = 0.150
<b>Protocol Comparison for Cold-Formed Steel Framed Shear Walls</b>																		
3A	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43	356	0.228	943	1.87	3.35	3.44	2.65	14.69	15.09	0.078
3B	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43	356	0.187	990	1.77	2.87	2.93	2.78	15.35	15.67	0.086
3C	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43	356	0.261	953	1.98	3.24	3.38	2.68	12.41	12.95	0.078
Mean										0.225	962	1.87	3.15	3.25	2.70	14.15	14.57	0.081
4A	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43	356	0.271	1056	2.40	3.07	-	2.97	11.33	-	0.170
4B	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43	356	0.185	1127	2.29	2.85	-	3.17	15.41	-	0.169
4C	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43	356	0.268	1200	2.35	2.54	2.78	3.37	9.48	10.37	0.163
Mean										0.241	1128	2.35	2.82	2.78	3.17	12.07	10.37	0.167
<b>Ratio CUREE to SPD</b>										1.07	1.17	1.25	0.89	0.86	1.17	0.85	0.71	2.07
<b>Recommended adjustment</b>										1.07	1.17	1.25	-	-				2.00
<b>Protocol Comparison for Wood-Framed Shear Walls - For Information Only - Not Used For Adjustments</b>																		
4	Gatto & Uang	SPD	I	8	8	3/8 OSB	4	2x4	330	0.37	871	2.25	2.83	3.11	2.64	7.65	8.41	0.115
8	Gatto & Uang	SPD	I	8	8	15/32 PLWD	4	2x4	330	0.29	855	2.44	2.91	3.18	2.59	10.03	10.97	0.118
Mean										0.330	863	2.35	2.87	3.15	2.62	8.84	9.69	0.117
2	Gatto & Uang	CUREE	I	8	8	3/8 OSB	4	2x4	330	0.34	1027	3.64	4.19	4.59	3.11	12.32	13.50	0.142
6	Gatto & Uang	CUREE	I	8	8	15/32 PLWD	4	2x4	330	0.27	1122	4.50	5.14	5.80	3.40	19.04	21.48	0.127
Mean										0.305	1075	4.07	4.67	5.20	3.26	15.68	17.49	0.135
<b>Ratio CUREE to SPD</b>										0.92	1.25	1.74	1.63	1.65	1.25	1.77	1.81	1.15

AISI Optimization Project  
Appendix E  
All Walls Data Set - with Protocol Conversion

Test	Test No.	Source	Protocol	Wall Type	Height	Length	Sheathing	Fastener Spacing	Stud Thickness	% Full Height	Opening height Rat.	C <sub>a</sub>	Elastic Stiffness	Vasd	ΔVasd	Δvasd Adj	Vp	Vp Adj	ΔVp	ΔVp Adj
				I or II	ft	ft		in	mills			AISI S213	lb / in	plf	in		plf		in	
					Geometry								From Table	=J3*H3*700/2.5	=J3/I3		=X (lb)/F3		From Plot	
Acyc1	1	Salenikovich	SPD	I	8	40	7/16 in OSB	6	33					280	0.190	0.203	644	753	1.33	1.66
Acyc2	2	Salenikovich	SPD	I	8	40	7/16 in OSB	6	33					280	0.150	0.161	686	803	1.02	1.28
Bcyc1	3	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.703	0.833	0.69	33681	193	0.140	0.150	704	823	1.36	1.70
Bcyc2	4	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.703	0.833	0.69	33687	193	0.130	0.139	757	886	1.42	1.78
Ccyc1	5	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.406	0.833	0.53	24639	148	0.110	0.118	788	922	1.41	1.76
Ccyc2	6	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.406	0.833	0.53	19150	148	0.130	0.139	800	937	1.69	2.11
Dcyc1	7	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.403	0.833	0.53	16497	148	0.180	0.193	701	820	1.61	2.01
Dcyc2	8	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.403	0.833	0.53	20539	148	0.130	0.139	732	856	1.38	1.73
Ecyc1	9	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.3	1	0.42	9280	118	0.150	0.161	542	634	1.90	2.38
Ecyc2	10	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.3	1	0.42	10320	118	0.100	0.107	542	634	1.40	1.75
3A	11	McGill University, Canada	SPD	I	8	4	2.5 mm CS	4	43					356	0.228	0.244	943	1103	1.87	2.34
3B	12	McGill University, Canada	SPD	I	8	4	2.5 mm CS	4	43					356	0.187	0.200	991	1159	1.78	2.23
3C	13	McGill University, Canada	SPD	I	8	4	2.5 mm CS	4	43					356	0.261	0.280	953	1115	1.98	2.48
4A	14	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	4	43					356	0.271	0.271	1056	1056	2.40	2.40
4B	15	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	4	43					356	0.185	0.185	1127	1127	2.29	2.29
4C	16	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	4	43					356	0.268	0.268	1200	1200	2.36	2.36
6A	17	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	4	43					472	0.207	0.207	1461	1461	2.31	2.31
6B	18	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	4	43					472	0.231	0.231	1450	1450	2.28	2.28
6C	19	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	4	43					472	0.244	0.244	1440	1440	2.31	2.31
8A	20	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	6	43					260	0.143	0.143	784	784	1.96	1.96
8B	21	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	6	43					260	0.161	0.161	789	789	1.97	1.97
8C	22	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	6	43					260	0.175	0.175	760	760	1.95	1.95
10A	23	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	3	43					532	0.274	0.274	1691	1691	2.37	2.37
10B	24	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	3	43					532	0.281	0.281	1734	1734	2.38	2.38
10C	25	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	3	43					532	0.353	0.353	1653	1653	2.37	2.37
12A	26	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	6	43					318	0.182	0.182	889	889	1.95	1.95
12B	27	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	6	43					318	0.165	0.165	1041	1041	2.02	2.02
12C	28	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	6	43					318	0.176	0.176	967	967	2.03	2.03
14A	29	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	3	43					606	0.249	0.249	2025	2025	2.65	2.65
14B	30	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	3	43					606	0.304	0.304	1812	1812	2.17	2.17
14C	31	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	3	43					606	0.251	0.251	1966	1966	2.70	2.70
14D	32	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	3	43					606	0.276	0.276	1894	1894	2.56	2.56
16A	33	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	6	43					130	0.069	0.069	758	758	2.82	2.82
16B	34	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	6	43					130	0.078	0.078	745	745	3.75	3.75
16C	35	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	6	43					130	0.304	0.304	719	719	3.73	3.73
18A	36	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	4	43					178	0.213	0.213	1078	1078	4.45	4.45
18B	37	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	4	43					178	0.120	0.120	1109	1109	3.95	3.95
18C	38	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	4	43					178	0.089	0.089	1183	1183	3.94	3.94
20A	39	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43					136	0.081	0.081	755	755	3.22	3.22
20B	40	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43					136	0.065	0.065	739	739	3.18	3.18
20C	41	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43					136	0.072	0.072	720	720	2.76	2.76
22A	42	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43					271	0.113	0.113	759	759	1.63	1.63
22B	43	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43					271	0.094	0.094	780	780	1.64	1.64
22C	44	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43					271	0.139	0.139	754	754	1.61	1.61
24A	45	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43					400	0.028	0.028	1131	1131	2.26	2.26
24B	46	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43					400	0.030	0.030	1133	1133	1.67	1.67
24C	47	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43					400	0.031	0.031	1138	1138	1.49	1.49
26A	48	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43					507	0.198	0.198	1608	1608	1.66	1.66
26B	49	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43					507	0.170	0.170	1517	1517	1.38	1.38
26C	50	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43					507	0.145	0.145	1599	1599	2.05	2.05
28A	51	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43					200	0.077	0.077	1143	1143	3.24	3.24
28B	52	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43					200	0.072	0.072	1134	1134	3.90	3.90
28C	53	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43					200	0.073	0.073	1213	1213	3.23	3.23
30A	54	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	6	43					260	0.104	0.104	874	874	1.90	1.90
30B	55	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	6	43					260	0.100	0.100	848	848	1.91	1.91
30C	56	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	6	43					260	0.124	0.124	875	875	1.88	1.88
32A	57	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	4	43					356	0.179	0.179	1306	1306	2.15	2.15
32B	58	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	4	43					356	0.173	0.173	1308	1308	2.19	2.19
32C	59	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	4	43					356	0.194	0.194	1312	1312	2.23	2.23
34A	60	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	3	43					532	0.247	0.247	1732	1732	2.42	2.42
34B	61	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	3	43					532	0.226	0.226	1857	1857	2.41	2.41
34C	62	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	3	43					532	0.240	0.240	1781	1781	2.38	2.38
34D	63	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	3	43					532	0.169	0.169	1990	1990	2.28	2.28
OSB1	64	Reynaud Serette, 1996	SPD	I	8	4	OSB	6	33					280	0.190	0.203	946	1107	2.05	2.56
OSB2	65	Reynaud Serette, 1996	SPD	I	8	4	OSB	6	33					280	0.307	0.328	967	1131	2.04	2.55

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OSB3	66	Reynaud Serette, 1996	SPD	I	8	4	OSB	4	33						366	0.264	0.282	1298	1519	2.28	2.85
OSB4	67	Reynaud Serette, 1996	SPD	I	8	4	OSB	4	33						366	0.210	0.225	1247	1459	2.33	2.91
PLY1	68	Reynaud Serette, 1996	SPD	I	8	4	PLY	6	33						312	0.265	0.284	1010	1182	1.73	2.16
PLY2	69	Reynaud Serette, 1996	SPD	I	8	4	PLY	6	33						312	0.248	0.265	970	1135	2.30	2.88
PLY3	70	Reynaud Serette, 1996	SPD	I	8	4	PLY	4	33						396	0.275	0.294	1206	1411	2.01	2.51
PLY4	71	Reynaud Serette, 1996	SPD	I	8	4	PLY	4	33						396	0.276	0.295	1420	1661	2.46	3.08
B1	72	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	43						356	0.215	0.230	933	1092	1.76	2.20
B2	73	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	43						356	0.203	0.217	1096	1282	1.96	2.45
B3	74	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	54						356	0.197	0.211	1031	1206	1.54	1.93
B4	75	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	54						356	0.179	0.192	1096	1282	1.75	2.19
D1	76	Reynaud Serette, 1997	SPD	I	8	4	18 mil STL	6	33						156	0.092	0.098	444	519	1.74	2.18
D2	77	Reynaud Serette, 1997	SPD	I	8	4	18 mil STL	6	33						156	0.102	0.109	433	507	1.33	1.66
E1	78	Reynaud Serette, 1997	SPD	I	8	2	OSB	6	33						140	0.089	0.095	771	902	2.40	3.00
E2	79	Reynaud Serette, 1997	SPD	I	8	2	OSB	6	33						140	0.092	0.098	835	977	2.80	3.50
E3	80	Reynaud Serette, 1997	SPD	I	8	2	OSB	4	33						183	0.094	0.101	1188	1390	2.84	3.55
E4	81	Reynaud Serette, 1997	SPD	I	8	2	OSB	4	33						183	0.092	0.098	1292	1512	2.59	3.24
14A	82	CoLA / UCI	TCCMAR	I	8	8	PLY	6	33						312	0.123	0.132	937	1096	1.45	1.81
14B	83	CoLA / UCI	TCCMAR	I	8	8	PLY	6	33						312	0.123	0.132	872	1020	1.45	1.81
14C	84	CoLA / UCI	TCCMAR	I	8	8	PLY	6	33						312	0.175	0.187	863	1010	1.75	2.19
15A	85	CoLA / UCI	TCCMAR	I	8	8	PLY	4	33						396	0.140	0.150	1251	1464	1.68	2.10
15B	86	CoLA / UCI	TCCMAR	I	8	8	PLY	4	33						396	0.162	0.173	1192	1395	1.72	2.15
15C	87	CoLA / UCI	TCCMAR	I	8	8	PLY	4	33						396	0.269	0.288	1222	1430	1.71	2.14
17A	88	CoLA / UCI	TCCMAR	I	8	8	OSB	6	33						280	0.146	0.156	772	903	1.47	1.84
17B	89	CoLA / UCI	TCCMAR	I	8	8	OSB	6	33						280	0.129	0.138	716	838	1.29	1.61
17C	90	CoLA / UCI	TCCMAR	I	8	8	OSB	6	33						280	0.174	0.186	693	811	1.50	1.88
18A	91	CoLA / UCI	TCCMAR	I	8	8	OSB	4	33						366	0.107	0.114	1093	1279	1.41	1.76
18B	92	CoLA / UCI	TCCMAR	I	8	8	OSB	4	33						366	0.093	0.100	1132	1324	1.39	1.74
18C	93	CoLA / UCI	TCCMAR	I	8	8	OSB	4	33						366	0.130	0.139	968	1133	1.31	1.64
2X8X43X30-2-C1	94	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	2	43						468	0.700	0.700	1200	1200	3.33	3.33
2X8X43X30-2-C2	95	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	2	43						468	0.700	0.700	1246	1246	3.07	3.07
2X8X43X30-4-C1	96	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	4	43						400	0.700	0.700	1065	1065	3.31	3.31
2X8X43X30-4-C2	97	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	4	43						400	0.600	0.600	1119	1119	3.18	3.18
2X8X43X33-2-C1	98	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	2	43						468	0.600	0.600	1450	1450	3.10	3.10
2X8X43X33-2-C2	99	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	2	43						468	0.700	0.700	1355	1355	3.19	3.19
2X8X43X33-4-C1	100	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	4	43						400	0.400	0.400	1257	1257	3.19	3.19
2X8X43X33-4-C2	101	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	4	43						400	0.500	0.500	1357	1357	3.34	3.34
4X8X33X27-2/12-C1	102	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	2	33						468	0.600	0.600	832	832	1.73	1.73
4X8X33X27-2/12-C2	103	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	2	33						468	0.600	0.600	913	913	2.06	2.06
4X8X33X27-4/12-C1	104	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	33						400	0.450	0.450	743	743	1.23	1.23
4X8X33X27-4/12-C2	105	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	33						400	0.400	0.400	694	694	1.22	1.22
4X8X43X30-2/12-C1	106	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	2	43						468	0.400	0.400	1079	1079	1.99	1.99
4X8X43X30-2/12-C2	107	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	2	43						468	0.450	0.450	1084	1084	1.84	1.84
4X8X43X30-4/12-C1	108	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	4	43						400	0.400	0.400	1073	1073	2.01	2.01
4X8X43X30-4/12-C2	109	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	4	43						400	0.500	0.500	1073	1073	2.05	2.05
4X8X43X33-2/12-C1	110	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	2	43						468	0.250	0.250	1401	1401	1.91	1.91
4X8X43X33-2/12-C2	111	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	2	43						468	0.300	0.300	1318	1318	2.08	2.08
4X8X43X33-4/12-C1	112	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	4	43						400	0.350	0.350	1225	1225	1.89	1.89
4X8X43X33-4/12-C2	113	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	4	43						400	0.350	0.350	1271	1271	1.70	1.70
A-3	114	AISI Steel Sheet Walls	CUREE	I	8	4.270833333	30 mil STL	2	43						468	0.400	0.400	1179	1179	1.60	1.60
A-5	115	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	2	43						468	0.400	0.400	1164	1164	2.04	2.04
A-6	116	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	43						400	0.400	0.400	954	954	1.40	1.40

Test No.	Source(1)	Protocol	Wall Type	Height	Length	Sheathing	Fastener Spacing	Stud Thickness	% Full Height	Opening height Rat.	C <sub>a</sub>	Elastic Stiffness	V <sub>asd</sub>	ΔV <sub>asd</sub>	ΔV <sub>asd</sub> Adj	V <sub>p</sub>	V <sub>p</sub> Adj	ΔV <sub>p</sub>	ΔV <sub>p</sub> Adj
				ft	ft		in	mills				lb / in	plf	in		plf		in	
Mean														0.231	0.235	1095	1153	2.164	2.328
Standard Deviation														0.155	0.154	344	335	0.695	0.661
Mean plus std dev														0.386	0.389	1440	1488	2.858	2.989
Mean minus std dev														0.076	0.082	751	819	1.469	1.667
COV														0.670	0.653	0	0	0.321	0.284

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$\Delta 0.8Vp$	$\Delta 0.65Vp$	Vp Adj/ Vasd	$\Delta 0.8Vp / \Delta asd$ Adj	$\Delta 0.65Vp / \Delta asd$ Adj	Equivalent Viscous Damping Ratio	Damping Adj
in	in					
	From Plot	=O3/N3	=M3/O3	=P3/M3	From Data	
Min=2.69 in	Min=3.46 in	Min=2.5	Min=11	Min=14	Min = 0.150	
1.61	1.74	2.69	7.92	8.56		
1.71	1.94	2.87	10.65	12.09		
1.55	1.79	4.26	10.35	11.95		
1.96	2.23	4.59	14.09	16.03		
2.24	2.84	6.21	19.03	24.13		
2.55	3.52	6.31	18.33	25.31		
2.61	-	5.53	13.55	-		
2.36	3.11	5.77	16.97	22.36		
2.36	2.57	5.39	14.70	16.01		
1.79	2.32	5.39	16.73	21.68		
3.35	3.44	3.10	13.71	14.08	0.078	0.156
2.87	2.93	3.25	14.37	14.67	0.086	0.172
3.24	3.38	3.13	11.58	12.08	0.078	0.156
3.07	-	2.96	11.32	-	0.170	0.170
2.85	-	3.16	15.40	-	0.169	0.169
2.54	2.88	3.37	9.49	10.76	0.163	0.163
2.82	3.21	3.10	13.59	15.47		
2.78	3.15	3.08	12.05	13.65		
3.02	3.31	3.05	12.35	13.54		
2.66	2.92	3.01	18.66	20.49		
2.42	2.75	3.03	14.99	17.04		
2.91	3.11	2.92	16.65	17.79		
2.89	3.12	3.18	10.56	11.40		
2.83	3.02	3.26	10.08	10.76		
2.59	2.89	3.11	7.34	8.19		
2.56	2.82	2.80	14.04	15.47		
2.62	2.87	3.27	15.84	17.36		
2.32	2.61	3.04	13.21	14.86		
3.05	3.23	3.34	12.24	12.96		
2.51	2.86	2.99	8.26	9.41		
3.12	3.29	3.25	12.44	13.12		
2.84	3.06	3.13	10.31	11.10		
3.66	3.60	5.82	52.82	51.95		
-	-	5.72	-	-		
-	-	5.52	-	-		
-	-	6.05	-	-		
-	-	6.22	-	-		
-	-	6.64	-	-		
4.04	4.18	5.56	49.57	51.29		
4.12	4.35	5.44	63.81	67.37		
3.46	3.74	5.31	48.02	51.91		
2.33	2.64	2.80	20.55	23.28		
2.39	2.70	2.87	25.40	28.69		
2.04	2.37	2.78	14.72	17.10		
2.40	1.99	2.83	85.86	71.19		
2.23	2.41	2.83	74.53	80.54		
1.84	2.10	2.84	59.92	68.38		
2.00	2.27	3.17	10.08	11.44		
1.91	2.19	2.99	11.20	12.85		
2.34	2.51	3.15	16.15	17.32		
4.38	-	5.71	56.76	-		
4.22	-	5.66	58.25	-		
3.68	4.01	6.06	50.53	55.06		
2.51	2.77	3.35	24.24	26.75		
2.55	2.81	3.25	25.40	27.99		
2.65	3.00	3.36	21.44	24.27		
2.54	2.88	3.66	14.21	16.11		
2.98	3.26	3.67	17.20	18.82		
2.97	3.27	3.68	15.33	16.88		
2.74	2.98	3.26	11.10	12.07		
3.20	3.49	3.49	14.18	15.47		
3.03	3.32	3.35	12.64	13.85		
2.56	2.77	3.74	15.19	16.44		
2.62	2.75	3.95	12.89	13.53	0.101	0.202
2.43	2.58	4.04	7.40	7.85	0.101	0.202

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2.47	2.56	4.15	8.74	9.06	0.098	0.196
2.63	2.68	3.99	11.70	11.93	0.105	0.210
2.29	2.34	3.79	8.08	8.25	0.131	0.262
2.50	2.65	3.64	9.42	9.99	0.105	0.210
2.49	2.60	3.56	8.46	8.84	0.098	0.196
2.69	2.86	4.20	9.11	9.68	0.087	0.174
1.99	2.16	3.07	8.65	9.39	0.096	0.192
2.48	2.63	3.60	11.42	12.11	0.093	0.186
1.67	1.77	3.39	7.92	8.40	0.106	0.212
2.04	2.14	3.60	10.65	11.17	0.091	0.182
2.55	2.81	3.33	25.90	28.55	0.111	0.222
2.17	2.40	3.25	19.88	21.99	0.115	0.230
-	-	6.44	-	-	0.085	0.170
-	-	6.98	-	-	0.080	0.160
-	-	7.60	-	-	0.077	0.154
-	-	8.26	-	-	0.077	0.154
1.85	2.00	3.51	14.06	15.20	0.109	0.218
1.99	2.13	3.27	15.12	16.18	0.112	0.224
2.34	2.48	3.24	12.50	13.24	0.097	0.194
2.37	2.53	3.70	15.82	16.89	0.098	0.196
2.18	2.25	3.52	12.58	12.98	0.099	0.198
2.10	2.20	3.61	7.30	7.64	0.096	0.192
2.01	2.20	3.23	12.87	14.08	0.112	0.224
1.83	2.00	2.99	13.26	14.49	0.117	0.234
1.79	2.02	2.90	9.61	10.85	0.114	0.228
1.91	2.03	3.49	16.68	17.73	0.113	0.226
1.85	2.03	3.62	18.59	20.40	0.110	0.220
1.55	1.63	3.09	11.14	11.72	0.120	0.240
-	-	2.56	-	-		
-	-	2.66	-	-		
-	-	2.66	-	-		
-	-	2.80	-	-		
-	-	3.10	-	-		
-	-	2.90	-	-		
-	-	3.14	-	-		
-	-	3.39	-	-		
2.15	2.25	1.78	3.58	3.75		
2.20	2.70	1.95	3.67	4.50		
2.20	2.50	1.86	4.89	5.56		
2.60	2.70	1.74	6.50	6.75		
2.85	3.30	2.31	7.13	8.25		
2.60	3.20	2.32	5.78	7.11		
2.01	2.70	2.68	5.03	6.75		
2.95	3.15	2.68	5.90	6.30		
2.10	3.15	2.99	8.40	12.60		
2.30	2.60	2.82	7.67	8.67		
2.20	2.30	3.06	6.29	6.57		
1.80	2.00	3.18	5.14	5.71		
3.20	3.75	2.52	8.00	9.38		
2.80	3.30	2.49	7.00	8.25		
2.20	3.40	2.39	5.50	8.50		

$\Delta 0.8Vp$	$\Delta 0.65Vp$	Vp adj/ Vasd Adj	$\Delta 0.8Vp/ \Delta asd Adj$	$\Delta 0.65Vp/ \Delta asd Adj$	Equivalent Viscous Damping Ratio	Equivalent Viscous Damping Ratio
	in	2.5min	11min	14min		.15min
2.528	2.744	3.700	17.173	17.874	0.106	0.197
0.573	0.557	1.282	15.600	14.974		
3.102	3.301	4.982	32.774	32.848		
1.955	2.187	2.419	1.573	2.900		
0.227	0.203	0.346	0.908	0.838		

AISI Optimization Project  
Appendix F  
Type II Walls Only

Test	Test No.	Source	Protocol	Wall Type	Height	Length	Sheating	Fastener Spacing	Stud Thickness	% Full Height	Opening height Rat.	C <sub>s</sub>	Elastic Stiffness	Vasd	ΔVasd	Vp	ΔVp	Δ0.8Vp	Δ0.65Vp	Vp/ Vasd	Δ0.8Vp/ Δasd	Δ0.65Vp/ Δasd	
				I or II	ft	ft		in	mills				lb / in	plf	in	plf	in	in	in	in			
					Geometry								AISI S213 From Table*H3*700/	=I3/I3	=X (lb)/F3 From Plot				From Plot	=O3/N3	=M3/O3	=P3/M3	
																		Min=2.69 in	Min=3.46 in	Min=2.5	Min=11	Min=14	
Bcyc1	3	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.703	0.833	0.69	33681	193	0.140	704	1.36	1.55	1.79	3.64	11.07	12.79	
Bcyc2	4	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.703	0.833	0.69	33687	193	0.130	757	1.42	1.96	2.23	3.92	15.08	17.15	
Ccyc1	5	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.406	0.833	0.53	24639	148	0.110	788	1.41	2.24	2.84	5.31	20.36	25.82	
Ccyc2	6	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.406	0.833	0.53	19150	148	0.130	800	1.69	2.55	3.52	5.39	19.62	27.08	
Dcyc1	7	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.403	0.833	0.53	16497	148	0.180	701	1.61	2.61	-	4.72	14.50	-	
Dcyc2	8	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.403	0.833	0.53	20539	148	0.130	732	1.38	2.36	3.11	4.93	18.15	23.92	
Ecyc1	9	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.3	1	0.42	9280	118	0.150	542	1.90	2.36	2.57	4.61	15.73	17.13	
Ecyc2	10	Salenikovich	SPD	II	8	40	7/16 in OSB	6	33	0.3	1	0.42	10320	118	0.100	542	1.40	1.79	2.32	4.61	17.90	23.20	

Test No.	Source(1)	Protocol	Wall Type	Height	Length	Sheating	Fastener Spacing	Stud Thickness	% Full Height	Opening height Rat.	C <sub>s</sub>	Elastic Stiffness	Vasd	ΔVasd	Vp	ΔVp	Δ0.8Vp	Δ0.65Vp	Vp/ Vasd	Δ0.8Vp/ Δasd	Δ0.65Vp/ Δasd	
				ft	ft		in	mills				lb / in	plf	in	plf	in	in	in	in			
Mean														0.134	696	1.521	2.178	2.626	4.642	16.55	21.01	
Standard Deviation														0.024	102	0.194	0.376	0.582	0.612	3.06	5.33	
Mean plus std dev														0.158	797	1.715	2.553	3.208	5.255	19.61	26.35	
Mean minus std dev														0.109	594	1.327	1.802	2.044	4.030	13.50	15.68	
COV														0.183	0.146	0.127	0.172	0.222	0.132	0.185	0.254	

AISI Optimization Project  
Appendix G  
All Walls Type I

Test	Test No.	Source	Protocol	Wall Type	Height ft	Length ft	Sheathing	Fastener Spacing in	Stud Thickness mills	% Full Height	Opening height Rat.	$C_p$	Elastic Stiffness lb / in	Vasd plf	$\Delta V_{asd}$ in	Vp plf	$\Delta V_p$ in	$\Delta 0.8V_p$ in	$\Delta 0.65V_p$ in	Vp / Vasd	$\Delta 0.8V_p / \Delta V_{asd}$	$\Delta 0.65V_p / \Delta V_{asd}$
				I or II	Geometry								AISI S213 From Table	$=H^3 \cdot 700 /$	$=J^3 / I^3$	$=X (lb) / F^3$	From Plot	From Plot	$=O_3 / N_3$	$=M_3 / O_3$	$=P_3 / M_3$	
																	Min=2.69 in	Min=3.46 in	Min=2.5	Min=11	Min=14	
3A	11	McGill University, Canada	SPD	I	8	4	2.5 mm CS	4	43					356	0.228	943	1.87	3.35	3.44	2.65	14.67	15.06
3B	12	McGill University, Canada	SPD	I	8	4	2.5 mm CS	4	43					356	0.187	991	1.78	2.87	2.93	2.78	15.38	15.70
3C	13	McGill University, Canada	SPD	I	8	4	2.5 mm CS	4	43					356	0.261	953	1.98	3.24	3.38	2.67	12.39	12.93
4A	14	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	4	43					356	0.271	1056	2.40	3.07	-	2.96	11.32	-
4B	15	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	4	43					356	0.185	1127	2.29	2.85	-	3.16	15.40	-
4C	16	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	4	43					356	0.268	1200	2.36	2.54	2.88	3.37	9.49	10.76
6A	17	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	4	43					472	0.207	1461	2.31	2.82	3.21	3.10	13.59	15.47
6B	18	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	4	43					472	0.231	1450	2.28	2.78	3.15	3.08	12.05	13.65
6C	19	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	4	43					472	0.244	1440	2.31	3.02	3.31	3.05	12.35	13.54
8A	20	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	6	43					260	0.143	784	1.96	2.66	2.92	3.01	18.66	20.49
8B	21	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	6	43					260	0.161	789	1.97	2.42	2.75	3.03	14.99	17.04
8C	22	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	6	43					260	0.175	760	1.95	2.91	3.11	2.92	16.65	17.79
10A	23	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	3	43					532	0.274	1691	2.37	2.89	3.12	3.18	10.56	11.40
10B	24	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	3	43					532	0.281	1734	2.38	2.83	3.02	3.26	10.08	10.76
10C	25	McGill University, Canada	CUREE	I	8	4	2.5 mm CS	3	43					532	0.353	1653	2.37	2.59	2.89	3.11	7.34	8.19
12A	26	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	6	43					318	0.182	889	1.95	2.56	2.82	2.80	14.04	15.47
12B	27	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	6	43					318	0.165	1041	2.02	2.62	2.87	3.27	15.84	17.36
12C	28	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	6	43					318	0.176	967	2.03	2.32	2.61	3.04	13.21	14.86
14A	29	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	3	43					606	0.249	2025	2.65	3.05	3.23	3.34	12.24	12.96
14B	30	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	3	43					606	0.304	1812	2.17	2.51	2.86	2.99	8.26	9.41
14C	31	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	3	43					606	0.251	1966	2.70	3.12	3.29	3.25	12.44	13.12
14D	32	McGill University, Canada	CUREE	I	8	4	2.5 mm DF	3	43					606	0.276	1894	2.56	2.84	3.06	3.13	10.31	11.10
16A	33	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	6	43					130	0.069	758	2.82	3.66	3.60	5.82	52.82	51.95
16B	34	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	6	43					130	0.078	745	3.75	-	-	5.72	-	-
16C	35	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	6	43					130	0.304	719	3.73	-	-	5.52	-	-
18A	36	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	4	43					178	0.213	1078	4.45	-	-	6.05	-	-
18B	37	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	4	43					178	0.120	1109	3.95	-	-	6.22	-	-
18C	38	McGill University, Canada	CUREE	I	8	2	2.5 mm CS	4	43					178	0.089	1183	3.94	-	-	6.64	-	-
20A	39	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43					136	0.081	755	3.22	4.04	4.18	5.56	49.57	51.29
20B	40	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43					136	0.065	739	3.18	4.12	4.35	5.44	63.81	67.37
20C	41	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43					136	0.072	720	2.76	3.46	3.74	5.31	48.02	51.91
22A	42	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43					271	0.113	759	1.63	2.33	2.64	2.80	20.55	23.28
22B	43	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43					271	0.094	780	1.64	2.39	2.70	2.87	25.40	28.69
22C	44	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43					271	0.139	754	1.61	2.04	2.37	2.78	14.72	17.10
24A	45	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43					400	0.028	1131	2.26	2.40	1.99	2.83	85.86	71.19
24B	46	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43					400	0.030	1133	1.67	2.23	2.41	2.83	74.53	80.54
24C	47	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43					400	0.031	1138	1.49	1.84	2.10	2.84	59.92	68.38
26A	48	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43					507	0.198	1608	1.66	2.00	2.27	3.17	10.08	11.44
26B	49	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43					507	0.170	1517	1.38	1.91	2.19	2.99	11.20	12.85
26C	50	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43					507	0.145	1599	2.05	2.34	2.51	3.15	16.15	17.32
28A	51	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43					200	0.077	1143	3.24	4.38	-	5.71	56.76	-
28B	52	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43					200	0.072	1134	3.90	4.22	-	5.66	58.25	-
28C	53	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43					200	0.073	1213	3.23	3.68	4.01	6.06	50.53	55.06
30A	54	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	6	43					260	0.104	874	1.90	2.51	2.77	3.35	24.24	26.75
30B	55	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	6	43					260	0.100	848	1.91	2.55	2.81	3.25	25.40	27.99
30C	56	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	6	43					260	0.124	875	1.88	2.65	3.00	3.36	21.44	24.27
32A	57	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	4	43					356	0.179	1306	2.15	2.54	2.88	3.66	14.21	16.11
32B	58	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	4	43					356	0.173	1308	2.19	2.98	3.26	3.67	17.20	18.82
32C	59	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	4	43					356	0.194	1312	2.23	2.97	3.27	3.68	15.33	16.88
34A	60	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	3	43					532	0.247	1732	2.42	2.74	2.98	3.26	11.10	12.07
34B	61	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	3	43					532	0.226	1857	2.41	3.20	3.49	3.49	14.18	15.47
34C	62	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	3	43					532	0.240	1781	2.38	3.03	3.32	3.35	12.64	13.85
34D	63	McGill University, Canada	CUREE	I	8	8	2.5 mm CS	3	43					532	0.169	1990	2.28	2.56	2.77	3.74	15.19	16.44
OSB1	64	Reynaud Serette, 1996	SPD	I	8	4	OSB	6	33					280	0.190	946	2.05	2.62	2.75	3.38	13.79	14.47
OSB2	65	Reynaud Serette, 1996	SPD	I	8	4	OSB	6	33					280	0.307	967	2.04	2.43	2.58	3.45	7.92	8.40
OSB3	66	Reynaud Serette, 1996	SPD	I	8	4	OSB	4	33					366	0.264	1298	2.28	2.47	2.56	3.55	9.36	9.70
OSB4	67	Reynaud Serette, 1996	SPD	I	8	4	OSB	4	33					366	0.210	1247	2.33	2.63	2.68	3.41	12.52	12.76
PLY1	68	Reynaud Serette, 1996	SPD	I	8	4	PLY	6	33					312	0.265	1010	1.73	2.29	2.34	3.24	8.64	8.83
PLY2	69	Reynaud Serette, 1996	SPD	I	8	4	PLY	6	33					312	0.248	970	2.30	2.50	2.65	3.11	10.08	10.69
PLY3	70	Reynaud Serette, 1996	SPD	I	8	4	PLY	4	33					396	0.275	1206	2.01	2.49	2.60	3.05	9.05	9.45





AISI Optimization Project  
Appendix H  
WSP Walls Only

Test	Test No.	Source	Protocol	Wall Type	Height ft	Length ft	Sheathing	Fastener Spacing in	Stud Thickness mills	Vasd plf	$\Delta$ Vasd in	Vp plf	$\Delta$ Vp in	$\Delta$ 0.8Vp in	$\Delta$ 0.65Vp in	Vp/ Vasd	$\Delta$ 0.8Vp/ $\Delta$ asd	$\Delta$ 0.65Vp/ $\Delta$ asd
				I or II	Geometry					$=J3*H3*700/$	$=J3/I3$	$=X (lb)/F3$	From Plot	From Plot	$=O3/N3$	$=M3/O3$	$=P3/M3$	
													Min=2.69 in	Min=3.46 in	Min=2.5	Min=11	Min=14	
3A	11	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43	356	0.228	943	1.87	3.35	3.44	2.65	14.67	15.06
3B	12	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43	356	0.187	991	1.78	2.87	2.93	2.78	15.38	15.70
3C	13	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43	356	0.261	953	1.98	3.24	3.38	2.67	12.39	12.93
4A	14	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43	356	0.271	1056	2.40	3.07	-	2.96	11.32	-
4B	15	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43	356	0.185	1127	2.29	2.85	-	3.16	15.40	-
4C	16	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43	356	0.268	1200	2.36	2.54	2.88	3.37	9.49	10.76
6A	17	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	4	43	472	0.207	1461	2.31	2.82	3.21	3.10	13.59	15.47
6B	18	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	4	43	472	0.231	1450	2.28	2.78	3.15	3.08	12.05	13.65
6C	19	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	4	43	472	0.244	1440	2.31	3.02	3.31	3.05	12.35	13.54
8A	20	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	6	43	260	0.143	784	1.96	2.66	2.92	3.01	18.66	20.49
8B	21	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	6	43	260	0.161	789	1.97	2.42	2.75	3.03	14.99	17.04
8C	22	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	6	43	260	0.175	760	1.95	2.91	3.11	2.92	16.65	17.79
10A	23	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	3	43	532	0.274	1691	2.37	2.89	3.12	3.18	10.56	11.40
10B	24	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	3	43	532	0.281	1734	2.38	2.83	3.02	3.26	10.08	10.76
10C	25	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	3	43	532	0.353	1653	2.37	2.59	2.89	3.11	7.34	8.19
12A	26	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	6	43	318	0.182	889	1.95	2.56	2.82	2.80	14.04	15.47
12B	27	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	6	43	318	0.165	1041	2.02	2.62	2.87	3.27	15.84	17.36
12C	28	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	6	43	318	0.176	967	2.03	2.32	2.61	3.04	13.21	14.86
14A	29	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43	606	0.249	2025	2.65	3.05	3.23	3.34	12.24	12.96
14B	30	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43	606	0.304	1812	2.17	2.51	2.86	2.99	8.26	9.41
14C	31	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43	606	0.251	1966	2.70	3.12	3.29	3.25	12.44	13.12
14D	32	McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43	606	0.276	1894	2.56	2.84	3.06	3.13	10.31	11.10
16A	33	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	6	43	130	0.069	758	2.82	3.66	3.60	5.82	52.82	51.95
16B	34	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	6	43	130	0.078	745	3.75	-	-	5.72	-	-
16C	35	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	6	43	130	0.304	719	3.73	-	-	5.52	-	-
18A	36	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	4	43	178	0.213	1078	4.45	-	-	6.05	-	-
18B	37	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	4	43	178	0.120	1109	3.95	-	-	6.22	-	-
18C	38	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	4	43	178	0.089	1183	3.94	-	-	6.64	-	-
20A	39	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43	136	0.081	755	3.22	4.04	4.18	5.56	49.57	51.29
20B	40	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43	136	0.065	739	3.18	4.12	4.35	5.44	63.81	67.37
20C	41	McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43	136	0.072	720	2.76	3.46	3.74	5.31	48.02	51.91
22A	42	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43	271	0.113	759	1.63	2.33	2.64	2.80	20.55	23.28
22B	43	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43	271	0.094	780	1.64	2.39	2.70	2.87	25.40	28.69
22C	44	McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43	271	0.139	754	1.61	2.04	2.37	2.78	14.72	17.10
24A	45	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43	400	0.028	1131	2.26	2.40	1.99	2.83	85.86	71.19
24B	46	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43	400	0.030	1133	1.67	2.23	2.41	2.83	74.53	80.54
24C	47	McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43	400	0.031	1138	1.49	1.84	2.10	2.84	59.92	68.38
26A	48	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43	507	0.198	1608	1.66	2.00	2.27	3.17	10.08	11.44
26B	49	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43	507	0.170	1517	1.38	1.91	2.19	2.99	11.20	12.85
26C	50	McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43	507	0.145	1599	2.05	2.34	2.51	3.15	16.15	17.32
28A	51	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43	200	0.077	1143	3.24	4.38	-	5.71	56.76	-
28B	52	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43	200	0.072	1134	3.90	4.22	-	5.66	58.25	-
28C	53	McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43	200	0.073	1213	3.23	3.68	4.01	6.06	50.53	55.06
30A	54	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	6	43	260	0.104	874	1.90	2.51	2.77	3.35	24.24	26.75
30B	55	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	6	43	260	0.100	848	1.91	2.55	2.81	3.25	25.40	27.99
30C	56	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	6	43	260	0.124	875	1.88	2.65	3.00	3.36	21.44	24.27
32A	57	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	4	43	356	0.179	1306	2.15	2.54	2.88	3.66	14.21	16.11
32B	58	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	4	43	356	0.173	1308	2.19	2.98	3.26	3.67	17.20	18.82
32C	59	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	4	43	356	0.194	1312	2.23	2.97	3.27	3.68	15.33	16.88
34A	60	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	3	43	532	0.247	1732	2.42	2.74	2.98	3.26	11.10	12.07
34B	61	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	3	43	532	0.226	1857	2.41	3.20	3.49	3.49	14.18	15.47

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Appendix H  
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34C	62	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	3	43	532	0.240	1781	2.38	3.03	3.32	3.35	12.64	13.85
34D	63	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	3	43	532	0.169	1990	2.28	2.56	2.77	3.74	15.19	16.44
OSB1	64	Reynaud Serette, 1996	SPD	I	8	4	OSB	6	33	280	0.190	946	2.05	2.62	2.75	3.38	13.79	14.47
OSB2	65	Reynaud Serette, 1996	SPD	I	8	4	OSB	6	33	280	0.307	967	2.04	2.43	2.58	3.45	7.92	8.40
OSB3	66	Reynaud Serette, 1996	SPD	I	8	4	OSB	4	33	366	0.264	1298	2.28	2.47	2.56	3.55	9.36	9.70
OSB4	67	Reynaud Serette, 1996	SPD	I	8	4	OSB	4	33	366	0.210	1247	2.33	2.63	2.68	3.41	12.52	12.76
PLY1	68	Reynaud Serette, 1996	SPD	I	8	4	PLY	6	33	312	0.265	1010	1.73	2.29	2.34	3.24	8.64	8.83
PLY2	69	Reynaud Serette, 1996	SPD	I	8	4	PLY	6	33	312	0.248	970	2.30	2.50	2.65	3.11	10.08	10.69
PLY3	70	Reynaud Serette, 1996	SPD	I	8	4	PLY	4	33	396	0.275	1206	2.01	2.49	2.60	3.05	9.05	9.45
PLY4	71	Reynaud Serette, 1996	SPD	I	8	4	PLY	4	33	396	0.276	1420	2.46	2.69	2.86	3.59	9.75	10.36
B1	72	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	43	356	0.215	933	1.76	1.99	2.16	2.62	9.26	10.05
B2	73	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	43	356	0.203	1096	1.96	2.48	2.63	3.08	12.22	12.96
B3	74	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	54	356	0.197	1031	1.54	1.67	1.77	2.90	8.48	8.98
B4	75	Reynaud Serette, 1997	SPD	I	8	4	PLY	6	54	356	0.179	1096	1.75	2.04	2.14	3.08	11.40	11.96
D1	76	Reynaud Serette, 1997	SPD	I	8	4	18 mil STL	6	33	156	0.092	444	1.74	2.55	2.81	2.85	27.72	30.54
D2	77	Reynaud Serette, 1997	SPD	I	8	4	18 mil STL	6	33	156	0.102	433	1.33	2.17	2.40	2.78	21.27	23.53
E1	78	Reynaud Serette, 1997	SPD	I	8	2	OSB	6	33	140	0.089	771	2.40	-	-	5.51	-	-
E2	79	Reynaud Serette, 1997	SPD	I	8	2	OSB	6	33	140	0.092	835	2.80	-	-	5.96	-	-
E3	80	Reynaud Serette, 1997	SPD	I	8	2	OSB	4	33	183	0.094	1188	2.84	-	-	6.49	-	-
E4	81	Reynaud Serette, 1997	SPD	I	8	2	OSB	4	33	183	0.092	1292	2.59	-	-	7.06	-	-
14A	82	CoLA / UCI	TCCMAR	I	8	8	PLY	6	33	312	0.123	937	1.45	1.85	2.00	3.00	15.04	16.26
14B	83	CoLA / UCI	TCCMAR	I	8	8	PLY	6	33	312	0.123	872	1.45	1.99	2.13	2.79	16.18	17.32
14C	84	CoLA / UCI	TCCMAR	I	8	8	PLY	6	33	312	0.175	863	1.75	2.34	2.48	2.77	13.37	14.17
15A	85	CoLA / UCI	TCCMAR	I	8	8	PLY	4	33	396	0.140	1251	1.68	2.37	2.53	3.16	16.93	18.07
15B	86	CoLA / UCI	TCCMAR	I	8	8	PLY	4	33	396	0.162	1192	1.72	2.18	2.25	3.01	13.46	13.89
15C	87	CoLA / UCI	TCCMAR	I	8	8	PLY	4	33	396	0.269	1222	1.71	2.10	2.20	3.09	7.81	8.18
17A	88	CoLA / UCI	TCCMAR	I	8	8	OSB	6	33	280	0.146	772	1.47	2.01	2.20	2.76	13.77	15.07
17B	89	CoLA / UCI	TCCMAR	I	8	8	OSB	6	33	280	0.129	716	1.29	1.83	2.00	2.56	14.19	15.50
17C	90	CoLA / UCI	TCCMAR	I	8	8	OSB	6	33	280	0.174	693	1.50	1.79	2.02	2.48	10.29	11.61
18A	91	CoLA / UCI	TCCMAR	I	8	8	OSB	4	33	366	0.107	1093	1.41	1.91	2.03	2.99	17.85	18.97
18B	92	CoLA / UCI	TCCMAR	I	8	8	OSB	4	33	366	0.093	1132	1.39	1.85	2.03	3.09	19.89	21.83
18C	93	CoLA / UCI	TCCMAR	I	8	8	OSB	4	33	366	0.130	968	1.31	1.55	1.63	2.64	11.92	12.54

Test No.	Source(1)	Protocol	Wall Type	Height ft	Length ft	Sheating	Fastener Spacing in	Stud Thickness mills	Vasd plf	ΔVasd in	Vp plf	ΔVp in	Δ0.8Vp in	Δ0.65Vp in	Vp/ Vasd	Δ0.8Vp/ Δasd	Δ0.65Vp/ Δasd
Mean										0.172	1134	2.217	2.614	2.756	3.630	20.17	20.57
Standard Deviation										0.076	364	0.675	0.594	0.557	1.174	16.94	16.22
Mean plus std dev										0.248	1498	2.892	3.208	3.312	4.804	37.11	36.79
Mean minus std dev										0.095	770	1.542	2.020	2.199	2.456	3.23	4.35
COV										0.444	0.321	0.305	0.227	0.202	0.323	0.840	0.788

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Appendix I  
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Source	Protocol	Wall Type	Height ft	Length ft	Sheating	Fastener Spacing in	Stud Thickness mills	Vasd plf	ΔVasd in	Vp plf	ΔVp in	Δ0.8Vp in	Δ0.65Vp in	Vp / Vasd	Δ0.8Vp/ Δasd	Δ0.65Vp/ Δasd	Δ0.8Vp/ Δp	Δ0.65Vp/ Δp
		I or II	Geometry					=J3*H3*700/ =J3/I3	=X (lb)/F3	From Plot	From Plot	From Plot	From Plot	=O3/N3	=M3/O3	=P3/M3	=M3/O3	=P3/M3
											Min=2.69 in	Min=3.46 in	Min=2.5	Min=11	Min=14			
McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	4	43	472	0.207	1461	2.31	2.82	3.21	3.10	13.59	15.47	1.22	1.39
McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	4	43	472	0.231	1450	2.28	2.78	3.15	3.08	12.05	13.65	1.22	1.38
McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	4	43	472	0.244	1440	2.31	3.02	3.31	3.05	12.35	13.54	1.31	1.43
McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	6	43	318	0.182	889	1.95	2.56	2.82	2.80	14.04	15.47	1.31	1.45
McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	6	43	318	0.165	1041	2.02	2.62	2.87	3.27	15.84	17.36	1.30	1.42
McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	6	43	318	0.176	967	2.03	2.32	2.61	3.04	13.21	14.86	1.14	1.29
McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43	606	0.249	2025	2.65	3.05	3.23	3.34	12.24	12.96	1.15	1.22
McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43	606	0.304	1812	2.17	2.51	2.86	2.99	8.26	9.41	1.16	1.32
McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43	606	0.251	1966	2.70	3.12	3.29	3.25	12.44	13.12	1.16	1.22
McGill University, Canada	CUREE	I	8	4	12.5 mm DFP	3	43	606	0.276	1894	2.56	2.84	3.06	3.13	10.31	11.10	1.11	1.20
McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43	136	0.081	755	3.22	4.04	4.18	5.56	49.57	51.29	1.25	1.30
McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43	136	0.065	739	3.18	4.12	4.35	5.44	63.81	67.37	1.30	1.37
McGill University, Canada	CUREE	I	8	2	11 mm OSB	6	43	136	0.072	720	2.76	3.46	3.74	5.31	48.02	51.91	1.25	1.36
McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43	271	0.113	759	1.63	2.33	2.64	2.80	20.55	23.28	1.43	1.62
McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43	271	0.094	780	1.64	2.39	2.70	2.87	25.40	28.69	1.46	1.65
McGill University, Canada	CUREE	I	8	4	11 mm OSB	6	43	271	0.139	754	1.61	2.04	2.37	2.78	14.72	17.10	1.27	1.47
McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43	400	0.028	1131	2.26	2.40	1.99	2.83	85.86	71.19	1.06	0.88
McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43	400	0.030	1133	1.67	2.23	2.41	2.83	74.53	80.54	1.34	1.44
McGill University, Canada	CUREE	I	8	4	11 mm OSB	4	43	400	0.031	1138	1.49	1.84	2.10	2.84	59.92	68.38	1.23	1.41
McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43	507	0.198	1608	1.66	2.00	2.27	3.17	10.08	11.44	1.20	1.37
McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43	507	0.170	1517	1.38	1.91	2.19	2.99	11.20	12.85	1.38	1.59
McGill University, Canada	CUREE	I	8	4	11 mm OSB	3	43	507	0.145	1599	2.05	2.34	2.51	3.15	16.15	17.32	1.14	1.22
McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43	200	0.077	1143	3.24	4.38	-	5.71	56.76	-	1.35	-
McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43	200	0.072	1134	3.90	4.22	-	5.66	58.25	-	1.08	-
McGill University, Canada	CUREE	I	8	2	11 mm OSB	4	43	200	0.073	1213	3.23	3.68	4.01	6.06	50.53	55.06	1.14	1.24
Reynaud Serette, 1996	SPD	I	8	4	OSB	6	33	280	0.190	946	2.05	2.62	2.75	3.38	13.79	14.47	1.28	1.34
Reynaud Serette, 1996	SPD	I	8	4	OSB	6	33	280	0.307	967	2.04	2.43	2.58	3.45	7.92	8.40	1.19	1.26
Reynaud Serette, 1996	SPD	I	8	4	OSB	4	33	366	0.264	1298	2.28	2.47	2.56	3.55	9.36	9.70	1.08	1.12
Reynaud Serette, 1996	SPD	I	8	4	OSB	4	33	366	0.210	1247	2.33	2.63	2.68	3.41	12.52	12.76	1.13	1.15
Reynaud Serette, 1996	SPD	I	8	4	PLY	6	33	312	0.265	1010	1.73	2.29	2.34	3.24	8.64	8.83	1.32	1.35
Reynaud Serette, 1996	SPD	I	8	4	PLY	6	33	312	0.248	970	2.30	2.50	2.65	3.11	10.08	10.69	1.09	1.15
Reynaud Serette, 1996	SPD	I	8	4	PLY	4	33	396	0.275	1206	2.01	2.49	2.60	3.05	9.05	9.45	1.24	1.29
Reynaud Serette, 1996	SPD	I	8	4	PLY	4	33	396	0.276	1420	2.46	2.69	2.86	3.59	9.75	10.36	1.09	1.16
Reynaud Serette, 1997	SPD	I	8	4	PLY	6	43	356	0.215	933	1.76	1.99	2.16	2.62	9.26	10.05	1.13	1.23
Reynaud Serette, 1997	SPD	I	8	4	PLY	6	43	356	0.203	1096	1.96	2.48	2.63	3.08	12.22	12.96	1.27	1.34
Reynaud Serette, 1997	SPD	I	8	4	PLY	6	54	356	0.197	1031	1.54	1.67	1.77	2.90	8.48	8.98	1.08	1.15
Reynaud Serette, 1997	SPD	I	8	4	PLY	6	54	356	0.179	1096	1.75	2.04	2.14	3.08	11.40	11.96	1.17	1.22
Reynaud Serette, 1997	SPD	I	8	2	OSB	6	33	140	0.089	771	2.40	-	-	5.51	-	-	-	-
Reynaud Serette, 1997	SPD	I	8	2	OSB	6	33	140	0.092	835	2.80	-	-	5.96	-	-	-	-
Reynaud Serette, 1997	SPD	I	8	2	OSB	4	33	183	0.094	1188	2.84	-	-	6.49	-	-	-	-
Reynaud Serette, 1997	SPD	I	8	2	OSB	4	33	183	0.092	1292	2.59	-	-	7.06	-	-	-	-
CoLA / UCI	TCCMAR	I	8	8	PLY	6	33	312	0.123	937	1.45	1.85	2.00	3.00	15.04	16.26	1.28	1.38
CoLA / UCI	TCCMAR	I	8	8	PLY	6	33	312	0.123	872	1.45	1.99	2.13	2.79	16.18	17.32	1.37	1.47
CoLA / UCI	TCCMAR	I	8	8	PLY	6	33	312	0.175	863	1.75	2.34	2.48	2.77	13.37	14.17	1.34	1.42
CoLA / UCI	TCCMAR	I	8	8	PLY	4	33	396	0.140	1251	1.68	2.37	2.53	3.16	16.93	18.07	1.41	1.51
CoLA / UCI	TCCMAR	I	8	8	PLY	4	33	396	0.162	1192	1.72	2.18	2.25	3.01	13.46	13.89	1.27	1.31
CoLA / UCI	TCCMAR	I	8	8	PLY	4	33	396	0.269	1222	1.71	2.10	2.20	3.09	7.81	8.18	1.23	1.29
CoLA / UCI	TCCMAR	I	8	8	OSB	6	33	280	0.146	772	1.47	2.01	2.20	2.76	13.77	15.07	1.37	1.50

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CoLA / UCI	TCCMAR	I	8	8	OSB	6	33	280	0.129	716	1.29	1.83	2.00	2.56	14.19	15.50	1.42	1.55
CoLA / UCI	TCCMAR	I	8	8	OSB	6	33	280	0.174	693	1.50	1.79	2.02	2.48	10.29	11.61	1.19	1.35
CoLA / UCI	TCCMAR	I	8	8	OSB	4	33	366	0.107	1093	1.41	1.91	2.03	2.99	17.85	18.97	1.35	1.44
CoLA / UCI	TCCMAR	I	8	8	OSB	4	33	366	0.093	1132	1.39	1.85	2.03	3.09	19.89	21.83	1.33	1.46
CoLA / UCI	TCCMAR	I	8	8	OSB	4	33	366	0.130	968	1.31	1.55	1.63	2.64	11.92	12.54	1.18	1.24

Source(1)	Protocol	Wall Type	Height ft	Length ft	Sheating	Fastener Spacing in	Stud Thickness mills	Vasd plf	$\Delta$ Vasd in	Vp plf	$\Delta$ Vp in	$\Delta$ 0.8Vp	$\Delta$ 0.65Vp in	Vp adj/ Vasd 2.5min	$\Delta$ 0.8Vp/ $\Delta$ asd 11min	$\Delta$ 0.65Vp/ $\Delta$ asd 14min	$\Delta$ 0.8Vp/ $\Delta$ p	$\Delta$ 0.65Vp/ $\Delta$ p
									0.163	1134	2.092	2.512	2.619	3.563	21.69	21.39	1.24	1.34
									0.076	330	0.596	0.671	0.606	1.171	19.72	18.74	0.11	0.14
									0.239	1464	2.688	3.183	3.225	4.734	41.41	40.14	1.35	1.48
									0.087	804	1.496	1.841	2.013	2.391	1.97	2.65	1.13	1.19
									0.467	0.291	0.285	0.267	0.231	0.329	0.909	0.876	0.085	0.108

AISI Optimization Project  
Appendix J  
CSP Only

Test	Test No.	Source	Protocol	Wall Type	Height ft	Length ft	Sheathing	Fastener Spacing in	Stud Thickness mills	Vasd plf	$\Delta$ Vasd in	Vp plf	$\Delta$ Vp in	$\Delta$ 0.8Vp in	$\Delta$ 0.65Vp in	Vp/ Vasd	$\Delta$ 0.8Vp/ $\Delta$ asd	$\Delta$ 0.65Vp/ $\Delta$ asd
				I or II	Geometry					=13"H3*700/ =13/F3	=K (lb)/F3	From Plot	From Plot	=03/N3	=M3/O3	=P3/M3		
														Min=2.69 in	Min=3.46 in	Min=2.5	Min=11	Min=14
3A	11	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43	356	0.228	943	1.87	3.35	3.44	2.65	14.67	15.06
3B	12	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43	356	0.187	991	1.78	2.87	2.93	2.78	15.38	15.70
3C	13	McGill University, Canada	SPD	I	8	4	12.5 mm CSP	4	43	356	0.261	953	1.98	3.24	3.38	2.67	12.39	12.93
4A	14	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43	356	0.271	1056	2.40	3.07	-	2.96	11.32	-
4B	15	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43	356	0.185	1127	2.29	2.85	-	3.16	15.40	-
4C	16	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	4	43	356	0.268	1200	2.36	2.54	2.88	3.37	9.49	10.76
8A	20	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	6	43	260	0.143	784	1.96	2.66	2.92	3.01	18.66	20.49
8B	21	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	6	43	260	0.161	789	1.97	2.42	2.75	3.03	14.99	17.04
8C	22	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	6	43	260	0.175	760	1.95	2.91	3.11	2.92	16.65	17.79
10A	23	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	3	43	532	0.274	1691	2.37	2.89	3.12	3.18	10.56	11.40
10B	24	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	3	43	532	0.281	1734	2.38	2.83	3.02	3.26	10.08	10.76
10C	25	McGill University, Canada	CUREE	I	8	4	12.5 mm CSP	3	43	532	0.353	1653	2.37	2.59	2.89	3.11	7.34	8.19
16A	33	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	6	43	130	0.069	758	2.82	3.66	3.60	5.82	52.82	51.95
16B	34	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	6	43	130	0.078	745	3.75	-	-	5.72	-	-
16C	35	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	6	43	130	0.304	719	3.73	-	-	5.52	-	-
18A	36	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	4	43	178	0.213	1078	4.45	-	-	6.05	-	-
18B	37	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	4	43	178	0.120	1109	3.95	-	-	6.22	-	-
18C	38	McGill University, Canada	CUREE	I	8	2	12.5 mm CSP	4	43	178	0.089	1183	3.94	-	-	6.64	-	-
30A	54	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	6	43	260	0.104	874	1.90	2.51	2.77	3.35	24.24	26.75
30B	55	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	6	43	260	0.100	848	1.91	2.55	2.81	3.25	25.40	27.99
30C	56	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	6	43	260	0.124	875	1.88	2.65	3.00	3.36	21.44	24.27
32A	57	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	4	43	356	0.179	1306	2.15	2.54	2.88	3.66	14.21	16.11
32B	58	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	4	43	356	0.173	1308	2.19	2.98	3.26	3.67	17.20	18.82
32C	59	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	4	43	356	0.194	1312	2.23	2.97	3.27	3.68	15.33	16.88
34A	60	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	3	43	532	0.247	1732	2.42	2.74	2.98	3.26	11.10	12.07
34B	61	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	3	43	532	0.226	1857	2.41	3.20	3.49	3.49	14.18	15.47
34C	62	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	3	43	532	0.240	1781	2.38	3.03	3.32	3.35	12.64	13.85
34D	63	McGill University, Canada	CUREE	I	8	8	12.5 mm CSP	3	43	532	0.169	1990	2.28	2.56	2.77	3.74	15.19	16.44

Test No.	Source(1)	Protocol	Wall Type	Height ft	Length ft	Sheathing	Fastener Spacing in	Stud Thickness mills	Vasd plf	$\Delta$ Vasd in	Vp plf	$\Delta$ Vp in	$\Delta$ 0.8Vp in	$\Delta$ 0.65Vp in	Vp/ Vasd	$\Delta$ 0.8Vp/ $\Delta$ asd	$\Delta$ 0.65Vp/ $\Delta$ asd
Mean									0.193	1184	2.503	2.853	3.076	3.817	16.55	18.13	
Standard Deviation									0.074	393	0.740	0.311	0.259	1.203	9.06	9.29	
Mean plus std dev									0.267	1577	3.243	3.163	3.335	5.020	25.61	27.42	
Mean minus std dev									0.119	791	1.762	2.542	2.816	2.613	7.49	8.84	
COV									0.382	0.332	0.296	0.109	0.084	0.315	0.548	0.512	

AISI Optimization Project  
Appendix K  
Steel Sheet Sheathed Walls Only

Test	Test No.	Source	Protocol	Wall Type	Height	Length	Sheathing	Fastener Spacing	Stud Thickness	Vasd	ΔVasd	Vp	ΔVp	Δ0.8Vp	Δ0.65Vp	Vp/ Vasd	Δ0.8Vp/ Δasd	Δ0.65Vp/ Δasd	Δ0.8Vp/ Δp	Δ0.65Vp/ Δp
				I or II	ft	ft		in	mills	plf	in	plf	in	in	in					
										$=J3*H3*700/$	$=J3/I3$	$=X(lb)/F3$	From Plot		From Plot	$=O3/N3$	$=M3/O3$	$=P3/M3$	$=M3/O3$	$=P3/M3$
														Min=2.69 in	Min=3.46 in	Min=2.5	Min=11	Min=14		
2X8X43X30-2-C1	94	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	2	43	468	0.700	1200	3.33	-	-	2.56	-	-	-	-
2X8X43X30-2-C2	95	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	2	43	468	0.700	1246	3.07	-	-	2.66	-	-	-	-
2X8X43X30-4-C1	96	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	4	43	400	0.700	1065	3.31	-	-	2.66	-	-	-	-
2X8X43X30-4-C2	97	AISI Steel Sheet Walls	CUREE	I	8	2	30 mil STL	4	43	400	0.600	1119	3.18	-	-	2.80	-	-	-	-
2X8X43X33-2-C1	98	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	2	43	468	0.600	1450	3.10	-	-	3.10	-	-	-	-
2X8X43X33-2-C2	99	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	2	43	468	0.700	1355	3.19	-	-	2.90	-	-	-	-
2X8X43X33-4-C1	100	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	4	43	400	0.400	1257	3.19	-	-	3.14	-	-	-	-
2X8X43X33-4-C2	101	AISI Steel Sheet Walls	CUREE	I	8	2	33 mil STL	4	43	400	0.500	1357	3.34	-	-	3.39	-	-	-	-
4X8X33X27-2/12-C1	102	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	2	33	468	0.620	794	1.71	2.17	2.40	1.70	3.50	3.87	1.27	1.40
4X8X33X27-2/12-C2	103	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	2	33	468	0.650	878	1.87	2.37	-	1.88	3.65	-	1.27	-
4X8X33X27-4/12-C1	104	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	33	400	0.430	740	1.20	1.91	2.21	1.85	4.44	5.14	1.59	1.84
4X8X33X27-4/12-C2	105	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	33	400	0.510	707	1.20	2.21	2.69	1.77	4.33	5.27	1.84	2.24
4X8X43X30-2/12-C1	106	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	2	43	468	0.400	1079	1.99	2.85	3.30	2.31	7.13	8.25	1.43	1.66
4X8X43X30-2/12-C2	107	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	2	43	468	0.450	1084	1.84	2.60	3.20	2.32	5.78	7.11	1.41	1.74
4X8X43X30-4/12-C1	108	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	4	43	400	0.400	1073	2.01	2.01	2.70	2.68	5.03	6.75	1.00	1.34
4X8X43X30-4/12-C2	109	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	4	43	400	0.500	1073	2.05	2.95	3.15	2.68	5.90	6.30	1.44	1.54
4X8X43X33-2/12-C1	110	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	2	43	468	0.250	1401	1.91	2.10	3.15	2.99	8.40	12.60	1.10	1.65
4X8X43X33-2/12-C2	111	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	2	43	468	0.300	1318	2.08	2.30	2.60	2.82	7.67	8.67	1.11	1.25
4X8X43X33-4/12-C1	112	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	4	43	400	0.350	1225	1.89	2.20	2.30	3.06	6.29	6.57	1.16	1.22
4X8X43X33-4/12-C2	113	AISI Steel Sheet Walls	CUREE	I	8	4	33 mil STL	4	43	400	0.350	1271	1.70	1.80	2.00	3.18	5.14	5.71	1.06	1.18
A-3	114	AISI Steel Sheet Walls	CUREE	I	8	<b>4.270833</b>	30 mil STL	2	43	468	0.400	1179	1.60	3.20	3.75	2.52	8.00	9.38	2.00	2.34
A-5	115	AISI Steel Sheet Walls	CUREE	I	8	4	30 mil STL	2	43	468	0.400	1164	2.04	2.80	3.30	2.49	7.00	8.25	1.37	1.62
A-6	116	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	43	400	0.310	913	1.38	2.42	-	2.28	7.81	-	1.75	-

Test No.	Source(1)	Protocol	Wall Type	Height	Length	Sheathing	Fastener Spacing	Stud Thickness	Vasd	ΔVasd	Vp	ΔVp	Δ0.8Vp	Δ0.65Vp	Vp/ Vasd	Δ0.8Vp/ Δasd	Δ0.65Vp/ Δasd	Δ0.8Vp/ Δp	Δ0.65Vp/ Δp
				ft	ft		in	mills	plf	in	plf	in	in	in	2.5min	11min	14min	11min	14min
Mean										0.488	1128	2.269	2.393	2.827	2.597	6.00	7.22	1.39	1.62
Standard Deviation										0.144	208	0.747	0.408	0.521	0.474	1.62	2.25	0.30	0.37
Mean plus std dev										0.632	1336	3.016	2.800	3.348	3.071	7.63	9.47	1.69	1.98
Mean minus std dev										0.344	920	1.522	1.985	2.306	2.123	4.38	4.97	1.09	1.25
COV										0.295	0.184	0.329	0.170	0.184	0.183	0.270	0.312	0.216	0.226

AISI Optimization Project  
Appendix L  
Steel Sheet - 5 Tests

Test	Test No.	Source	Protocol	Wall Type	Height ft	Length ft	Sheating	Fastener Spacing in	Stud Thickness mills	% Full Height	Opening height Rat.	$C_s$	Elastic Stiffness lb / in	Vasd plf	$\Delta$ Vasd in	Vp plf	$\Delta$ Vp in	$\Delta$ 0.8Vp in	$\Delta$ 0.65Vp in	Vp / Vasd	$\Delta$ 0.8Vp/ $\Delta$ asd	$\Delta$ 0.65Vp/ $\Delta$ asd	$\Delta$ 0.8Vp/ $\Delta$ p	$\Delta$ 0.65Vp/ $\Delta$ p
				I or II	Geometry								AISI S213 From Tables H3-700	=35/13	=X lb/F3	From Plot			From Plot	=D3/M3	=M3/O3	=P3/M3	=M3/O3	=P3/M3
																		Min=2.69 in	Min=3.46 in	Min=2.5	Min=11	Min=14	Min=11	Min=14
4X8X33X27-2/12-C1	102	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	2	33					468	0.620	794	1.71	2.17	2.40	1.70	3.50	3.87	1.27	1.40
4X8X33X27-2/12-C2	103	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	2	33					468	0.650	878	1.87	2.37	-	1.88	3.65	-	1.27	-
4X8X33X27-4/12-C1	104	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	33					400	0.430	740	1.20	1.91	2.21	1.85	4.44	5.14	1.59	1.84
4X8X33X27-4/12-C2	105	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	33					400	0.510	707	1.20	2.21	2.69	1.77	4.33	5.27	1.84	2.24
A-6	116	AISI Steel Sheet Walls	CUREE	I	8	4	27 mil STL	4	43					400	0.310	913	1.38	2.42	-	2.28	7.81	-	1.75	-
Test No.		Source(1)	Protocol	Wall Type	Height ft	Length ft	Sheating	Fastener Spacing in	Stud Thickness mills	% Full Height	Opening height Rat.	$C_s$	Elastic Stiffness lb / in	Vasd plf	$\Delta$ Vasd in	Vp plf	$\Delta$ Vp in	$\Delta$ 0.8Vp in	$\Delta$ 0.65Vp in	Vp / Vasd	$\Delta$ 0.8Vp/ $\Delta$ asd	$\Delta$ 0.65Vp/ $\Delta$ asd	$\Delta$ 0.8Vp/ $\Delta$ p	$\Delta$ 0.65Vp/ $\Delta$ p
Mean														0.504	806	1.472	2.216	2.433	1.895	4.75	4.76	1.54	1.83	
Standard Deviation														0.140	88	0.305	0.201	0.242	0.228	1.76	0.77	0.27	0.42	
Mean plus std dev														0.644	894	1.777	2.417	2.675	2.123	6.51	5.54	1.81	2.25	
Mean minus std dev														0.364	718	1.167	2.015	2.192	1.666	2.99	3.99	1.28	1.41	
COV														0.277	0.109	0.207	0.091	0.099	0.120	0.371	0.163	0.173	0.229	





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