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Testing and evaluation of light gauge steel frame / 9.5 mm csp wood panel shear walls

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TESTING AND EVALUATION OF LIGHT GAUGE STEEL FRAME / 9.5 MM CSP WOOD PANEL SHEAR WALLS

by

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ABSTRACT

The use of light gauge steel framing elements sheathed with wood plywood or oriented strand board are becoming more common in the construction of structural shear walls for low-rise platform frame structural systems in Canada. Canadian standards and codes do not currently outline design methods for this type of wall system. Therefore, research at McGill University is underway to help develop design parameters for seismic and wind loading that can be used in conjunction with the 2005 National Building Code of Canada for this type of shear wall system. The research is based on the monotonic and reversed cyclic testing of full-scale wall specimens.

This report presents design capacity and stiffness parameters for walls with 9.5 mm (3/8”) Canadian softwood plywood sheathing for various screw spacing configurations, based on the analysis of results from 25 full-scale wall tests following the equivalent energy elastic-plastic (EEEP) method.

The results of the test specimens constructed with spruce based plywood sheathing were found to represent the lower bound for shear wall strength and stiffness. Wall specimens constructed with sheathing panels of this species make-up were used to develop the final recommended design parameters.

This research concludes that a resistance factor (ϕ) of 0.7 should be used for limit states design calculations for walls subjected to wind or seismic loading as determined from the 2005 NBCC. It was determined that an overstrength factor of 1.2 should be used for capacity design calculations of all non-fuse elements that are part of the seismic force resisting system. It was found that a ductility-related force modification factor (R_d) of 2.5 and an overstrength-related force modification factor (R_o) of 1.7 should be used for the calculation of seismic design forces using the 2005 NBCC. Yield strength (F_y) and elastic stiffness design values for various wall configurations are presented in this report.

RÉSUMÉ

L'utilisation d'éléments en acier roulé à froid avec des panneaux de contreplaqué en bois ou de lamelles orientées (OSB) devient de plus en plus commune dans la construction des murs de refend des bâtiments de construction plateforme de faible hauteur au Canada. Les normes et codes Canadiens ne suggèrent actuellement pas de méthode pour la conception de ce type de système de mur. En conséquence, des recherches à l'université de McGill sont présentement en cours pour aider à développer des paramètres de conception pour des charges sismiques et de vent qui pourront éventuellement être utilisé conjointement avec le code national de bâtiment 2005 pour ce type de système de mur de refend. Ces recherches sont basées sur des essais d'échantillons grandeur réelle de murs sous des chargements monotoniques et cycliques.

Ce rapport présente les paramètres de conception de capacité et de rigidité pour des murs faits de contreplaqué de résineux canadiens (CSP) de 9,5 mm (3/8'') d'épaisseur et ce, pour différentes configurations d'espacement de vis. Les valeurs recueillies sont basées sur l'analyse des résultats de 25 essais de murs grandeur réelle suivant la méthode d'énergie équivalente élastique plastique (equivalent energy elastic-plastic (EEEP) method).

Les résultats des échantillons d'essais construits avec des panneaux d'épinette ont démontré les valeurs des limites inférieures en résistance et rigidité. Les échantillons de mur construits avec des panneaux de cette espèce de bois ont été utilisés pour développer les paramètres de conception recommandés.

Les résultats de la présente recherche démontrent qu'un facteur de résistance (ϕ) de 0,7 devrait être utilisé pour les calculs en états limites de murs qui résistent aux charges sismiques et de vent selon le Code national de bâtiment 2005. Cette recherche permet également de recommander qu'un facteur de sur-résistance égal à 1,2 devrait être utilisé pour les calculs de capacité des éléments non-fusibles qui font partie du système de refend sismique. Finalement, cette recherche démontre qu'un facteur de modification de

force pour la ductilité égal à 2,5 et un facteur de modification de force pour la sur-résistance égal à 1,7 devraient être utilisés en calculant les efforts sismiques selon le CNB 2005. Les valeurs de conception pour la résistance élastique (F_y) et rigidité élastique pour différentes configurations de mur sont présentées dans ce rapport.

ACKNOWLEDGEMENT

First and foremost, I would like to express my sincere thanks to Professor Colin A. Rogers for his dedication both as a teacher and a researcher. Your constant availability and interest in this research were key elements during the testing of the walls and the preparation of this report.

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CHAPTER 1 INTRODUCTION

1.1 Background

An integral part of low-rise platform frame structural systems are the walls which support gravity loads and can be constructed to resist lateral loads, from wind and seismic excitation for example. Specifically, shear walls are utilized to transfer upper-storey lateral loads to the foundation of the structure. It has become more common for this type of platform construction to consist of light gauge steel framing elements sheathed with wood plywood or oriented strand board (OSB).

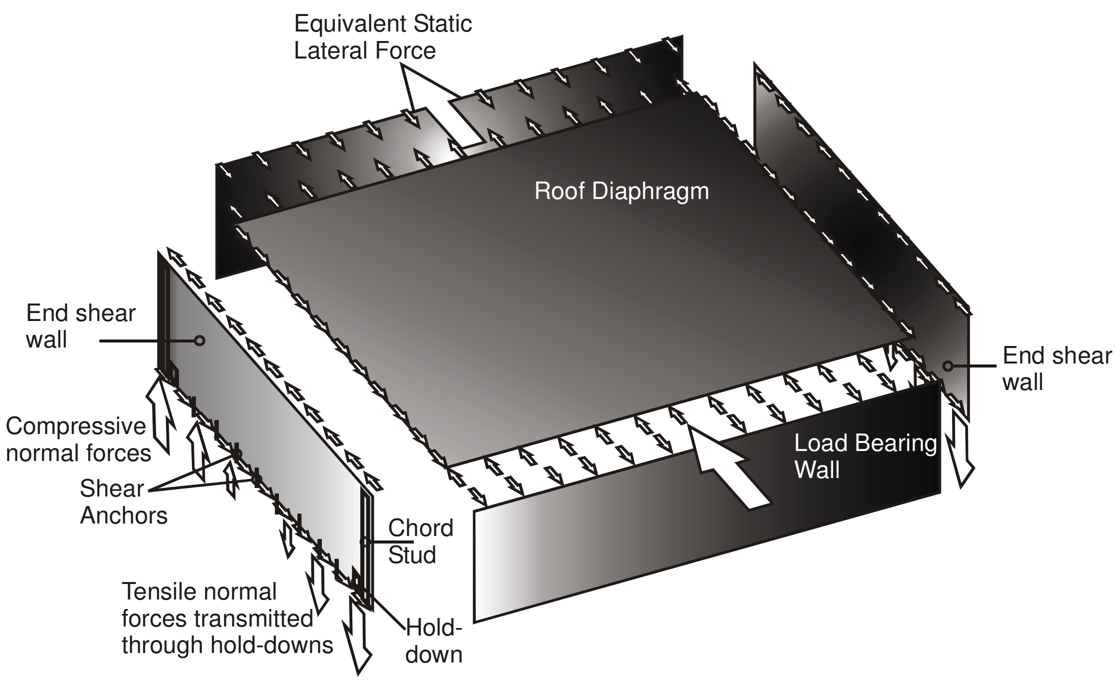

Figure 1.1: Lateral Load Transfer through Roof Diaphragm to Shear Walls (*CWC, 2001, 2002*)

Roof and floor systems provide the horizontal stiffness and capacity to transfer the imposed lateral loads to the shear walls. Properly anchored walls sheathed with wood panelling act as deep cantilever beams transferring the lateral forces in the structure through the sheathing connectors by shear and into the panelling, as shown in Figure 1.1.

The sheathing acts as the web of the deep beam that transfers the lateral forces to the lower storey or foundation through shear anchors and holddown connectors. The spacing of the sheathing connectors has a direct impact on the stiffness and capacity of the shear wall. The closer the perimeter sheathing connectors are spaced, the higher the stiffness and capacity of the wall to resist lateral loads.

To date, there are no existing methods in Canadian standards and codes for the design of light gauge steel frame shear walls sheathed with wood panels. A research program is currently under way at McGill University with the overall goal of developing a design method that can be used in conjunction with the 2005 National Building Code of Canada (*NBCC*) (*NRCC, 2005*) for this type of shear wall system. The research is mainly based on tests, which involve, but are not limited to, varying the wall specimen geometry, fastener schedule, sheathing type and / or thickness. The wall specimen testing involves both monotonic and reversed cyclic loading with which design parameters for seismic and wind loading can be developed. Prior to the completion of this report only testing of walls sheathed with ½" (12.5 mm) plywood, as well as 7/16" (11 mm) and 3/8" (9 mm) OSB had been completed at McGill University.

1.2 Objectives

The objectives of this research were as follows: i) To carry out a suite of tests on light gauge steel frame / wood panel shear walls constructed with 3/8" (9.5 mm) CSP sheathing. ii) To extract the relevant design information from the lateral test results. iii) To determine the yield capacity and various design parameter values from the relevant test results according to an existing data interpretation technique recommended by Branston (*2004*). iv) To propose a limit states design resistance factor for this type of shear wall and to determine the corresponding factor of safety for various shear wall configurations. v) To develop ductility-related and overstrength-related seismic force modification factors for various shear wall configurations as per the approach developed by Boudreault (*2005*). Both ductility-related and overstrength-related force modification factors are used to develop lateral seismic design forces according to the 2005 National Building Code of Canada.

1.3 Scope and Limitations of Study

Lateral resistance tests were conducted on twenty-five (3 configurations) single-storey light gauge steel frame / wood panel shear walls during May 2004. The wall specimens were constructed with Canadian cold-formed steel and 3/8" (9.5 mm) Canadian softwood plywood (CSP) sheathing (*CSA O151, 1978*). Of the wall configurations, which were tested both monotonically and cyclically, only the spacing of the steel-frame-to-sheathing fasteners and the source mill of the CSP sheathing were varied. The results of the wall tests were analyzed and are discussed in this report.

The results presented and values proposed in this report are limited to individual 4' x 8' (1220 mm x 2440 mm) light gauge steel frame / wood panel shear walls designed to resist lateral in-plane loading only. This report does not discuss multiple-storey shear walls nor combined vertical and lateral loading design values. The design values presented in this body of research are valid only for shear walls constructed as indicated in Chapter 2 of this report.

1.4 Report Outline

The general focus of this report is to determine design values for laterally loaded light gauge steel frame / wood panel shear walls according to the Canadian limit states design philosophy. Chapter 2 discusses the test matrix, materials and methods used to construct the wall test specimens, the test set-up, test apparatus and data acquisition methods, the data reduction techniques, general test results, modes of failure and the testing of the materials used to construct the test walls. In Chapter 3 the design parameters are developed, the inelastic drift limit criterion is established, and the design values are presented. Chapter 4 discusses the calibration of the resistance factor, the design approach, the factors of safety, capacity design, and the force modification factors. Finally, Chapter 5 presents the conclusions and recommendations for further research.

1.5 Literature Review

Detailed literature reviews that cover past research on shear walls have been completed by Zhao (*2002*), Branston (*2004*), Boudreault (*2005*) and Chen (*2004*) as part of the McGill University shear wall research program. Since this past work has already been documented, only the investigations that were carried out by these researchers, which add to the base of knowledge concerning shear walls, are presented in this literature review.

Zhao (*2002*) presented the existing test programs for light gauge steel frame shear walls that have been carried-out in various countries. As an example, the test programs of Serrette (*1997*), Serrette and Ogunfunmi (*1996*), and Serrette *et al.* (*1996a, 1996b, 1997a, 1997b, 2002*), who performed the testing of steel frame / wood panel shear walls were discussed. In addition, the COLA-UCI (*2001*) study on both light gauge steel and wood frame specimens sheathed with either OSB (oriented strand board) or plywood of various thicknesses was summarized. Zhao was also responsible for the determination of an R value for use with the 1995 NBCC (*NRCC, 1995*) seismic design calculations of steel frame shear walls, as well as the design of a shear wall testing frame, which was used for the tests described in this report.

Branston (*2004*) provided test results for 43 light gauge steel frame / wood panel shear walls, which were sheathed with 12.5 mm CSP and DFP, as well as 11 mm OSB panels. He proposed design parameters based on the combined data of 109 wall specimens tested by Boudreault (*2004*), Branston *et al.* (*2004*) and Chen (*2004*). The thesis includes a literature review detailing existing North American test programs, existing light gauge steel frame shear wall test programs outside of North America, and sheathing materials. The design parameters for in-plane strength and stiffness were developed using the equivalent energy elastic-plastic (EEEP) method, which was originally developed by Park (*1989*) and then presented in a modified form by Foliente (*1996*). Based on the data of the 109 tests, Branston recommends a resistance factor of 0.7 for walls with a maximum aspect ratio of 2:1, and found that the specimens exhibited an approximate overstrength of 1.2.

Chen (*2004*) examined the performance of the 109 shear wall tests, 46 of which he carried out. Chen tested walls of different lengths (2', 4', & 8' (610 mm, 1220 mm & 2440 mm)) that were sheathed with 12.5 mm CSP and 11 mm OSB. He developed an analytical model to theoretically calculate the resistance and lateral deflection of light gauge steel frame / wood panel shear walls of various configurations based on the strength and stiffness of the sheathing connections.

Boudreault (*2005*) first carried out a total of 20 shear wall tests, which were used to establish that the CUREE reversed cyclic loading protocol (*Krawinkler et al., 2000; ASTM E2126, 2005*) should be incorporated into the shear wall testing program at McGill University. He then established and explained in detail the experimental program and parameter development tools used in this report. Seismic force modification factors for use with the 2005 NBCC (*NRCC, 2005*) were determined from the combined data of the 109 tests presented in Branston *et al*. (*2004*). A value of 2.5 was recommended for the ductility-related force modification factor (R_d) for walls with a maximum aspect ratio of 2:1. Furthermore, an overstrength-related force modification factor value (R_o) of 1.8 was recommended. Both of these values are for use when designing light gauge steel frame / wood panel shear walls according to the 2005 NBCC and using the design values obtained with the EEEP analysis approach as documented by Branston.

More recent shear wall testing by Landolfo *et al.* (*2004, 2006*) and Fulop & Dubina (*2004*) has been completed in Europe. As well, Blais (*2006*) carried out the testing of 18 light gauge steel frame shear walls, at McGill University, that were sheathed with 9 mm OSB.

While many different wall configurations were represented in the data of the 127 tests completed by Branston, Chen, Boudreault and Blais, no test specimens constructed with a plywood sheathing thickness of 3/8” (9.5 mm) were performed. Since plywood of this thickness and grade is commonly used as sheathing for platform construction walls, design parameters would prove useful for structural engineers. Therefore, this report recommends design parameters, a ductility-related force modification factor and an overstrength-related force modification factor for laterally loaded light gauge steel frame / wood panel shear walls constructed with 3/8” (9.5 mm) plywood sheathing. All of these parameters were determined following the relevant approaches recommended by Branston and Boudreault.

CHAPTER 2 SHEAR WALL TEST PROGRAM

In May 2004, twenty-five lateral resistance tests on light gauge steel frame / wood panel shear walls were conducted using the shear wall testing frame in McGill University's Jamieson Structures Laboratory. This Chapter contains a discussion of the test program and the results that were obtained.

The wall specimens were 2440 mm (8') in height and 1220 mm (4') in length. The light gauge steel frame was composed of 1.09 mm (0.043") ASTM A653 (*2002*) Grade 230 steel. Wood sheathing was attached to one side of the steel frame with No. 8 sheathing screws at 75 mm (3"), 100 mm (4") and 150 mm (6") spacing around the panel perimeter. The scope of testing was selected such that it added to the bank of existing data for different configurations of light gauge steel frame / wood panel shear walls subject to lateral earthquake and wind loading. Research by Boudreault (*2005*), Branston (*2004*) and Chen (*2004*) included walls with 12.7 mm (1/2") plywood panels, whereas the tests described in this report were constructed of 9.5 mm (3/8") Canadian Softwood Plywood (CSP) panels (*CSA, 1978*). Each wall configuration consisted of a minimum of six specimens, three of which were tested monotonically and three cyclically using the CUREE protocol for ordinary ground motions (*Krawinkler et al., 2000; ASTM E2126, 2005*). The test data was utilized to determine a design capacity, stiffness, energy absorption and ductility parameters, as well as failure modes for the three wall configurations. The design parameters were calculated using a limit states design approach, as described in Chapter 3, which is based upon the measured strengths and displacements of the walls.

Shear wall tests were carried out using a setup that can be generally described as an 11 m long, 5 m high structural steel reaction frame, as shown in Figure 2.1. Once the base of the test wall is mounted to the test frame, a 250 mm stroke dynamic actuator in series with a 250 kN load cell can be used to displace the top of the wall longitudinally. Lateral movement of the top of the test wall is restricted by the frame's lateral supports

(*Branston, 2004*). During testing the measurement of displacements of and forces on the wall specimen is carried out.

Figure 2.1: Shear Wall Testing Frame

In this report the 25 tests carried out by the author are discussed in detail. A comprehensive description of the wall components, construction sequence, instrumentation, testing protocols and data reduction is provided by Branston (*2004*) and Boudreault (*2005*), and hence is not repeated in this document.

2.1 Test Matrix

The test matrix consisted of three monotonic and three reversed cyclic tests for three different wall configurations. The number of tests per wall configuration was established in order to meet a minimum requirement for validity / reliability for the test data (*Branston, 2004*). Several additional tests were performed in order to further investigate the specimens from the original eighteen, which exhibited performance levels that were not consistent with previous shear wall testing by Branston (*2004*). The matrix was conceived to investigate the design parameters associated with 9.5 mm (3/8") CSP sheathing materials from various mills and three perimeter sheathing-to-steel-frame screw spacings (Table 2.1).

The components of the twenty-five - 1220 mm x 2440 mm (4' x 8') test specimens were as follows:

- 9.5 mm CSA 0151M Exterior Canadian Softwood Plywood (CSP) (*CSA, 1978*) wall sheathing. Wall sheathing mounted on one side of the steel frame with face grain (i.e. strong axis) aligned vertically.

- 1.09 mm nominal thickness light gauge steel studs (*ASTM A653 (2002)*) with nominal grade of 230 MPa. The nominal dimensions of the steel studs spaced at 610 mm on centre (o.c.) were 92.1 mm web, 41.3 mm flange, and 12.7 mm lip.

- 1.09 mm nominal thickness light gauge steel top and bottom tracks (*ASTM A653 (2002)*) with nominal grade of 230 MPa. The nominal dimensions of the steel tracks were 92.1 mm web and 31.8 mm flange.

- 1.09 mm nominal thickness light gauge steel chord studs (*ASTM A653*) with nominal grade of 230 MPa connected back-to-back by two No.10 gauge 19.1 mm self-drilling Hex washer head screws spaced at 305 mm o.c.

- Two Simpson Strong-Tie S/HD10 hold-down connectors. The hold-down connectors were attached to the base of the chord studs by thirty-three No.10 gauge 19.1 mm self-drilling Hex washer head screws. Each hold-down connector was fastened to the test frame by one 22.2 mm (7/8") anchor rod ASTM A307 (*2003)* equivalent.

- No.8 gauge 12.7 mm self-drilling wafer head Phillips drive screws were used to connect the tracks to the studs.

- No.8 gauge 38.1 mm self-piercing Bugle head LOX drive (Grabber Superdrive) screws were used to fasten the plywood sheathing to the steel framing. The fastener schedule (screw o.c. spacing) varied as per test configuration between 75 mm (3”), 100 mm (4”), and 152 mm (6”) along the perimeter of the wall. The sheathing was fastened to the interior stud (interior field) at 305 mm o.c. for all test specimens. The fastener schedule, mill that fabricated the sheathing, and species of wood are detailed in Table 2.1.

Specimens of the various plywood panels produced by each mill were sent to the Canadian Plywood Association for identification of the species in each of the three layers. Previous testing showed that the species type of each layer has a direct effect on the strength and stiffness of the shear wall specimen (*Chen, 2004; Chen et al., 2006*). Therefore, in order to determine lower bound design values, various sheathing layer compositions were tested, as outlined in Table 2.1.

A detailed description of each wall specimen is provided in the test data sheets which are found in Appendix I.

Table 2.1: Light Gauge Steel Frame / Wood Panel Shear Wall Test Program Matrix

Specimen ID	Mill	Layer Species			Loading Protocol[1,2]	Panel Type	Thickness of Panel (mm)	Fastener Schedule[3] (mm/mm)
		Face[4]	Inner	Back				
35 - A	BC 055	S[5]	DF[6]	LPP[7]	Monotonic[1]	CSP	9.5	152/305
35 - B	BC 055	S	DF	LPP	Monotonic	CSP	9.5	152/305
35 - C	BC 055	S	DF	LPP	Monotonic	CSP	9.5	152/305
35 - D	BC 462	S	LPP	S	Monotonic	CSP	9.5	152/305
35 - E	AB 244	S	S	S	Monotonic	CSP	9.5	152/305
35 - F	AB 244	S	S	S	Monotonic	CSP	9.5	152/305
36 - A	AB 244	S	S	S	CUREE[2]	CSP	9.5	152/305
36 - B	AB 244	S	S	S	CUREE	CSP	9.5	152/305
36 - C	AB 244	S	S	S	CUREE	CSP	9.5	152/305
37 - A	BC 055	S	DF	LPP	Monotonic	CSP	9.5	100/305
37 - B	BC 055	S	DF	LPP	Monotonic	CSP	9.5	100/305
37 - C	BC 055	S	DF	LPP	Monotonic	CSP	9.5	100/305
37 - D	BC 462	S	LPP	S	Monotonic	CSP	9.5	100/305
37 - E	AB 244	S	S	S	Monotonic	CSP	9.5	100/305
37 - F	AB 244	S	S	S	Monotonic	CSP	9.5	100/305
38 - A	AB 244	S	S	S	CUREE	CSP	9.5	100/305
38 - B	AB 244	S	S	S	CUREE	CSP	9.5	100/305
38 - C	AB 244	S	S	S	CUREE	CSP	9.5	100/305
39 - A	BC 055	S	DF	LPP	Monotonic	CSP	9.5	75/305
39 - B	AB 244	S	S	S	Monotonic	CSP	9.5	75/305
39 - C	AB 244	S	S	S	Monotonic	CSP	9.5	75/305
40 - A	BC 462	S	LPP	S	CUREE	CSP	9.5	75/305
40 - B	AB 244	S	S	S	CUREE	CSP	9.5	75/305
40 - C	BC 055	S	DF	LPP	CUREE	CSP	9.5	75/305
40 - D	BC 462	S	LPP	S	CUREE	CSP	9.5	75/305

[1]Section 2.5 explains in detail the monotonic testing protocol
[2]Section 2.6 explains in detail the CUREE reversed cyclic protocol for ordinary ground motions
[3]The fastener schedule (e.g. 152/305) specifies the spacing of the sheathing-to-framing screws along the perimeter of the panel and along the interior studs (field spacing), respectively
[4] Face is the panel side marked the grade stamp and mill identification
[5]S = Western White Spruce
[6]DF = Douglas Fir
[7]LPP = Lodgepole Pine

2.2 Shear Wall Materials, Components and Fabrication Method

Prior to the construction of each test wall, the sheathing was stored in the structures laboratory at room temperature in order to allow the panel to achieve its equilibrium moisture content (EMC). This was done to reduce the possible expansion / contraction of the sheathing due to fluctuations in humidity once fastened to the light gauge steel frame. The actual moisture content of each wood panel was recorded after testing of the shear wall specimen.

CSP sheathing panels from three mills were used, as outlined in Section 2.1. These types of sheathing represent a typical range of CSP panels that are available from local lumber yards. Sample grade stamps of the three panels used are shown in Figures 2.2, 2.3, and 2.4.

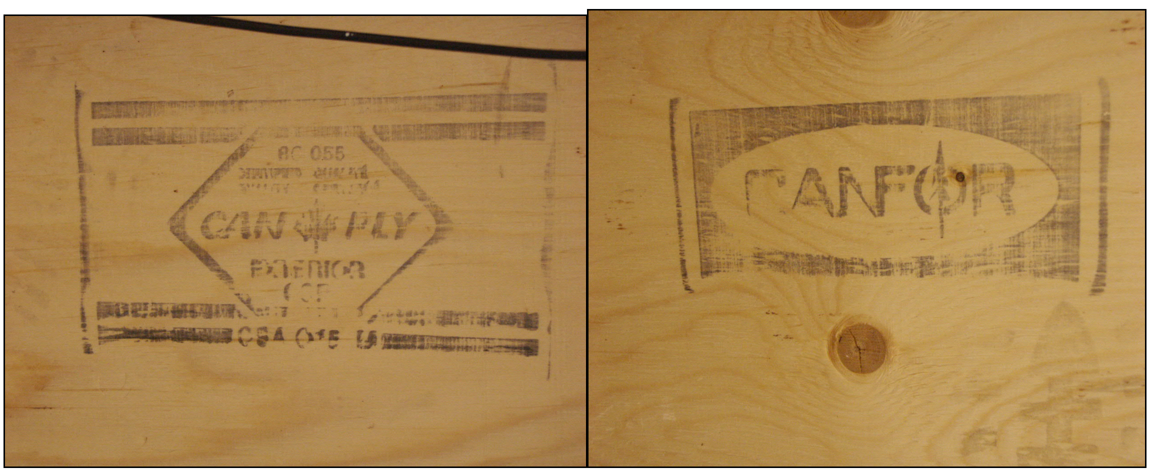

Figure 2.2: Panel Markings for BC 055 Sheathing

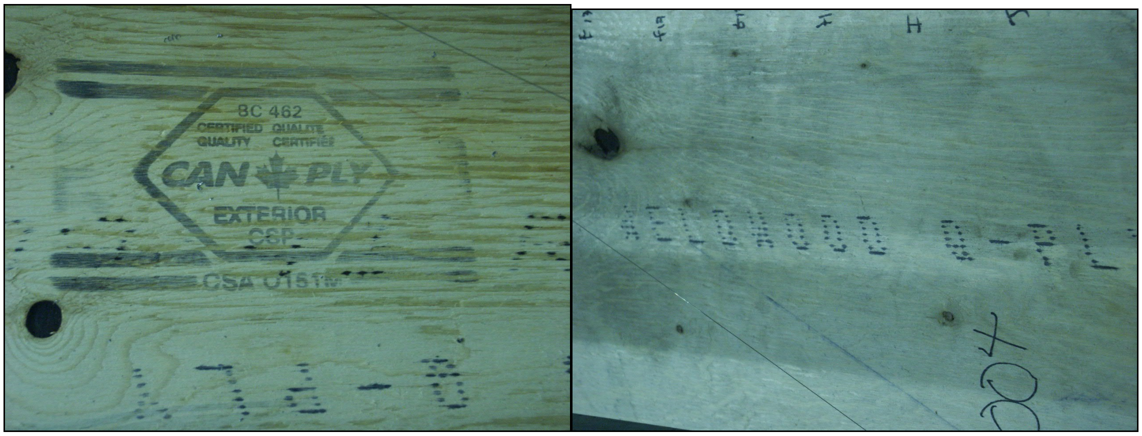

Figure 2.3: Panel Markings for BC 462 Sheathing

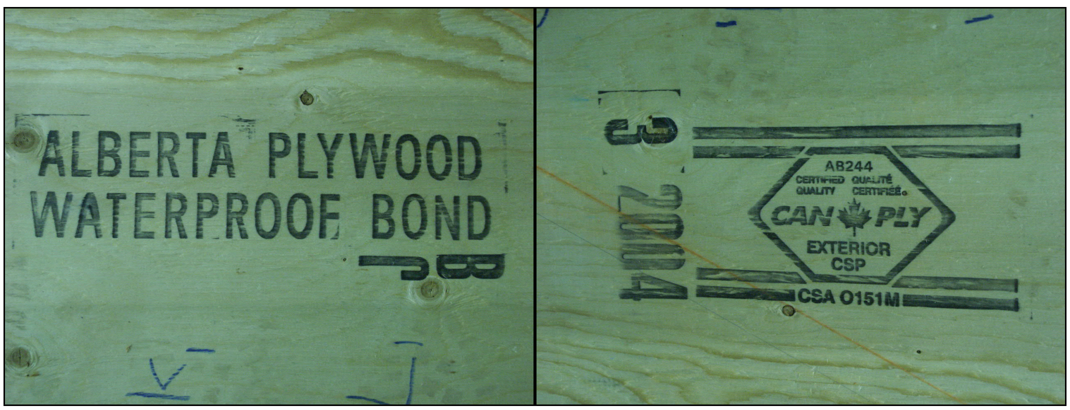

Figure 2.4: Panel Markings for AB 244 Sheathing

The stud and track components of the light gauge steel frames, as described in Section 2.1, were assembled prior to fastening the CSP sheathing (*Branston, 2004*). As previously mentioned, one hold-down connector was attached to the base of each built-up chord stud. The purpose of the hold-down connector is to transfer the uplift force, found at the corner of the base of the wall during lateral loading, to the foundation or storey below, or to the test frame as in the case for this test program.

Once each light gauge steel frame was assembled, the CSP sheathing was attached according to the respective fastener schedule of the wall as outlined in Table 2.1. Prior to installing the sheathing the moisture content of the panel was taken in order to confirm that it was not greater than 10%. Great care was taken to limit the depth of the sheathing screws so that each fastener would be driven until its head became flush with the exterior surface of the sheathing (*Branston, 2004*). However, upon completing the fabrication of test wall 40C it was discovered that most of the sheathing screws had been over-driven by 2 to 5 mm. Test wall 40C was subsequently included in the overall test matrix to show the effect of over-driven sheathing screws on the performance of light gauge steel frame / wood panel shear walls. Figures 2.5 and 2.6 show sample properly driven and over-driven sheathing screws.

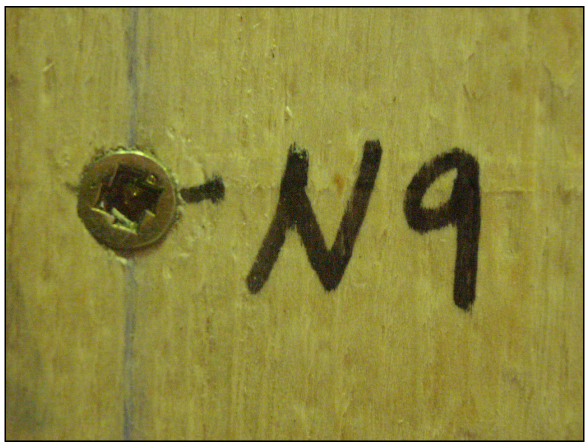

Figure 2.5: Properly Driven Sheathing Screw

Figure 2.6: Over-driven Sheathing Screw in Test Wall 40C

Once the wall specimen was properly mounted in the testing frame, imperfections were recorded on the respective Test Data Sheet and Test Observation Sheet. These sheets can be found in Appendices I and II, respectively, for all twenty-five tests.

Upon completion of each test, samples of each sheathing panel were taken (Figure 2.7) in order to determine the true moisture content as per APA Test Method (*APA PRP-108, 2001*) (*Branston, 2004*).

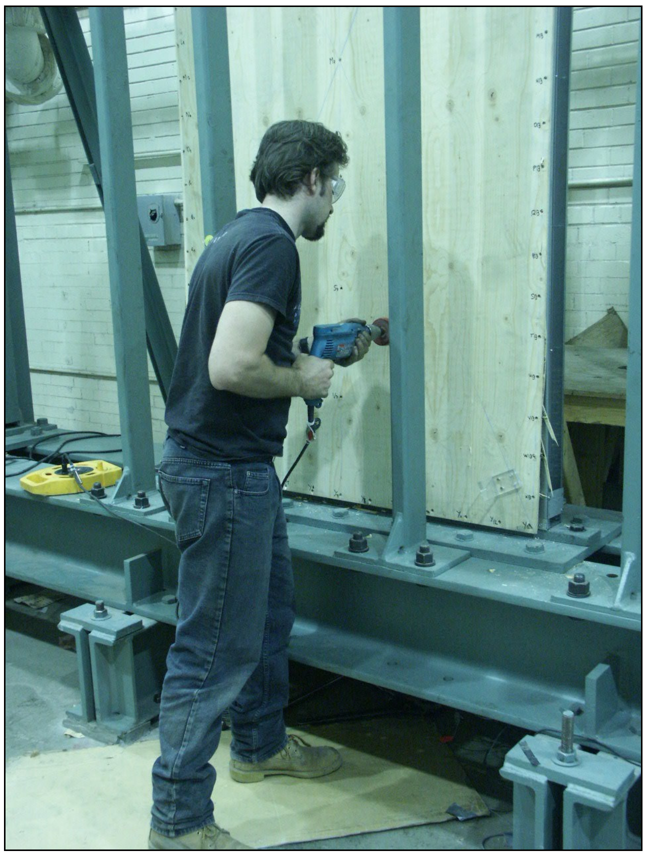

Figure 2.7: Sheathing Sample Removal for Moisture Content Evaluation

2.3 Test Set-up

Once the fabrication of a test wall was completed, it was manoeuvred into the test frame (Figure 2.8). The wall was then anchored at its base to the frame via two 19.1 mm (3/4")

ASTM A325 shear anchors and two 22.2 mm (7/8") ASTM A307 hold-down anchors. Load cells were installed on the hold-down anchors to measure the uplift force caused by displacement of the wall during testing. The top of the test wall was then attached to the loading beam using six 19.1 mm (3/4") ASTM A325 bolts. The position of each of the top and bottom mounting bolts is illustrated in Figure 2.9. Steel washers were used during the installation of the anchors in order to limit local damage of the steel frame channel members. Spacer plates (25 mm thick) were placed above and below the wall to allow rotation and displacement of the sheathing as the walls deflected under loading (*Branston, 2004*).

Figure 2.8: Test Apparatus

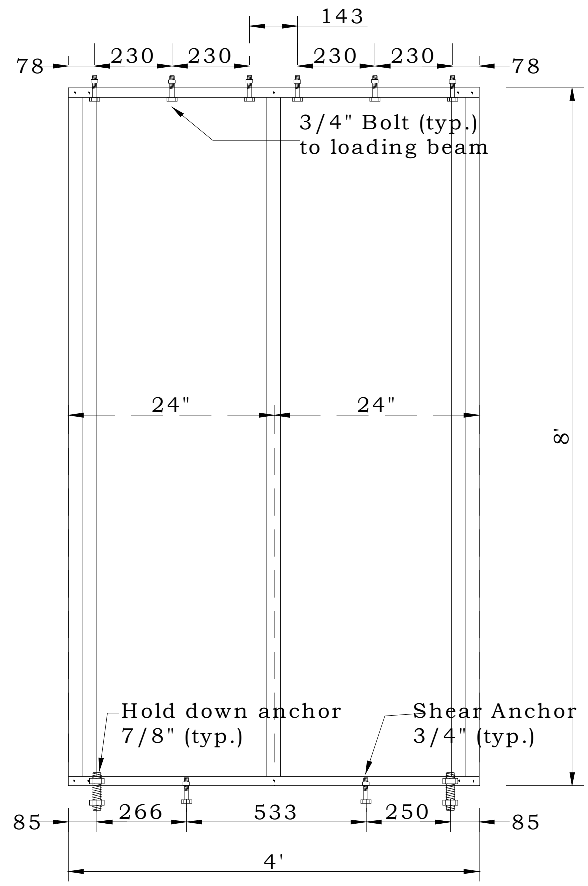

Figure 2.9: Test Frame Anchorage of Wall Specimens

(*Branston, 2004*)

2.4 Data Acquisition and Apparatus

Once a wall specimen was properly attached to the test frame, linear variable differential transformers (LVDTs), also known as displacement transducers, were installed. A total of fourteen LVDTs were used to measure the movement of each wall specimen. Nine LVDTs were attached to the wall specimens (Figure 2.10) to measure the uplift encountered at the base of the walls (2 LVDTs), the longitudinal slip measured at the base of the walls (2 LVDTs), the in-plane lateral displacement of the top of the walls (1 LVDT), and the displacement of the sheathing with respect to the steel framing of the walls (4 LVDTs). Two LVDTs were used to measure the displacement of the lateral braces perpendicular to the motion of the actuator for each test wall. The loading actuator also contained one LVDT which was relied on to control the protocol specified for testing. An additional two LVDTs were connected to the sheathing of the wall specimens to measure the shear deformation of the wood panel.

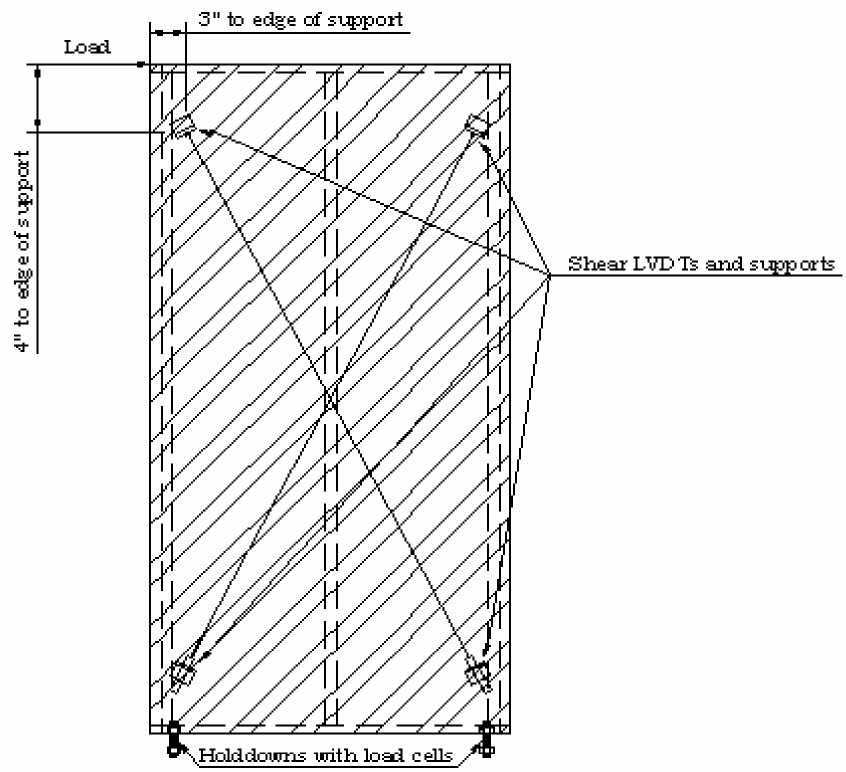

Figure 2.10: Location of LVDTs for Wall Displacement Measurements
(*Blais, 2006*)

A total of three load cells were used to measure the reaction of the test walls and actuator at specific locations. The in-plane wall resistance was measured by one load cell mounted to the loading beam. The axial load in the hold-down anchors was recorded as well.

The acceleration at the top of the wall specimen during reversed cyclic loading was measured using an accelerometer. These readings, along with the wall mass were later relied on to correct the measured wall resistance (*Branston, 2004*).

All of the measuring devices were connected to Vishay Model 5100B scanners to record the data. Vishay System 5000 StrainSmart software was used to control the data acquisition system. Data for the monotonic tests were recorded at 2 scans per second and for the reversed cyclic tests at 50 scans per second.

2.5 Monotonic Testing

The monotonic test protocol replicates that implemented by Serrette *et al.* (*1996b*). The protocol provides for a single-direction lateral loading on the walls at a constant rate of 7.5 mm per minute until a significant reduction in the performance of the wall was observed. The permanent set was measured by unloading the specimen to zero load once a marker deflection was met, then increasing the load until the next marker was reached or failure of the wall took place. The two marker deflections for each test were 0.5% and 1.5% of the wall height (12.5 mm and 38.0 mm, respectively). The relationship between wall resistance and corrected displacement for a typical monotonic test is shown in Figure 2.11. The deflection correction method is detailed in Section 2.7 of this report.

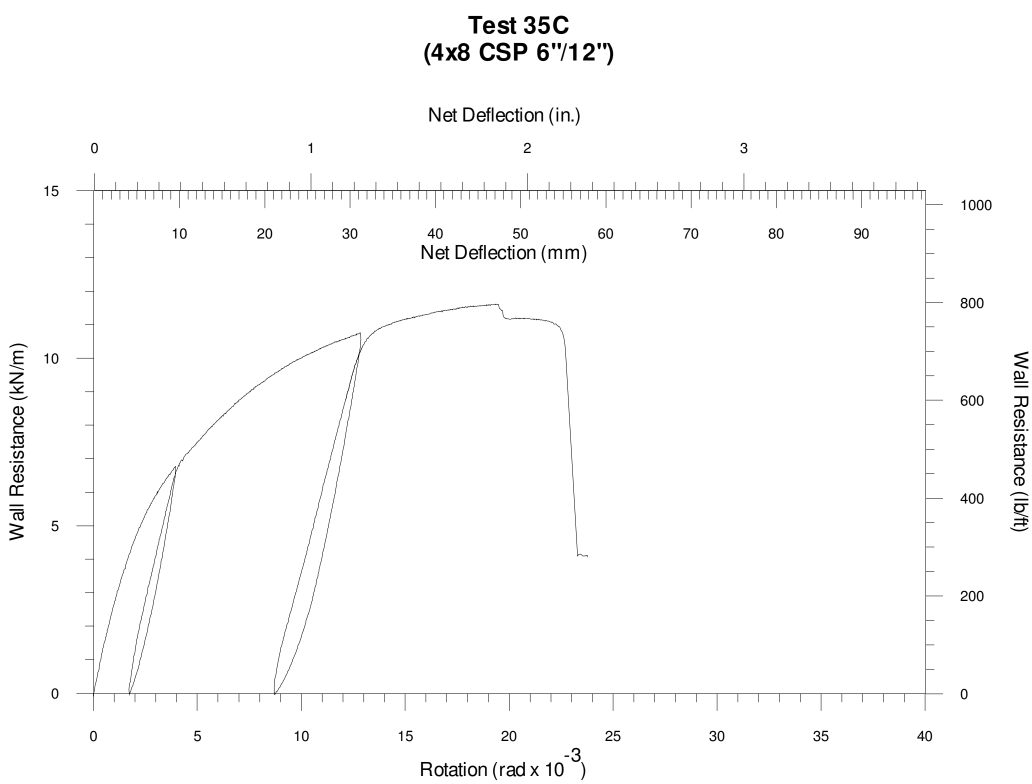

Figure 2.11: Wall Resistance versus Deflection Curve of Typical Shear Wall under Monotonic Loading

2.6 Reversed Cyclic Testing

The reversed cyclic test protocol replicates the CUREE (Consortium of Universities for Research in Earthquake Engineering) ordinary ground motions protocol as detailed by Krawinkler *et al.* (*2000*) and ASTM E2126 (*2005*). The selection process for this protocol is discussed in Boudreault (*2005*). The protocol for each wall configuration is calculated using the ultimate deformation capacity found during the monotonic testing (*Branston, 2004*). The CUREE protocol for each of the three wall configurations is provided in Appendix IV. A typical deflection time history for the CUREE reversed cyclic protocol, which was run at 0.5 Hz, is shown in Figure 2.12.

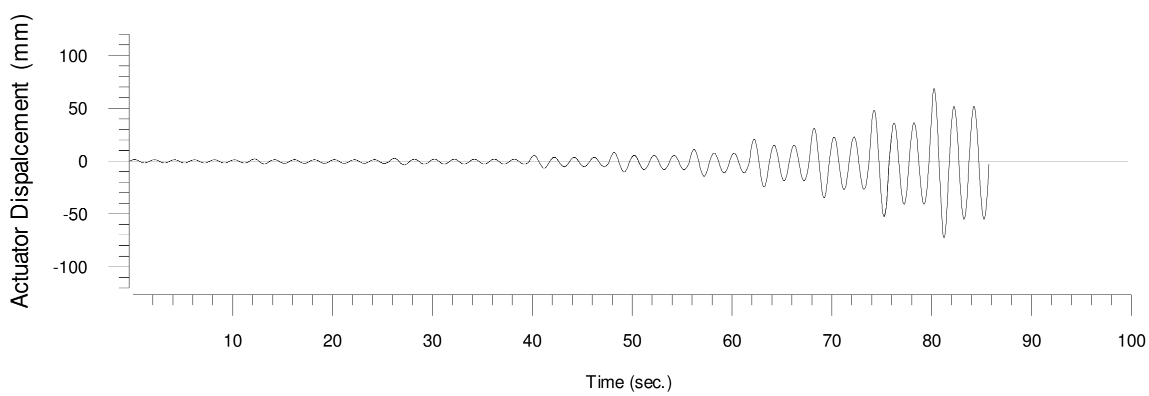

Figure 2.12: CUREE Ordinary Ground Motions Reversed Cyclic Protocol

The relationship between the corrected wall resistance and net deflection / net rotation for a typical reversed cyclic test is shown in Figure 2.13. The deflection and resistance correction method is detailed in Section 2.7 of this report.

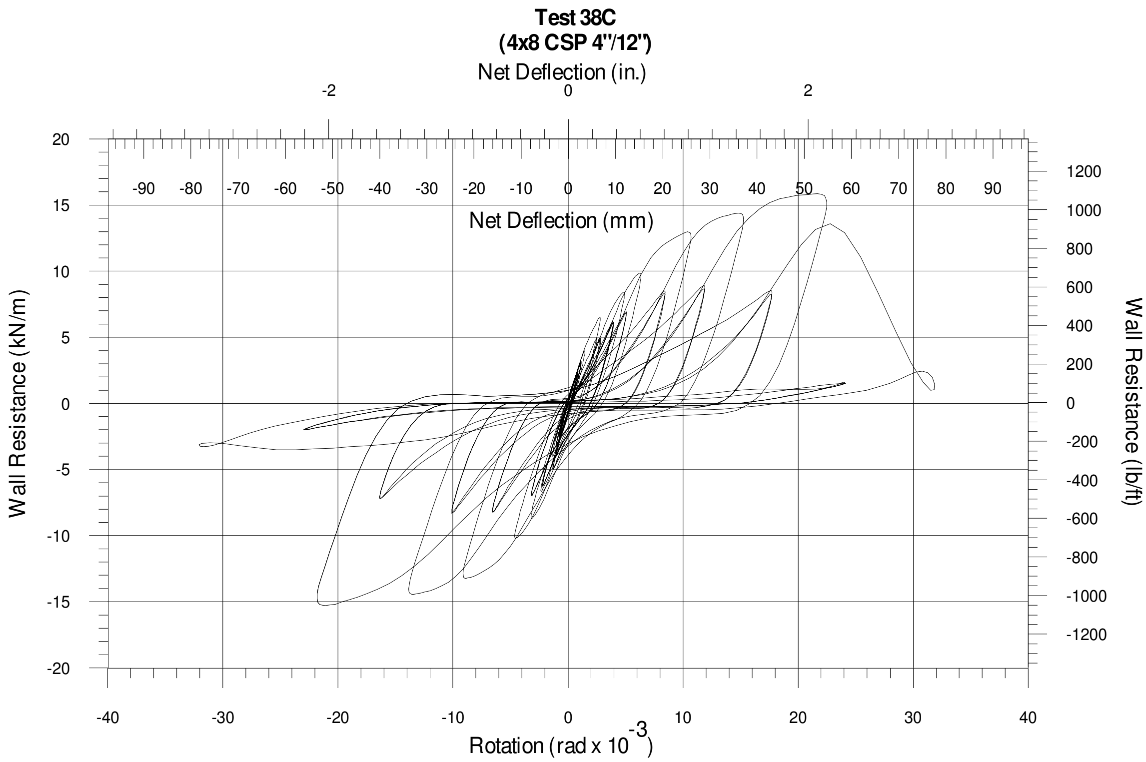

Figure 2.13: Wall Resistance versus Deflection Curve of Typical Shear Wall Under Reversed Cyclic Loading

2.7 Data Reduction

Before the raw data retrieved from the LVDTs was assembled to be presented in this report, the displacement values from the LVDT connected to the top of the wall were modified to represent the net deflection of the wall specimen. This measured wall displacement was modified to account for two phenomena: rigid body translation and rigid body rotation of the test specimen. Rigid body translation was defined as the in-plane slip displacement occurring at the bottom two corners of the wall specimens. It was calculated as the average of the two slip displacement values. Rigid body rotation was identified as the uplift displacement also occurring at the bottom two corners of the wall specimens. It was calculated as the difference in the two uplift displacement values multiplied by the height to length ratio of the wall. The net in-plane displacement of the top of the wall (Δ_{net}) was then calculated by subtracting the displacement values due to rigid body translation and rotation as indicated in Eq 2-1.

$$\Delta_{net} = \Delta_{walltop} - \left[\left(\frac{\Delta_{baseslip1} + \Delta_{baseslip2}}{2} \right) \right] - \left[\left(\Delta_{uplift1} - \Delta_{uplift2} \right) \times \frac{H}{L} \right] \quad (2\text{-}1)$$

where,

Δ_{net} = Net lateral in-plane displacement at top of wall

$\Delta_{wall\ top}$ = Total measured wall-top displacement

$\Delta_{base\ slip}$ = Measured slip at ends of wall specimen

Δ_{uplift} = Measured uplift at ends of wall specimen

H = Height of test specimen

L = Length of test specimen

The net rotation of the wall (θ_{net}) is calculated by dividing the net in-plane displacement (Δ_{net}) of the top of the wall by the height of the wall.

The wall resistance (S), expressed as shear flow, was calculated for the monotonic tests as the in-plane resistance measured by the load cell divided by the length of the wall. In order to calculate the wall resistance for the reversed cyclic tests (S'), the inertial effects of the wall were subtracted from the direct wall resistance (S). The inertial effects of the wall were calculated as the product of the acceleration of the wall (as measured by the accelerometer) and mass of the loading beam apparatus (200 kg), divided by the length of the wall (*Branston, 2004*) as shown in Eq 2-2.

$$S' = S \pm \left(\frac{a \times g \times m}{1000 \times L} \right) \quad (2\text{-}2)$$

where,

S' = Wall resistance (corrected for inertia), [force per unit length]

S = Wall resistance, [force per unit length]

a = Acceleration measured by accelerometer, [g]

g = Acceleration due to gravity (m/s^2)

m = Mass (kg)

2.8 General Test Results

A summary of the results obtained from the monotonic and reversed cyclic testing (positive and negative cycles) of the twenty-five wall specimens is found in Tables 2.2, 2.3 and 2.4 respectively. The parameters that are listed include: maximum wall resistance (S_u), displacement at $0.4S_u$ ($\Delta_{net,\ 0.4u}$), displacement at S_u ($\Delta_{net,\ u}$), displacement at $0.8S_u$ ($\Delta_{net,\ 0.8u}$), rotation at S_u ($\theta_{net,\ u}$), rotation at $0.8S_u$ ($\theta_{net,\ 0.8u}$), energy dissipation (E) for the monotonic tests; maximum wall resistance for both positive and negative cycles ($S_u'{}_+$ and $S_u'{}_-$), displacement at $S_u'{}_+$ and $S_u'{}_-$ ($\Delta_{net,\ u+}$ and $\Delta_{net,\ u-}$), rotation at $S_u'{}_+$ and $S_u'{}_-$ ($\theta_{net,\ u+}$ and $\theta_{net,\ u-}$), and energy dissipation (E) for the reversed cyclic tests. All displacement measurements and wall resistance values (cyclic tests only) have been modified following the correction method described in Section 2.7. A detailed description of all shear wall test results, including graphs, test data sheets and test observations can be found in Appendix 'I'. A full explanation of the parameters listed in these tables may be found in Section 3.2. An average value for each of the parameters of the wall specimens built with AB 244 sheathing is presented because it represented the lower bound response of the various shear wall types that were tested.

Past research by Blais (*2006*) and Chen (*2004*) has shown that ultimate wall resistances of cyclically loaded walls were lower than those for monotonically loaded walls. In fact, they observed that as the stiffness of the tested specimens increased (i.e. as the fastener schedules were reduced) so did the divergence between the monotonic and cyclic ultimate wall resistances. However, the 9.5 mm CSP sheathing results from this body of research did not clearly support the observations of Blais and Chen. In fact, when comparing the AB 244 results, only the 152 mm / 305 mm walls showed higher monotonic ultimate wall resistances. The 102 mm and 75 mm fastener schedules showed monotonic ultimate wall resistance reductions of 5.8% and 10.8%, respectively.

Table 2.2: Test Results for Monotonic Tests

Test	Panel Type	Plywood Manufacturer	Fastener Schedule mm/mm	Maximum Wall Resistance (S_u) kN/m	Displacement at $0.4S_u$ ($\Delta_{net,\ 0.4u}$) mm	Displacement at S_u ($\Delta_{net,\ u}$) mm	Displacement at $0.8S_u$ ($\Delta_{net,\ 0.8u}$) mm	Rotation at S_u ($\theta_{net,\ u}$) rad	Rotation at $0.8S_u$ ($\theta_{net,\ 0.8u}$) rad	Energy Dissipation, E Joules
35A	CSP	BC 055	152/305	10.9	5.7	55.7	66.0	0.0228	0.0270	684
35B	CSP	BC 055	152/305	12.5	5.6	52.8	62.0	0.0216	0.0254	735
35C	CSP	BC 055	152/305	11.6	4.9	47.2	56.8	0.0193	0.0233	633
35D	CSP	BC 462	152/305	12.3	5.1	43.3	59.8	0.0177	0.0245	727
35E	CSP	AB 244	152/305	10.3	4.5	48.5	69.2	0.0199	0.0284	724
35F	CSP	AB 244	152/305	11.9	4.9	45.8	68.0	0.0188	0.0279	800
AVERAGE				**11.6**	**5.1**	**48.9**	**63.6**	**0.0200**	**0.0261**	**717**
AVERAGE AB 244				**11.1**	**4.7**	**47.1**	**68.6**	**0.0193**	**0.0281**	**762**
37A	CSP	BC 055	100/305	16.4	7.0	57.2	67.5	0.0235	0.0277	1055
37B	CSP	BC 055	100/305	17.9	6.3	53.3	58.8	0.0218	0.0241	958
37C	CSP	BC 055	100/305	16.2	6.1	57.8	73.2	0.0237	0.0300	1184
37D	CSP	BC 462	100/305	16.9	6.1	57.4	66.3	0.0235	0.0272	1082
37E	CSP	AB 244	100/305	14.7	6.8	58.6	70.9	0.0240	0.0291	985
37F	CSP	AB 244	100/305	14.3	6.2	55.4	69.5	0.0227	0.0285	976
AVERAGE				**16.1**	**6.4**	**56.6**	**67.7**	**0.0232**	**0.0277**	**1040**
AVERAGE AB 244				**14.5**	**6.5**	**57.0**	**70.2**	**0.0234**	**0.0288**	**981**
39A	CSP	BC 055	75/305	22.3	7.4	58.1	64.7	0.0238	0.0265	1282
39B	CSP	AB 244	75/305	17.4	8.1	55.2	59.2	0.0226	0.0242	895
39C	CSP	AB 244	75/305	17.4	7.9	47.4	48.2	0.0194	0.0197	723
AVERAGE				**19.0**	**7.8**	**53.6**	**57.3**	**0.0220**	**0.0235**	**967**
AVERAGE AB 244				**17.4**	**8.0**	**51.3**	**53.7**	**0.0210**	**0.0220**	**809**

Table 2.3: Test Results for Reversed Cyclic Tests (positive cycles)

Test	Panel Type	Plywood Manufacturer	Fastener Schedule mm/mm	Maximum Wall Resistance ($S_u`_+$) (positive cycle) kN/m	Displacement at $S_u`_+$ ($\Delta_{net, u+}$) mm	Displacement at $0.8S_u`_+$ ($\Delta_{net, u+}$) mm	Rotation at $S_u`_+$ ($\theta_{net, u+}$) rad	Energy Dissipation, E Joules
36A	CSP	AB 244	152/305	9.7	44.7	52.5	0.0183	2647
36B	CSP	AB 244	152/305	10.8	47.5	58.0	0.0195	2653
36C	CSP	AB 244	152/305	10.9	49.4	63.0	0.0202	3121
AVERAGE	**CSP**			**10.5**	**47.2**	**57.8**	**0.0193**	**2807**
AVERAGE AB 244	**CSP**			**10.5**	**47.2**	**57.8**	**0.0193**	**2807**
38A	CSP	AB 244	100/305	15.4	50.3	74.1	0.0206	4973
38B	CSP	AB 244	100/305	14.9	49.6	60.3	0.0203	4080
38C	CSP	AB 244	100/305	15.9	52.9	60.0	0.0217	4383
AVERAGE	**CSP**			**15.4**	**50.9**	**64.8**	**0.0209**	**4479**
AVERAGE AB 244	**CSP**			**15.4**	**50.9**	**64.8**	**0.0209**	**4479**
40A[1]	CSP	BC 462	75/305	22.1	61.0	61.0	0.0250	5747
40B	CSP	AB 244	75/305	19.5	59.8	59.8	0.0245	4333
40C	CSP	BC 055	75/305	14.7	20.4	23.8	0.0084	2254
40D	CSP	BC 462	75/305	19.9	46.3	56.1	0.0190	4329
AVERAGE[2]	**CSP**			**20.5**	**55.7**	**59.0**	**0.0228**	**4803**
AVERAGE AB 244	**CSP**			**19.5**	**59.8**	**59.8**	**0.0245**	**4333**

[1]Test 40A capacity governed by 2.5% inelastic drift limit

[2]The data from Test 40C is not included in any design value averages

Table 2.4: Test Results for Reversed Cyclic Tests (negative cycles)

Test	Panel Type	Plywood Manufacturer	Fastener Schedule mm/mm	Maximum Wall Resistance (S_u`-) (negative cycle) kN/m	Displacement at S_u`- ($\Delta_{net, u-}$) mm	Displacement at 0.8S_u`- ($\Delta_{net, u-}$) mm	Rotation at S_u`- ($\theta_{net, u-}$) rad	Energy Dissipation, E Joules
36A	CSP	AB 244	152/305	-9.4	-50.1	-58.3	-0.0205	2647
36B	CSP	AB 244	152/305	-9.7	-32.6	-55.5	-0.0134	2653
36C	CSP	AB 244	152/305	-9.8	-50.6	-58.8	-0.0207	3121
AVERAGE	**CSP**			**-9.6**	**-44.4**	**-57.5**	**-0.0182**	**2807**
AVERAGE AB 244	**CSP**			**-9.6**	**-44.4**	**-57.5**	**-0.0182**	**2807**
38A	CSP	AB 244	100/305	-14.9	-52.6	-73.4	-0.0216	4973
38B	CSP	AB 244	100/305	-14.1	-51.9	-60.0	-0.0213	4080
38C	CSP	AB 244	100/305	-15.3	-51.4	-63.6	-0.0210	4383
AVERAGE	**CSP**			**-14.8**	**-51.9**	**-65.7**	**-0.0213**	**4479**
AVERAGE AB 244	**CSP**			**-14.8**	**-51.9**	**-65.7**	**-0.0213**	**4479**
40A[1]	CSP	BC 462	75/305	-20.0	-46.1	-63.3	-0.0189	5747
40B	CSP	AB 244	75/305	-18.1	-56.5	-56.5	-0.0232	4333
40C	CSP	BC 055	75/305	-12.1	-17.2	-23.8	-0.0071	2254
40D	CSP	BC 462	75/305	-18.8	-46.8	-57.2	-0.0192	4329
AVERAGE[2]	**CSP**			**-18.9**	**-49.8**	**-59.0**	**-0.0204**	**4803**
AVERAGE AB 244	**CSP**			**-18.1**	**-56.5**	**-56.5**	**-0.0232**	**4333**

[1]Test 40A capacity governed by 2.5% inelastic drift limit

[2]The data from Test 40C is not included in any design value averages

2.9 Modes of Failure

During the testing of the wall specimens, the reduction of wall resistance leading to the failure of the specimens was in all cases attributed to the deterioration of the sheathing-to-framing connections. This loss of capacity at the sheathing connections was categorized as one of, or a combination of, pull-through of the sheathing (full and partial), tearing-out of the sheathing, wood bearing failure and fatigue fracture of the sheathing to steel framing screws. The type of failure observed for each connection was recorded on the Test Observation Sheets (Appendix II).

Some or all of the above-mentioned connection failures were observed in the 25 wall specimens tested. As the sheathing-to-framing screws tilt, the load transferred to the screw in shear is transformed into a combination of shear and tension. This transformation in the loading increases the capacity of the screw and hence increases the instances of failure occurring due to a break down of the sheathing. It was noted that the sheathing-to-framing screws never pulled-out of the light gauge steel framing members.

It was observed that the remaining components of the test shear walls were undamaged by the testing in both monotonic and cyclic testing. It should be noted that buckling / crushing of the compression chord of the wall specimens did not occur during any of the tests.

2.9.1 Pull-through Sheathing Failure (PT)

Enlargement of the screw holes in the wood sheathing occurred due to the repeated tilting of the screws as shown in Figure 2.14. Once the screw holes were enlarged, the screw heads were able to completely pull through the sheathing as shown in Figure 2.15.

Figure 2.14: Enlargement of Screw Holes in Sheathing on Test Wall 38A

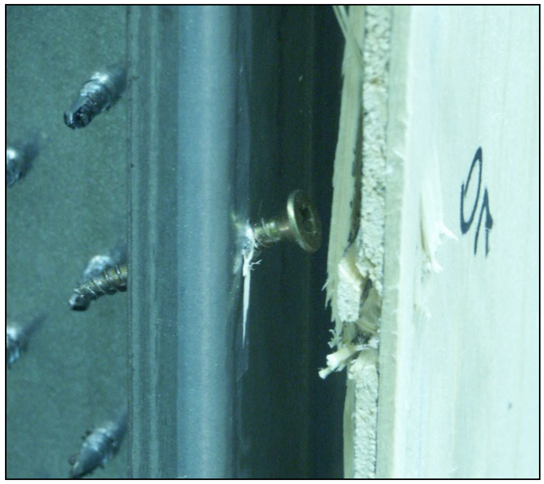

Figure 2.15: Pull Through in Sheathing in Test Wall 36A

2.9.2 Partial Pull-through Failure (PPT)

Partial pull-through failure describes the case where the tilted screw heads did not completely pull through the sheathing as shown in Figure 2.16.

Figure 2.16: Partial Pull Through in Sheathing in Test Wall 40A

2.9.3 Wood Bearing (WB) and Tear-out of Sheathing Failure (TO)

The failure of several, but not necessarily all, of the plies of the sheathing is characterized as a wood bearing / plug shear failure as shown in Figure 2.17. During in-plane displacement of the wall specimens, the sheathing and the steel framing move independently of each other as the wood of the sheathing compresses under the stresses imposed by the deflection of the wall. This type of failure was evident along the perimeter of the wall specimens. Tear-out of sheathing is caused by bearing failure of the wood plies as shown in Figure 2.18. Plug shear failure of the inner plies would also typically take place. This failure type is easily identified as the sheathing material is torn-away behind a perimeter screw.

Figure 2.17: Wood Bearing Failure in Test Wall 39C

Figure 2.18: Tear-out of Sheathing Failure in Test Wall 35E

2.9.4 Fatigue Fracture (FF)

Fatigue fracture of the sheathing-to-steel-framing screws was observed in several of the wall specimens with 152 mm fastener schedules along the perimeter of the sheathing as shown in Figure 2.19. It typically occurred at the corner locations where the sheathing screw was installed through two layers of steel (stud & track). The extra steel layer did not allow for the screw to tilt, which in some cases resulted in its shear failure.

Figure 2.19: Fatigue Fracture in Test Wall 35F

2.9.5 Shear Buckling

Elastic shear buckling of the sheathing was observed prior to failure of several of the specimens, as illustrated in Figure 2.20. This phenomenon was observed during the testing of walls with perimeter fastener schedules of 75 and 100 mm. Out-of-plane forces that occurred in the sheathing, as a result of the buckled panel, typically caused the interior field sheathing screws to pull-through the wood panel at the mid-height of the wall. These tests demonstrated the first observation of sheathing shear buckling for the light gauge steel frame / wood panel shear walls tested to date at McGill University. This behaviour can be attributed to the decrease in shear stiffness of the 9.5 mm thick plywood panel compared with the 12.7 mm plywood specimens that were tested by Boudreault (*2005*), Branston (*2004*) and Chen (*2004*).

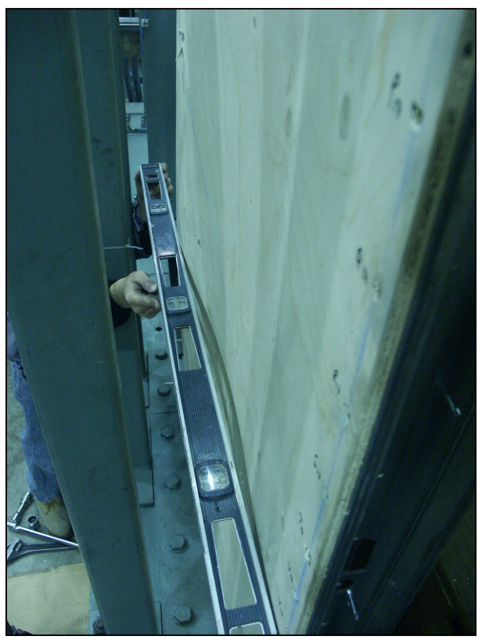

Figure 2.20: Shear Buckling of Sheathing

2.10 Testing of Materials

2.10.1 CSP Wood Sheathing Properties

Six CSP specimens were taken from the test walls in order to carry-out the ancillary sheathing tests. The test specimens measured 254 x 90 mm and were tested according to the edgewise shear test as per ASTM Standard D1037 (*1999*). A 150 kN load cell attached to an MTS® Sintech 30/G universal loading frame was used to provide the 0.5 mm/min displacement loading. Figure 2.21 represents the two rail loading setup used to impose the shear displacements on the CSP specimens. An LVDT aligned with the loading rails was used to record the shear displacements during testing.

Three of the specimens were tested with the grain of the outermost layers aligned parallel to the imposed displacements, and the remaining three specimens were tested with the grain of the outermost layers aligned perpendicular to the imposed displacements.

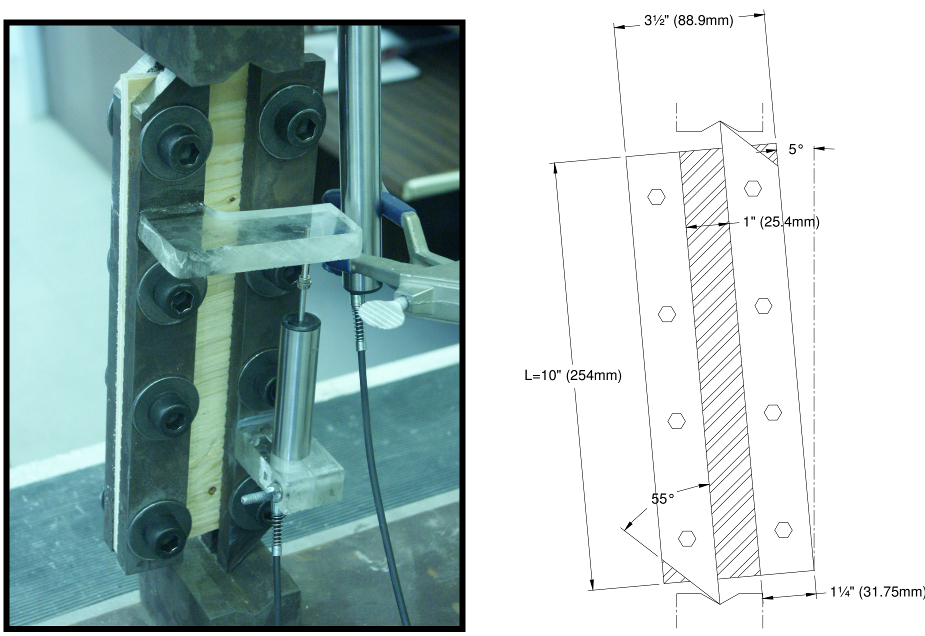

Figure 2.21 Edgewise Shear Test Setup
(*Boudreault, 2005*)

The ASTM Standard D1037 dictates that the ultimate shear resistance (ν_p) and modulus of rigidity (G) are to be calculated according to Equations 2-1 and 2-2, respectively:

$$\nu_P = \frac{P_{\max}}{L \times t} \qquad (2\text{-}1)$$

$$G = 1.19 \times \frac{P \times b}{L \times t \times r} \quad (2\text{-}2)$$

$$B_v = G \times t \quad (2\text{-}3)$$

where,

v_P = Edgewise shear strength (kPa)

P_{max} = Maximum compressive load (kN)

L = Coupon length (254 mm)

t = Coupon average thickness (mm)

G = Modulus of rigidity (MPa)

b = Shear width of member (88.9 mm)

P = Maximum compressive load up to 40% of P_{max} (N)

r = Displacement at load P (mm)

B_v = Shear through-thickness rigidity (N/mm)

It should be noted that the 1.19 multiplier in Equation 2-2 is to account for the small-scale test non-uniform stress distribution as per ASTM D2719 (*1994*). Table 2.4 presents a comparison of the v_p, G and B_v experimental values with the respective CSA O86 (*2001*) values. The CSA O86 is the Canadian timber design code.

Table 2.5: Shear properties of CSP panels

CSP 9.5 mm	**CSA O86**	**Experimental Data**	**Corrected Experimental Data[1]**	**Difference (%)**
v_P (MPa)	2.42	5.8	2.90	20
G (MPa)	453	700		54
B_v (N/mm)	4300	6248		45

[1] A load modification factor of 2 was applied to the experimental shear strength values to account for the short duration of the test and safety (*Blais, 2006*)

The results presented in Table 2.4 reflect the average of the parallel and perpendicular test results because the values in both directions were comparable, as observed by Boudreault (*2005*) and Blais (*2006*) for OSB sheathing. A load modification factor of 2 was applied to the calculated edgewise shear strength values to account for the short test duration in comparison to field behaviour and also to incorporate safety factors (*Boudreault, 2005; Parasin & Stieda, 1985*).

2.10.2 Light Gauge Steel Properties

Five coupons from the light gauge steel studs and tracks were tested according to ASTM A370 (*2002*) in order to determine their average material properties. The same coil of steel was used to produce both the tracks and the studs, therefore the average material properties presented in Table 2.5 represent both of these structural elements.

The steel coupons were tested under a dual cross-head speed procedure: an initial speed of 0.5 mm/min was provided in the elastic range; the speed was then increased to 4 mm/min after plastic behaviour was observed. A 50 mm gauge length extensometer was used to measure the coupon elongation. The elongation and applied loads were divided by the base metal cross-sectional area to calculate the strain and stress values, respectively. The average values of base metal thickness, yield stress, ultimate stress, and modulus of elasticity for the coupons tested, are found in Table 2.5.

Table 2.6 Light Gauge Steel Properties for Studs and Tracks

Specimen	**Component**	**Base Metal Thickness (mm)**	**Yield Stress F_y (MPa)**	**Ultimate Stress F_u (MPa)**	**F_u / F_y**	**Modulus of Elasticity, E (MPa)**	**% Elongation**
1.09 mm, 230 MPa	stud / track	1.12	264	345	1.3	198700	31.50

From Table 2.5, it can be seen that the F_u / F_y ratio is greater than 1.08 and that the elongation is greater than 10 %. The light gauge steel properties meet the requirements of the North American Specification for the Design of Cold-Formed Steel Structural Members *(AISI, 2001)*.

Chapter 3 Design Parameters and Interpretation of Test Results

The purpose of this Chapter is to provide engineers with the information necessary to be able to design, for lateral loads, similarly constructed shear walls to those that were tested. An interpretation of the test results is presented, including the development of the equivalent energy design parameters and the drift limit criteria.

In the case of test wall 40C it was found that the majority of the sheathing-to-framing screws were over-driven. Nevertheless the results from this test specimen were analysed and interpreted to compare with those of the properly constructed wall specimens. The results from wall specimen 40C were not, however, used in this report to develop the design parameters for light gauge steel frame / wood panel shear walls.

3.1 Design Parameters

Test results are often interpreted to develop design parameters used in the calculation of structural member / system design resistance, stiffness, ductility, etc. The design parameters for light gauge steel frame / wood panel shear walls are generally based on the yield strength of the system. Since it is difficult to identify the precise yield strength of a non-linear resistance-deflection response, the Equivalent Energy Elastic-Plastic (EEEP) model was deemed most appropriate to develop parameters for design (*Branston, 2004*; *Branston et al., 2006a, 2006b; Park, 1989; ASTM E2126, 2005*). The EEEP data interpretation technique was applied to the test results; with the nominal design values presented in tabular format. Considering that a detailed description of the EEEP method for establishing design parameters from the results of shear wall tests can be found in Branston (*2004*), only an overview is provided in this report.

3.2 Developing Design Parameters using the Equivalent Energy Elastic-Plastic Model

The Equivalent Energy Elastic-Plastic (EEEP) model was applied to all monotonic and reversed cyclic test data to describe the behaviour of the light gauge steel frame / wood panel shear wall test specimens. The model dictates that the energy dissipated by the test wall during the monotonic or reversed cyclic excitation is equivalent to the energy found under the corresponding bi-linear elastic-plastic curve, or as shown in Figure 3.1. where areas A_1 and A_2 are equal.

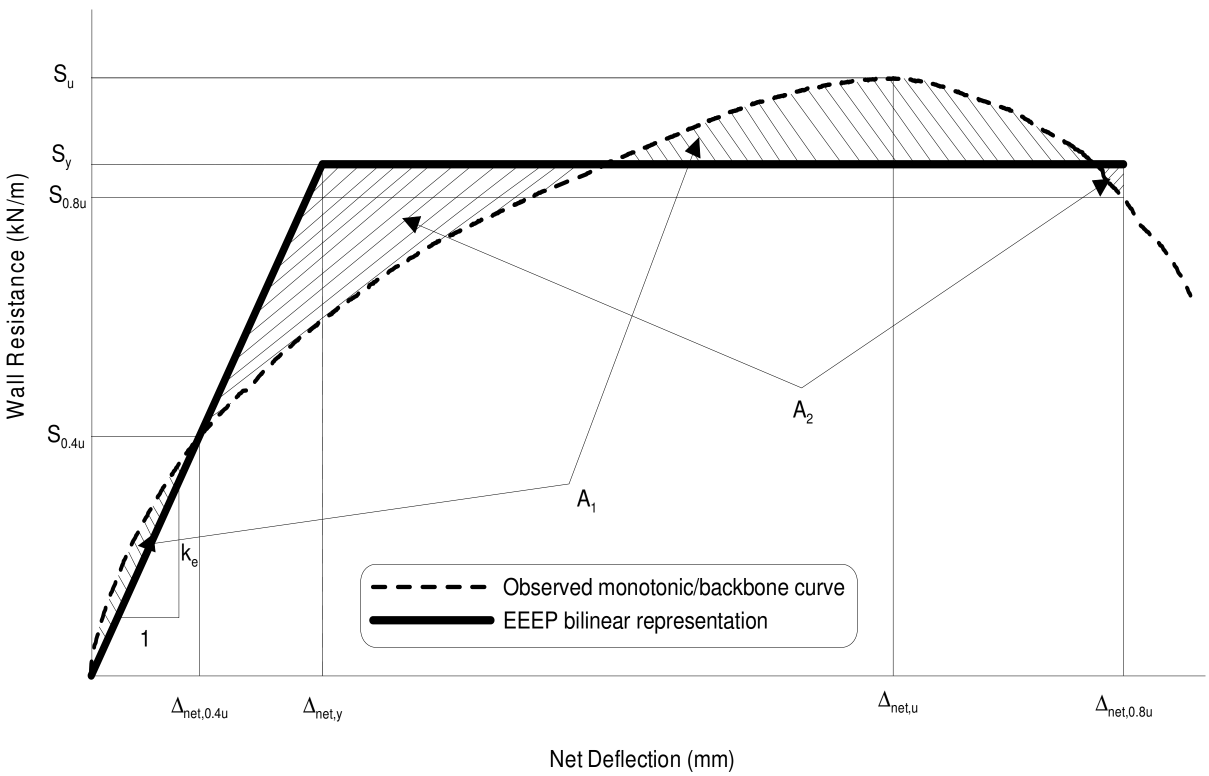

Figure 3.1: EEEP Model

(*Park, 1989; Branston, 2004*)

The bi-linear elastic-plastic curve represents a shear wall for which linear elastic behaviour takes place until the yield point is reached. Once yielding has commenced, the bi-linear curve represents perfectly linear plastic behaviour until failure of the specimen. As can be seen in Figure 3.1 the true resistance vs. deflection behaviour of a steel frame / wood panel is quite nonlinear, somewhat different from the EEEP curve. Nonetheless, the behaviour of the test and design method wall is identical based on an energy approach. This data interpretation method was selected because it provides basic strength and stiffness information that can be used for design, it gives a measure of the ductility inherent in the shear wall, it can be used regardless of the loading protocol followed, and because it has historically been used for the analysis of other structural systems that have exhibited a non linear resistance vs. deflection behaviour (*Branston, 2004*).

The test data for the unloading sections of the monotonic protocol were not included in the EEEP model energy calculations, as shown in Figure 3.2.

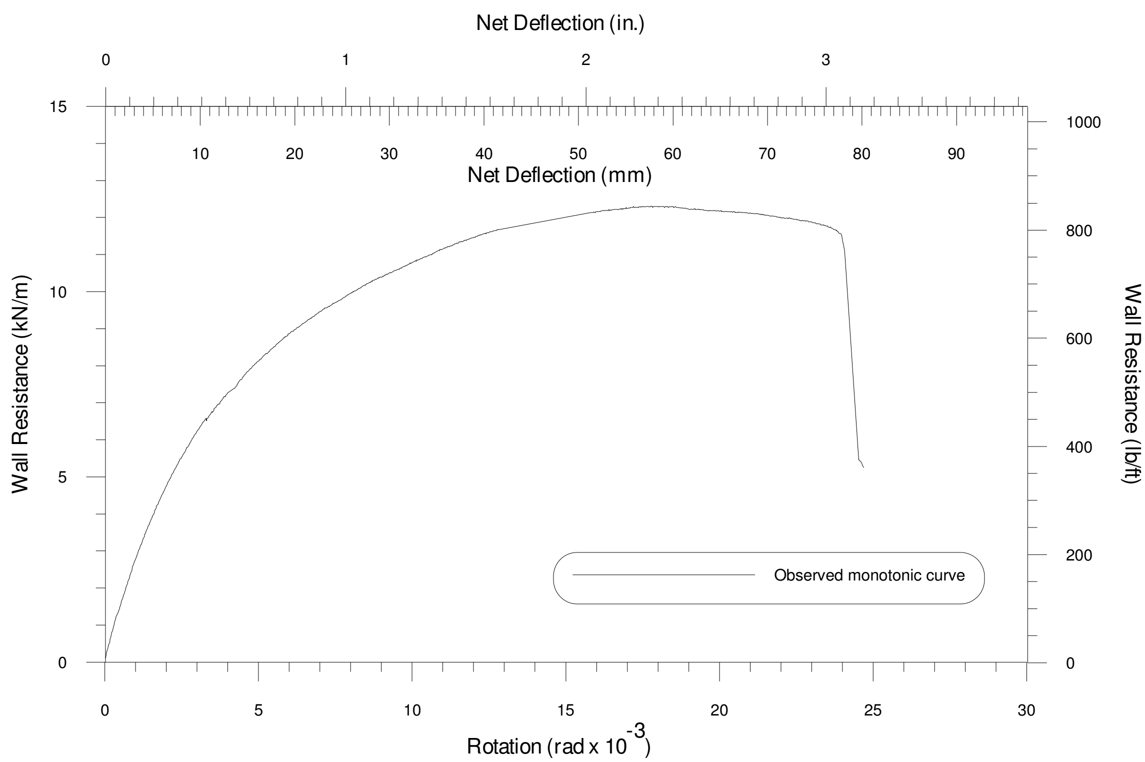

Figure 3.2: Example Monotonic Curve without Unloading Segments

Only the backbone curve of the reversed cyclic test data was used in the EEEP model energy calculations (Figure 3.3). The backbone curve was constructed from the displacement value when the maximum resistance is achieved during a particular cycle and / or the resistance achieved at the maximum displacement of each primary cycle (*Branston, 2004*).

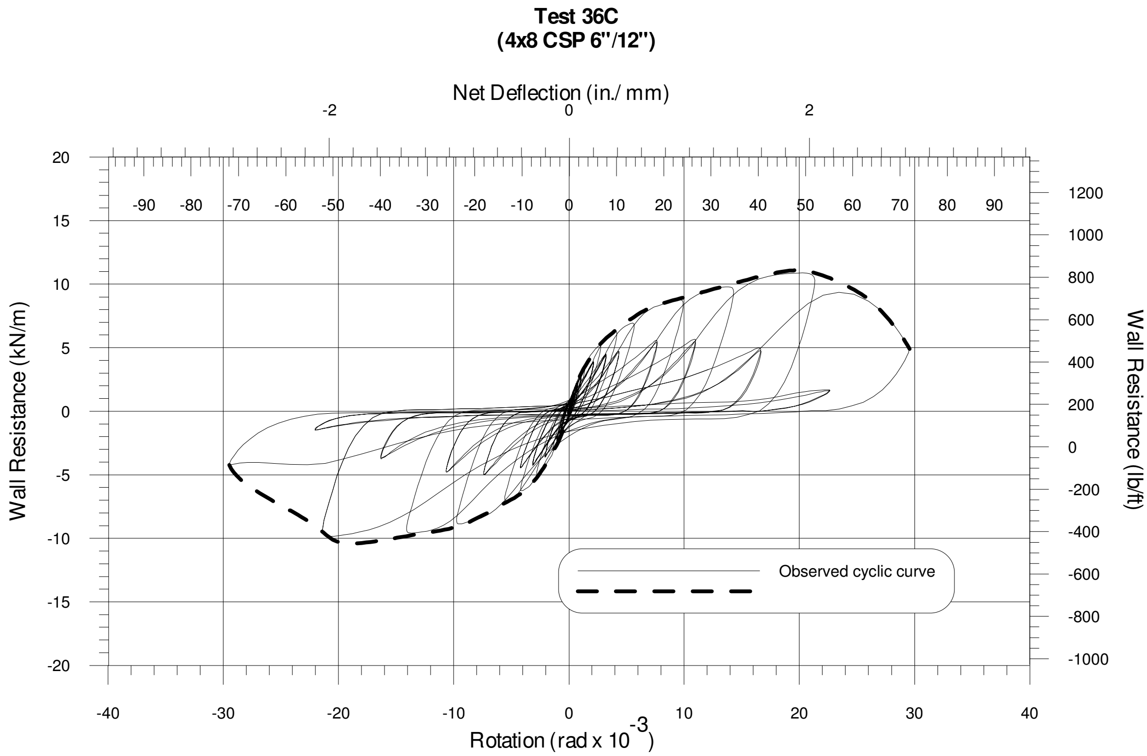

Figure 3.3: Reversed Cyclic Backbone Curve for Test 36C

With the aid of several automated spreadsheets developed by Boudreault (*2005*) the raw data acquired from both the monotonic and cyclic tests was manipulated to develop the design parameters outlined in this Chapter. In order to develop the EEEP curve, the peak wall resistance (S_u) was first determined and then the 40% peak resistance and 80% post-peak resistance values were calculated ($0.4S_u$ and $0.8S_u$, respectively). The corresponding displacements of these three wall resistances were then determined from the backbone or monotonic curve. The 80% post-peak resistance is considered to be the functional capacity and failure point of the test walls (*ASTM E2126, 2005*). The wall resistance at yield (S_y) was then calculated by means of an energy balance as outlined by Branston (*2004*). The elastic segment of the bi-linear EEEP curve is a straight line from the origin passing through the $0.4S_u$ point on the backbone / monotonic curve and ending at the yield point (S_y, $\Delta_{net,y}$) (Figure 3.1). The bi-linear EEEP curve for a typical monotonic test is shown in Figure 3.4.

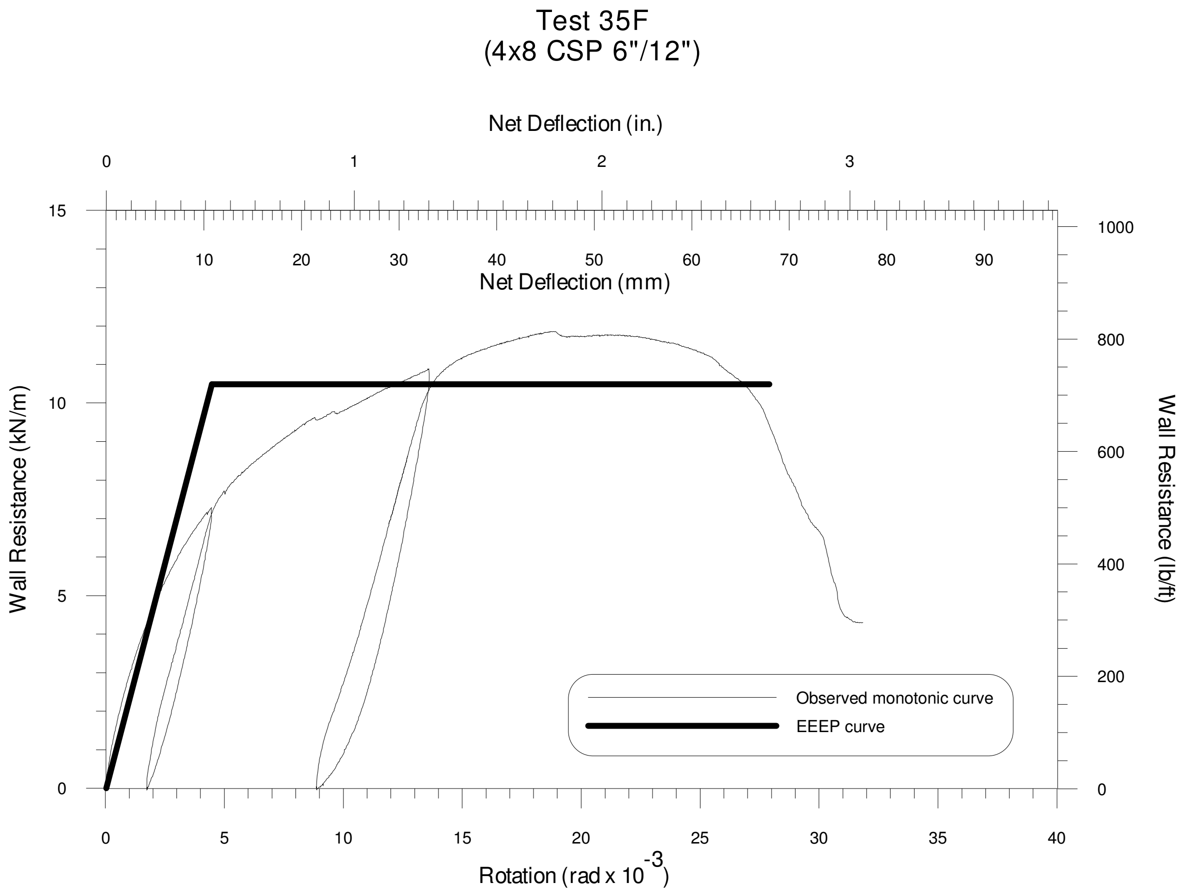

Figure 3.4: Monotonic Resistance versus Deflection Curve with EEEP Curve for Test 35

For the reversed cyclic tests bi-linear EEEP curves were developed for both the positive and negative cycles of each test as shown in Figure 3.5.

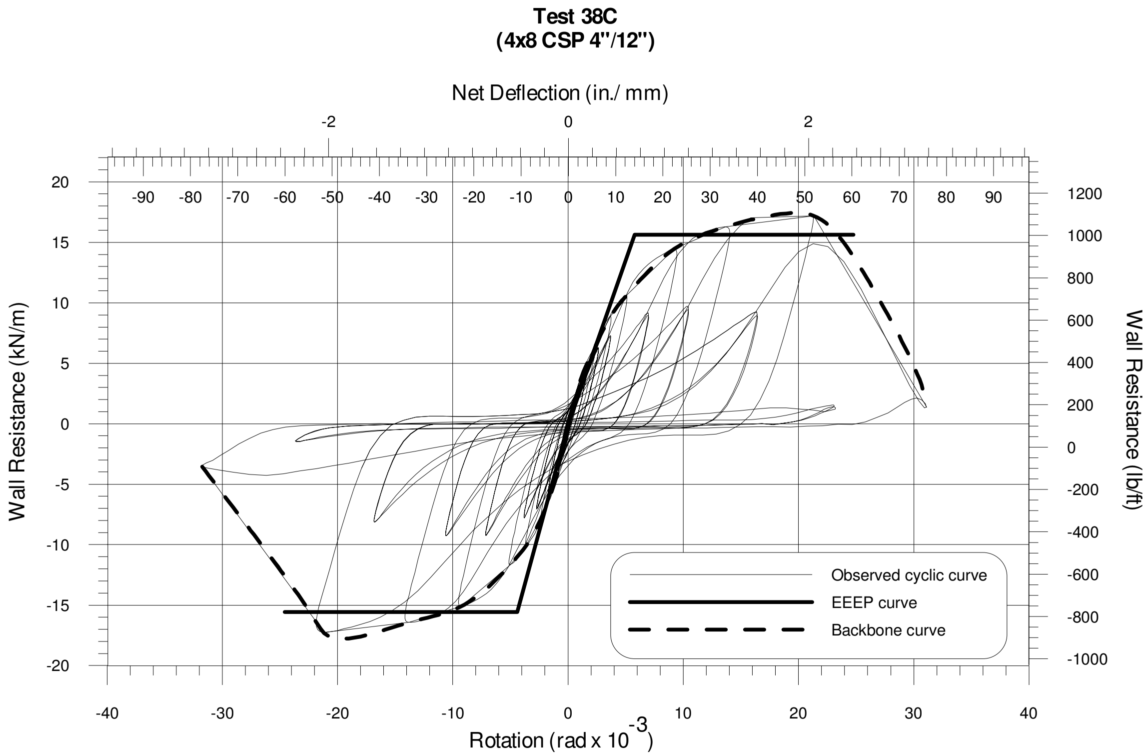

Figure 3.5: Reversed Cyclic Resistance versus Deflection Curve with EEEP Curve for Test 38C

The design parameters were then used to calculate the elastic deflection ($\Delta_{net,y}$) and ductility of each wall specimen as shown in Equations 3-1 and 3-2 (*Branston, 2004*).

$$\Delta_{net,y} = \frac{S_y}{k_e} \tag{3-1}$$

$$S_y = \frac{-\Delta_{net,0.8u} \pm \sqrt{\Delta_{net,0.8u}{}^2 - \frac{2A}{k_e}}}{-\frac{1}{k_e}} \tag{3-2}$$

where,

$$k_e = \frac{0.4 \times S_u}{\Delta_{net,0.4u}} \tag{3-3}$$

S_y = Yield wall resistance (kN/m)

S_u = Ultimate wall resistance (kN/m)

A = Area under monotonic response curve or cyclic backbone curve up to failure ($\Delta_{net,0.8u}$)

k_e = Unit elastic stiffness (kN/mm/m)

$\Delta_{net,0.8u}$ = Displacement at $0.8S_u$ (post-peak)

$\Delta_{net,y}$ = Yield displacement at S_y

Summary tables of the design parameters (including elastic stiffness and ductility) calculated for each of the monotonic and reversed cyclic tests are found in Appendix II.

3.3 NBCC 2005 Drift Limit Criteria

3.3.1 Serviceability Deflection Limit

Designing structural members under service loading is a criterion of the 2005 National Building Code of Canada (*NBCC*) (*NRCC, 2005*). The goal of this criterion is to limit the deflection of the structure and the individual structural elements in order to guarantee the functionality of the structure and all non-structural elements under normal service loading. The storey drift limit as outlined in the Building Code is 0.2% of the storey height, in order to prevent cracking of interior finishes. In the case of the 2440 mm tall wall specimens evaluated in this report, the storey drift limit is therefore 4.9 mm.

It was estimated that the wall resistance at 40% of ultimate ($0.4S_u$) would typically represent a service wind load level for light gauge steel frame / wood panel shear walls (*Branston, 2004*). Only three of the fifteen wall specimens tested under monotonic loading respected the storey drift limit of 4.9 mm at $0.4S_u$, as presented in Table 3.1. However, the wall with perimeter screws spaced at 152 mm (6") exhibited $\Delta_{net,0.4u}$ values that were close to the assumed limit. The remaining walls experienced greater in-plane displacements at the 40% load level, indicating that service level loads may cause damage to the non-structural elements attached to a shear wall. It is suggested that further research be carried out to better evaluate the validity of the service load level that was assumed, as well as the service performance of this type of wall system. A service wind loading deformation limit was not considered in the final calculation of recommended design values.

3.3.2 Inelastic Interstorey Drift limit

According to the 2005 NBCC, in order to estimate the true inelastic response of a structure, the lateral displacements under seismic loading from a linear elastic analysis must be multiplied by R_dR_o/I_E. R_d is defined as the ductility-related force modification factor, R_o as the overstrength-related force modification factor, and I_E as the earthquake importance factor. The R_d and R_o values are further explained in Chapter 4. The inelastic interstorey drift limit is 2.5% of the storey height (*NRCC, 2005*), which corresponds to 61 mm for the 2440 mm tall shear walls. In the development of the EEEP approach to analysing the test data an upper bound on the useful inelastic capacity of the wall was set equal to this interstorey drift limit. At deformations above this level, the shear wall was considered to have exceeded its useful capacity, and hence only energy dissipated before a deflection of 61 mm has been reached was used in the calculation of a yield capacity. The inelastic drift limit affects the design resistance of the wall specimen by either Case I: when 61 mm < $\Delta_{net,u}$ (Figure 3.6) or Case II: when $\Delta_{net,u}$ < 61 mm < $\Delta_{net,0.8u}$ (Figure 3.7). A more detailed description of each case is explained by Branston (*2004*).

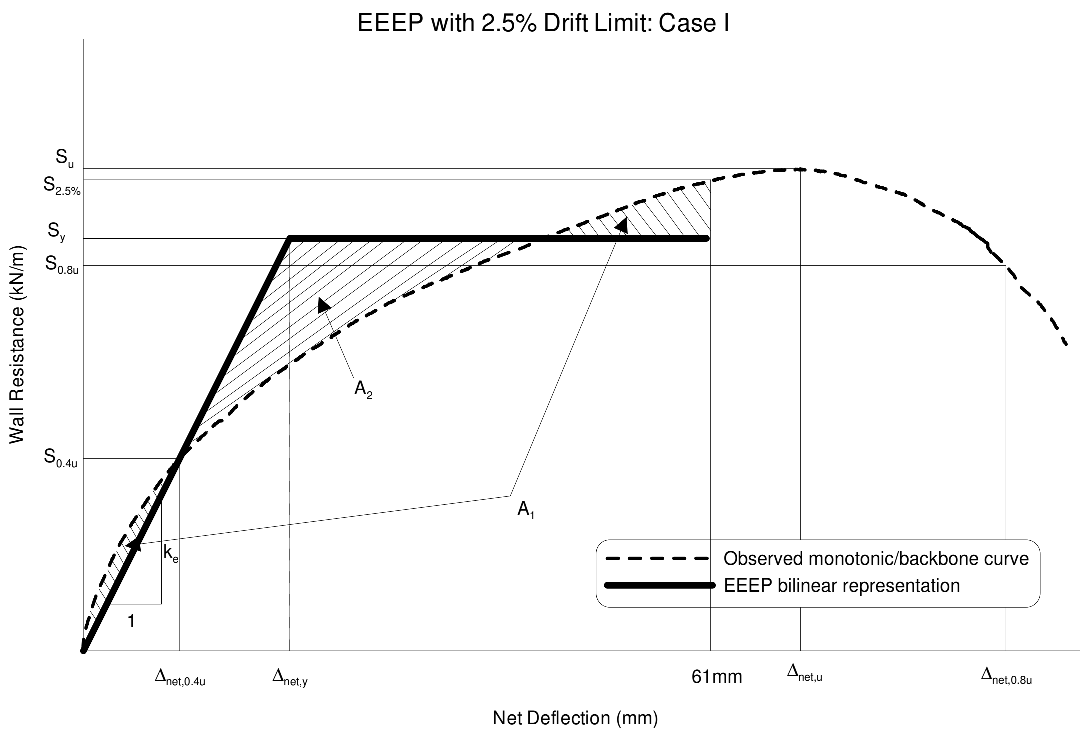

Figure 3.6: Case I (61 mm < $\Delta_{net,u}$) EEEP Curve and 2.5% Drift Limit (*Branston, 2004*)

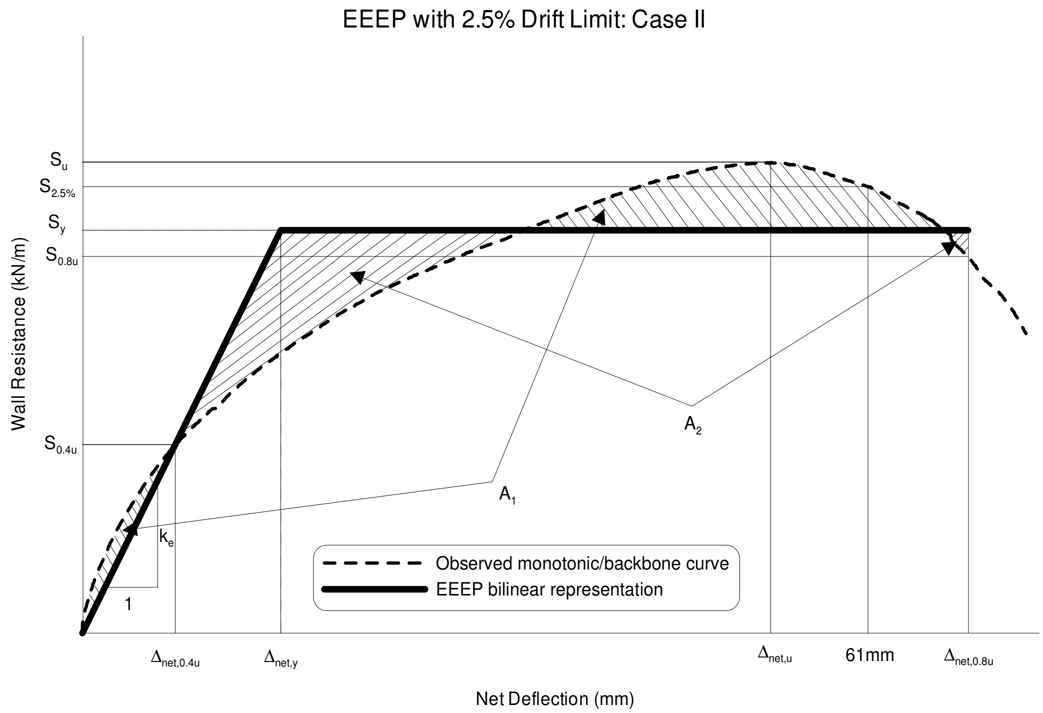

Figure 3.7: Case II ($\Delta_{net,u}$ < 61mm < $\Delta_{net,0.8u}$) EEEP Curve and 2.5% Drift Limit (*Branston, 2004*)

Test 40A was the only test whose performance was governed by the 2.5% drift limit. The deflection of this wall was found to be 60.96 mm at ultimate load and 63.30 mm at the 80% post peak load. This specimen was therefore considered to fall in the Case II category and the analysis approach illustrated in Figure 3.7 was applied. This test was able to attain its maximum capacity before reaching the inelastic interstorey drift limit.

Design values calculated from the monotonic and reversed cyclic test results are presented in Tables 3.1, 3.2, and 3.3. An average design value for each of the wall specimens built with AB 244 sheathing is also presented. It should be noted that the design values shown in the aforementioned tables are representative for lateral loading only. The engineer of record would have to ascertain that the chord studs are capable of resisting both the axial force cause by the lateral load combined with the direct compression force due to gravity.

Table 3.1: Design Values from Monotonic Tests

Test	Panel Type	Plywood manufacturer	Fastener Schedule mm/mm	Yield Load (S_y) kN/m	Displacement at $0.4S_u$ ($\Delta_{net, 0.4u}$) mm	Displacement at S_y ($\Delta_{net, y}$) mm	Elastic Stiffness (K_e) kN/mm	Rotation at S_y ($\theta_{net, y}$) rad	Ductility μ	Energy Dissipation, (E) Joules
35A	CSP	BC 055	152/305	9.4	5.7	12.2	0.94	0.0050	5.43	684
35B	CSP	BC 055	152/305	10.8	5.6	12.1	1.09	0.0050	5.14	735
35C	CSP	BC 055	152/305	10.1	4.9	10.7	1.15	0.0044	5.33	633
35D	CSP	BC 462	152/305	11.0	5.1	11.4	1.18	0.0047	5.23	727
35E	CSP	AB 244	152/305	9.3	4.5	10.1	1.12	0.0041	6.86	724
35F	CSP	AB 244	152/305	10.5	4.9	10.8	1.18	0.0044	6.28	800
AVERAGE				**10.2**	**5.1**	**11.2**	**1.11**	**0.0046**	**5.71**	**717**
AVERAGE AB 244				**9.9**	**4.7**	**10.5**	**1.15**	**0.0043**	**6.57**	**762**
37A	CSP	BC 055	102/305	14.5	7.0	15.4	1.15	0.0063	4.39	1055
37B	CSP	BC 055	102/305	15.1	6.3	13.2	1.39	0.0054	4.46	958
37C	CSP	BC 055	102/305	14.6	6.1	13.8	1.29	0.0057	5.31	1184
37D	CSP	BC 462	102/305	14.9	6.1	13.5	1.34	0.0055	4.90	1082
37E	CSP	AB 244	102/305	12.7	6.8	14.6	1.06	0.0060	4.85	985
37F	CSP	AB 244	102/305	12.8	6.2	13.7	1.14	0.0056	5.08	976
AVERAGE				**14.1**	**6.4**	**14.0**	**1.23**	**0.0058**	**4.83**	**1040**
AVERAGE AB 244				**12.8**	**6.5**	**14.2**	**1.10**	**0.0058**	**4.97**	**981**
39A	CSP	BC 055	75/305	18.4	7.4	15.3	1.47	0.0063	4.23	1282
39B	CSP	AB 244	75/305	14.5	8.1	16.9	1.05	0.0069	3.51	895
39C	CSP	AB 244	75/305	15.0	7.9	17.0	1.10	0.0070	2.83	723
AVERAGE				**16.0**	**7.8**	**16.4**	**1.21**	**0.0067**	**3.52**	**967**
AVERAGE AB 244				**14.8**	**8.0**	**17.0**	**1.10**	**0.0069**	**3.17**	**809**

Table 3.2: Design Values from Reversed Cyclic Tests (Positive Cycles)

Test	Panel Type	Plywood manufacturer	Fastener Schedule	Yield Load (S_y) kN/m	Displacement at S_{y+} ($\Delta_{net,\,y+}$) mm	Elastic Stiffness (K_e) kN/mm	Rotation at S_{y+} ($\theta_{net,\,y+}$) rad	Ductility μ	Energy Dissipation[1], E Joules
36A	CSP	AB 244	152/305	8.4	10.2	1.00	0.0042	5.13	486
36B	CSP	AB 244	152/305	9.7	12.3	0.96	0.0050	4.71	611
36C	CSP	AB 244	152/305	9.4	10.1	1.13	0.0042	6.23	667
AVERAGE				**9.2**	**10.9**	**1.03**	**0.0045**	**5.36**	**588**
AVERAGE AB 244				**9.2**	**10.9**	**1.03**	**0.0045**	**5.36**	**588**
38A	CSP	AB 244	102/305	13.8	14.6	1.16	0.0060	5.09	1125
38B	CSP	AB 244	102/305	12.8	14.0	1.12	0.0057	4.31	833
38C	CSP	AB 244	102/305	13.8	14.5	1.15	0.0060	4.13	884
AVERAGE				**13.5**	**14.4**	**1.14**	**0.0059**	**4.51**	**947**
AVERAGE AB 244				**13.5**	**14.4**	**1.14**	**0.0059**	**4.51**	**947**
40A[2]	CSP	BC 462	75/305	19.9	16.0	1.52	0.0065	3.82	1283
40B	CSP	AB 244	75/305	17.5	15.4	1.38	0.0063	3.87	1109
40C	CSP	BC 055	75/305	12.6	10.6	1.45	0.0043	2.25	283
40D	CSP	BC 462	75/305	17.4	17.5	1.21	0.0072	3.20	1006
AVERAGE[3]				**18.3**	**16.3**	**1.37**	**0.0067**	**3.63**	**1133**
AVERAGE AB 244				**17.5**	**15.4**	**1.38**	**0.0063**	**3.87**	**1109**

[1]Energy calculation based on area below backbone curve
[2]Test 40A capacity governed by 2.5% inelastic drift limit
[3]The data from Test 40C is not included in any design value averages

Table 3.3: Design Values from Reversed Cyclic Tests (Negative Cycles)

Test	Panel Type	Plywood manufacturer	Fastener Schedule	Yield Load (S_y) kN/m	Displacement at S_{y-} ($\Delta_{net, y-}$) mm	Elastic Stiffness (K_e) kN/mm	Rotation at S_{y-} ($\theta_{net, y-}$) rad	Ductility μ	Energy Dissipation[1], E Joules
36A	CSP	AB 244	152/305	-8.3	-10.6	0.95	-0.0044	5.48	538
36B	CSP	AB 244	152/305	-8.7	-10.3	1.02	-0.0042	5.39	532
36C	CSP	AB 244	152/305	-9.0	-10.8	1.02	-0.0044	5.47	586
AVERAGE				**-8.7**	**-10.6**	**1.00**	**-0.0043**	**5.45**	**552**
AVERAGE AB 244				**-8.7**	**-10.6**	**1.00**	**-0.0043**	**5.45**	**552**
38A	CSP	AB 244	102/305	-13.4	-12.1	1.35	-0.0050	6.05	1103
38B	CSP	AB 244	102/305	-12.8	-10.8	1.44	-0.0044	5.54	850
38C	CSP	AB 244	102/305	-13.8	-11.3	1.49	-0.0046	5.62	977
AVERAGE				**-13.4**	**-11.4**	**1.43**	**-0.0047**	**5.74**	**977**
AVERAGE AB 244				**-13.4**	**-11.4**	**1.43**	**-0.0047**	**5.74**	**977**
40A[2]	CSP	BC 462	75/305	-18.2	-15.9	1.39	-0.0065	3.98	1226
40B	CSP	AB 244	75/305	-16.2	-13.6	1.45	-0.0056	4.14	981
40C	CSP	BC 055	75/305	-11.0	-8.6	1.55	-0.0035	2.76	260
40D	CSP	BC 462	75/305	-16.7	-16.5	1.24	-0.0067	3.48	998
AVERAGE[3]				**-17.0**	**-15.3**	**1.36**	**-0.0063**	**3.87**	**1068**
AVERAGE AB 244				**-16.2**	**-13.6**	**1.45**	**-0.0056**	**4.14**	**981**

[1]Energy calculation based on area below backbone curve
[2]Test 40A capacity governed by 2.5% inelastic drift limit
[3]The data from Test 40C is not included in any design value averages

Chapter 4 Limit States Design Procedure

This Chapter contains a discussion of the calculation procedures implemented in the calibration of a resistance factor for limit states design and in the determination of force modification factors needed for seismic design. A recommended design approach, to be used with the 2005 National Building Code of Canada *(NRCC 2005)*, for light gauge steel frame / wood panel shear walls is also provided, including the resulting factors of safety and overstrength values.

4.1 Calibration of Resistance Factor

According to the limit states design philosophy, the factored resistance of any structural element is required to be of greater value than the effect of the factored loads applied to the element (Eq. 4-1), as outlined in Clause 4.1.3.2 of the NBCC 2005.

$$\Phi R \geq \sum \alpha S \tag{4-1}$$

where,

Φ = Resistance factor for specific structural element
R = Nominal resistance of structural element
α = Load factor
S = Worst case effect of combined specified loads

Branston (*2004*) and Branston *et al.* (*2006b*) recommended a value of Φ = 0.7 for the design of light gauge steel frame / wood panel shear walls whose nominal shear strengths are obtained using the EEEP analysis approach documented in Chapter 3. This value was based on the previous testing of shear walls sheathed with either 12.7 mm plywood (CSP & DFP) or 11 mm OSB. The objective of this Section is to determine a limit states resistance factor using the results of the testing carried out on the shear walls sheathed with 9.5 mm Canadian Softwood Plywood, and to determine if it is in the same range as found for the previous shear wall tests.

The structural element resistance factor is defined in Equation 4-2 as:

$$\Phi = C_{\Phi}(M_m F_m P_m)e^{-\beta_o\sqrt{V_M^2+V_F^2+C_P V_P^2+V_S^2}} \tag{4-2}$$

where,

C_{Φ} = Calibration coefficient

M_m = Mean value of material factor (component respective)

F_m = Mean value of fabrication factor (component respective)

P_m = Mean value of professional factor (component respective)

e = Natural logarithmic base = 2.718 …

β_o = Reliability / safety index = 2.5 (*Branston, 2004*)

V_M = Coefficient of variation of material factor = 0.11 (*Branston, 2004*)

V_F = Coefficient of variation of fabrication factor = 0.10 (*Branston, 2004*)

C_P = Correction factor for sample size

V_P = Coefficient of variation of professional factor

V_S = Coefficient of variation of the load effect = 0.37 (*Branston, 2004*)

The calibration equation (Eq 4-2) is as found in the North American Specification for the Design of Cold-Formed Steel Structural Members (*AISI, 2001*). Its derivation is provided by Branston (*2004*). The calibration coefficient (C_{Φ}) is calculated as the load factor (α) divided by the ratio of the mean value of the load effect ($\bar{S}$) and the load effect (S). The material factor accounts for the variability of the strength of the materials. A value of M_m = 1.05 was assigned to this factor to account for an assumed 5% overstrength in the wood sheathing (*Branston, 2004*). The fabrication factor (F_m) accounts for the variability of the measured dimensions of the materials and was conservatively defined as unity. The professional factor (P_m) is defined as the summation of the ratios of nominal shear capacity (S_y) and average nominal shear capacity ($S_{y,\,avg}$) for each test of a specified wall configuration divided by the number of tests for the specified wall configuration, as expressed in Equation 4-3. The average of both the monotonic and reversed cyclic nominal capacities were used to calculate the average nominal shear capacity ($S_{y,\ avg}$) as shown in Equations (4-4) and (4-5).

$$P_m = \frac{\sum_{i=1}^{n} \left(S_y \Big/ S_{y,avg} \right)_i}{n} \tag{4-3}$$

where,

$$S_{y,avg} = \frac{S_{y,mono,avg} + S_{y+,avg}}{2} \tag{4-4}$$

(combined monotonic and positive reversed cyclic values)

or

$$S_{y,avg} = \frac{S_{y,mono,avg} + \dfrac{S_{y+,avg} + S_{y-,avg}}{2}}{2} \tag{4-5}$$

(combined monotonic and average of positive and negative reversed cyclic values)

$S_{y,\ mono,\ avg}$ = Average nominal shear capacity of monotonic tests for a specific wall configuration

$S_{y+,\ avg}$ = Average positive cycle nominal shear capacity of reversed cyclic tests for a specific wall configuration

$S_{y-,\ avg}$ = Average negative cycle nominal shear capacity of reversed cyclic tests for a specific wall configuration

The coefficient of variation of the professional factor is defined in Equation 4-6.

$$V_P = \frac{\sigma}{P_m} \tag{4-6}$$

where,

$$\sigma^2 = \frac{1}{n-1} \sum_{i=1}^{n} \left[\left(S_y \Big/ S_{y,avg} \right)_i - P_m \right]^2 \tag{4-7}$$

where,

n = number of test results included in configuration grouping considered

The correction factor for sample size is defined in Equation 4-8. This relationship illustrates that as the sample size increases the correction factor tends to unity.

$$C_P = (1 + 1/n)m/(m-2) \qquad \text{(when } n \geq 4) \qquad (4\text{-}8)$$
$$= 5.7 \qquad \text{(when } n = 3)$$

where,

m = Degrees of freedom = n - 1

4.1.1 Calibration of Resistance Factor for Wind Loads

This calibration was carried out with respect to the 2005 NBCC, which now requires a wind load factor of 1.4 and a 1 in 50 year wind pressure. To account for wind loading, the resistance factor is calibrated by applying two wind dependant factors: the coefficient of variation of the load effect (V_S) and the calibration coefficient (C_Φ). The coefficient of variation of the load effect was conservatively proposed by Branston (*2004*) to be 0.37 based on documented wind load statistics. The calibration coefficient is determined as the quotient of the load factor for wind loads (α) divided by the mean-to-nominal ratio of the wind load ($\bar{S}/S$). The mean-to-nominal ratio of the wind load was conservatively assigned a value of 0.76. Therefore, the calibration coefficient (C_Φ) was calculated as 1.842.

The resistance factors (Φ) for the wall configurations discussed in this report and respective factors used in their calculation, as outlined in Equation 4-2, are detailed in Table 4.1. It can be seen from these results that the resistance factors were similar for all of the wall configurations consisting of 9.5 mm CSP sheathing. Statistical values are tabulated for each of the fastener patterns individually, for all of the test data, and for those walls that were constructed with AB244 sheathing. The values obtained are similar to those recommended by Branston (*2004*), which shows that a ϕ value of 0.7 is appropriate for shear walls sheathed with 9.5 mm thick CSP panels.

Table 4.1: Resistance Factor Calibration for Wind Loads

		α	S_m / S	C_ϕ	M_m	F_m	P_m	β_o	V_M	V_F	V_S	n	C_p	V_p	Φ
MONO / CYCLIC +/-	ALL TESTS	1.4	0.76	1.842	1.05	1.00	1.00	2.50	0.11	0.10	0.37	24	1.141	0.0856	**0.693**
	ALL AB244 TESTS	1.4	0.76	1.842	1.05	1.00	1.00	2.50	0.11	0.10	0.37	13	1.292	0.0626	**0.699**
MONO / CYCLIC POS.	ALL TESTS	1.4	0.76	1.842	1.05	1.00	1.00	2.50	0.11	0.10	0.37	24	1.141	0.0862	**0.693**
	ALL AB244 TESTS	1.4	0.76	1.842	1.05	1.00	1.00	2.50	0.11	0.10	0.37	13	1.292	0.0675	**0.697**

4.1.2 Calibration of Resistance Factor for Seismic Loads

As outlined in Clause 4.1.8.11 of the 2005 NBCC, the seismic base shear for a normal structure can be calculated using the equivalent static force method as shown in Equation 4-9:

$$V = \frac{S(T_a) M_v I_E W}{R_d R_o} \tag{4-9}$$

where,

V = Minimum lateral earthquake design force at base of structure

$S(T_a)$ = Design spectral response acceleration (function of the period of the structure and location of site)

T_a = Fundamental lateral period of vibration of structure

M_v = Higher mode factor

I_E = Earthquake importance factor = 1.0 for normal buildings

W = Weight of structure

R_d = Ductility related force modification factor

R_o = Overstrength related force modification factor

The force modification factors R_d and R_o for these configurations of light gauge steel frame / wood panel shear walls are calculated and further explained in Section 4.5 of this Chapter. It should be noted that the overstrength related force modification factor (R_o) is inversely proportional to the resistance factor of the structural element as outlined in Mitchell *et al*. (*2003*).

When Eq. 4-1 is equated to the factored resistance of the shear wall it can be manipulated to show that the resistance factor is found in the numerator on both sides of the equation and can therefore be eliminated from the relationship. This indicates that the resistance factor (Φ) has no effect when designing shear walls for seismic loading (*Branston, 2004*). However, in seismic design a Φ = 0.7 should be used to be consistent with the value recommended for wind design, and because, as shown in Section 4.5, the R_o factor is determined based on this value for the resistance factor.

4.2 Design Approach for Light Gauge Steel Frame / Wood Panel Shear Walls

All of the wall configurations discussed in this report were tested under monotonic and reversed cyclic loading. The reversed cyclic loading tests were performed to develop capacities under simulated seismic excitation and to validate that the monotonic and reversed cyclic capacities of these types of shear walls are similar. The aspect ratio for all of the wall configurations was 2:1 (1220 x 2440 mm), and hence no reduction in shear resistance would be necessary in both the AISI Standard for Cold-formed Steel Framing – Lateral Design (*2004*) and the CSA O86 Wood Design Standard (*2001*). The average nominal strength ($S_{y,\ avg}$) for each wall configuration was calculated using Equation (4-5) and is listed in Table 4.2. When calculating these values, the results from the AB244 sheathing specimens were used because they represent the lower bound values. As expected, the average nominal strength of the walls tested increased as the fastener schedule decreased.

Table 4.2: Average Nominal Strength ($S_{y, avg}$) Values for Shear Wall Specimens

Specimen	Sheathing Type	Sheathing Thickness (mm)	Fastener Schedule (mm)	$S_{y, avg}$ (kN/m)
39 -B,C; 40 -B	CSP	9.5	75/ 305	**15.8**
37 -E,F; 38 -A,B,C	CSP	9.5	102/ 305	**13.1**
35 -E,F; 36 -A,B,C	CSP	9.5	152/ 305	**9.4**

As expected, the average nominal strengths for the 75/305, 102/305 and 152/305 fastener schedules found in Table 4.2 are lower when compared to the 20.6, 14.4 and 10.6 kN/m values of their respective 12.5 mm CSP sheathing specimens (*Branston, 2004*). These lower values are likely due to the direct relation between the reduced bearing area of the sheathing connections for the 9.5 mm sheathing panels and the reduction in the overall shear capacity of the wall specimen.

The average unit elastic wall stiffness values ($k_{e, avg}$) were calculated in a similar manner to the average nominal strength values as defined in the explanation of Equation (4-5) divided by the length of the wall specimens (1.22 m). The average unit elastic stiffness ($k_{e, avg}$) for each wall configuration is listed in Table 4.3. When calculating these values, the results from the AB 244 sheathing specimens were used as they represent the lower bound values. The average unit elastic stiffness of the walls tested increased as the spacing between sheathing fasteners decreased.

Table 4.3: Average Unit Elastic Stiffness ($k_{e, avg}$) (per millimeter wall length) Values for Shear Wall Specimens

Specimen	Sheathing Type	Sheathing Thickness (mm)	Fastener Schedule (mm)	$k_{e, avg}$ ((kN/m)/mm wall length)
39 -B,C; 40 -B	CSP	9.5	75/ 305	**1.02**
37 -E,F; 38 -A,B,C	CSP	9.5	102/ 305	**0.98**
35 -E,F; 36 -A,B,C	CSP	9.5	152/ 305	**0.89**

As expected, the average unit elastic stiffness value for the 75/305 fastener schedule found in Table 4.3 is lower when compared to the 1.16 kN/m/mm value of the respective 12.5 mm CSP sheathing specimen (*Branston, 2004*). However, the average unit elastic stiffness values for the 102/305 and 152/305 fastener schedules found in Table 4.3 are slightly higher when compared to the 0.97 and 0.88 kN/m/mm values of their respective 12.5 mm CSP sheathing specimens (*Branston, 2004*) (Table 4.4).

Blais (*2006*) also reported that shear walls sheathed with 9 mm OSB panels provided a higher initial stiffness, k_e, compared with walls constructed of 11 mm OSB. It is possible that because a greater percentage of the wood thickness, in the 9.5 mm CSP and 9 mm OSB panels, was in contact with the head of the screw that less screw tilting occurred and a higher shear stiffness of the wall was obtained. It is also possible that a variation in the stiffness properties of the 12.5 mm and 9 mm CSP panels existed even though the sheathing was obtained from the same mill. The measured shear stiffness of the walls with sheathing screws spaced at 75 mm was less than that recorded for the walls with 12.5 mm sheathing probably because the specimens with the thinner sheathing experienced some degree of elastic shear buckling, thus allowing for greater in-plane deflection of the test specimens.

When comparing both the ultimate load (S_u) and post-peak $0.8S_u$ deflections of the monotonic tests for the 9.5 mm specimens tested as part of this research with the 12.5 mm specimens tested by Branston (*2004*), it was determined that the latter values were higher. This observation supports the assumption that the initial stiffness of the walls is reduced as the sheathing thickness is increased. A comparison of the ultimate load (S_u) deflections of the cyclic tests for 9.5 mm specimens tested as part of this research with the 12.5 mm specimens tested by Branston (*2004*) led to inconclusive results as the deflections for the 9.5 mm specimens were lower for the 152 mm fastener spacing and higher for the 75 mm fastener spacing. Additional research is needed to precisely identify the reason behind the higher shear stiffness measured for the walls with 9.5 mm CSP sheathing.

Table 4.4 contains the recommended nominal design values for unit elastic stiffness and nominal shear strength for the three fastener schedules. These design values are valid only for light gauge steel frame / wood panel shear walls with 9.5 mm thick CSP sheathing and with an aspect ratio of less than 2:1.

The previous research by Branston (*2004*), Chen (*2004*) and Boudreault (*2005*) indicated that longer walls (that is those with a lower aspect ratio than 2:1) were at least as stiff and as strong as the 2:1 walls. It is therefore reasonable to assume that walls with aspect ratios lower or equal to 2:1 (i.e., 2440 x 2440 mm) could be designed with the values presented in Table 4.4.

Table 4.4: Nominal Shear Strength, S_y (kN/m), and Unit Elastic Stiffness, k_e ((kN/m)/mm), for Light Gauge Steel Frame / Wood Panel Shear Walls Dependent on Sheathing Material

Minimum Nominal Panel Thickness (mm) and Grade	**Screw Spacing at Panel Edges (mm)**					
	75		**102**		**152**	
	S_y (kN/m)	**k_e ((kN/m)/mm)**	**S_y (kN/m)**	**k_e ((kN/m)/mm)**	**S_y (kN/m)**	**k_e ((kN/m)/mm)**
9.5 mm Canadian Softwood Plywood (CSP) CSA O151	15.8	1.02	13.1	0.98	9.4	0.89
12.5 mm Canadian Softwood Plywood (CSP) CSA O151	21.6	1.16	14.4	0.97	10.6	0.88

Notes:

1) $\Phi = 0.7$ to obtain factored resistance for design.
2) Full-height shear wall segments of maximum aspect ratio 2:1 shall be included in resistance calculations. Increase of nominal strength for sheathing installed on both sides of the wall shall not be permitted

3) Tabulated values are applicable for dry service conditions (sheathing panels) and short-term load duration (K_D = 1.0) such as wind or earthquake loading. For shear walls under permanent loading, tabulated values must be multiplied by 0.565; and under standard term loads, tabulated values must be multiplied by 0.870.
4) Back-to-back chord studs connected by two No. 10-16 x 3/4" (19.1 mm) screws at 12" (305 mm) o.c. equipped with industry standard hold-downs must be used for all shear wall segments with intermediate studs spaced at a maximum spacing of 24" (610 mm) o.c. For 8' (2440 mm) long shear walls, back-to-back studs are also used at the centre of the wall to facilitate the use of a 1/2" (12.7 mm) edge spacing.
5) All panel edges shall be fully blocked with edge fasteners installed at not less than 1/2" (12.7 mm) from the panel edge and fasteners along intermediate supports shall be spaced at 305 mm o.c. Sheathing panels must be installed vertically with strength axis parallel to framing members.
6) Minimum No.8 x 1/2" (12.7 mm) framing and No.8 x 1-1/2" (38.1 mm) sheathing screws shall be used.
7) ASTM A653 grade 230 MPa minimum uncoated base metal thickness 1.09 mm steel shall be used throughout.
8) Studs: 3-5/8" (92.1 mm) web, 1-5/8" (41.3 mm) flange, 1/2" (12.7 mm) return lip.
Tracks: 3-5/8" (92.1 mm) web, 1-1/4" (31.8 mm) flange.
9) Plywood: CSA O151.
10) The above values are for lateral loading only. It must be noted that the compression chord failure may exist, particularly when gravity loads exist in combination with lateral loads, and the compression chord must be designed to account for these loads.

The average nominal strength and average unit elastic wall stiffness values found in Tables 4.2, 4.3, and 4.4 are valid for lateral loading conditions. Under in-plane wind loading, the back-to-back chord studs must be designed for the additional gravity loads in order to protect the structure against compression / local buckling failure. With respect to seismic loading, the shear wall should be designed according to a capacity based design approach as detailed in Section 4.4. The designer should also note that the shear and hold-down anchors used to restrict movement of the base of the shear wall must be designed to resist the respective forces associated with the calculated lateral loads for wind or the capacity based loads for seismic loading.

It is recommended that the factored shear resistance of light gauge steel frame / wood panel shear walls constructed as outlined in this report be calculated according to

Equation 4-10. It is imperative that the application of Equation 4-10, to determine factored shear resistances, be carried-out in conjunction with the information found in Table 4.4.

$$S_r = \sum S_{rs} \tag{4-10}$$

where,

$S_{rs} = \Phi S_y K'_D L$ Factored shear resistance of wall section (kN)

S_r = Factored shear resistance of wall (kN)

Φ = 0.7

S_y = Nominal shear strength of shear wall section as detailed in Table 4.4 (kN/m)

K'_D = Load duration factor

= 1.0 for short term loading

= 0.565 for permanent loading

= 0.870 for standard loading

L = Length of the shear wall section, measured parallel to the direction of the load (m)

It was decided that the calculation of the factored shear resistance of light gauge steel frame / wood panel shear walls should include the load duration factor to account for the fact that the laboratory tests were carried using short duration loading. Since the capacity of the walls is mainly controlled by the wood sheathing to steel frame connection performance the K'_D factor should be used for standard duration or long term loads. The resistance of wood is, in most cases, dependent on the length of time that the load is in place. The load duration factor values outlined in Equation 4-10 match those prescribed in the CSA O86 Engineering in Wood Design Standard (*2001)*, except that they have been modified such that K'_D = 1.0 for the short term loading case instead of 1.15.

In addition, it should be noted that the design values found in Table 4.4 are only valid for walls for use in dry conditions. All design values discussed in this report were determined from wood sheathing panels considered to be dry, i.e. less than 12% moisture content.

The average post test moisture readings for the wood sheathing specimens used in these tests ranged from 4.54 to 8.00 %. If service conditions, as defined by the CSA O86 Standard (*2001*), are not dry then the appropriate reduction factors should be used for design. It is expected that as the moisture content of the sheathing panel in a light gauge steel frame / wood shear panel shear wall increases the strength and stiffness will decrease. Furthermore, with an increase in moisture content of the wood, which usually is caused by high humidity in the surrounding environment, the impact on the service performance of the steel frame would need to be investigated.

4.3 Factor of Safety

The factor of safety (F.S.) was calculated as the ratio of the ultimate wall resistance (S_u) to the factored wall resistance (S_r) for each test specimen, as expressed in Equation 4-11.

$$F.S. = \frac{S_u}{S_r} \tag{4-11}$$

where,

F.S. = Factor of safety
S_u = Ultimate resistance of shear wall test specimen
S_r = Factored resistance of shear wall (Table 4.4)

The factored resistance, as calculated using Equation 4-10, incorporates a resistance factor (Φ) of 0.7. The factor of safety under wind loading for the monotonic and reversed cyclic tests is shown in Tables 4.5 and 4.6, respectively. The relationship between the factor of safety and the ultimate and factored resistances is illustrated in Figure 4.1.

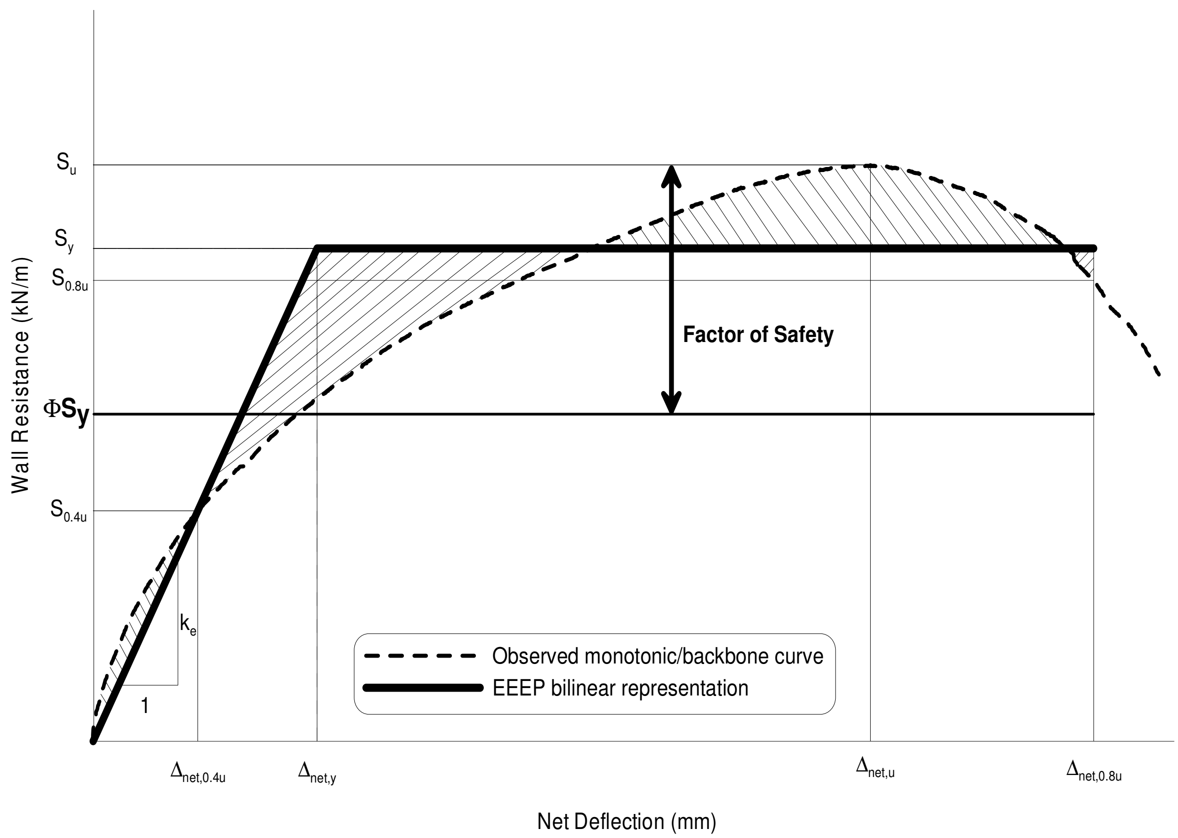

Figure 4.1: Factor of Safety Relationship with Ultimate and Factored Resistances (*Branston, 2004*)

The average factor of safety for the monotonic tests was determined to be 1.7. The results of the test specimens constructed with AB244 sheathing were isolated because it was found that their ultimate capacities represented a lower bound for Canadian Softwood Plywood (*Chen, 2004*). The average factor of safety for the AB244 specimens was calculated to be 1.6. These values are valid for use with the limit states design (LSD) method only. In order to present an equivalent working or allowable stress (ASD) factor of safety these values were multiplied by the wind load factor, 1.4, found in the 2005 NBCC. The AB244 factor of safety for use with ASD is therefore 2.24. Both LSD and ASD factors of safety for the monotonically loaded wall specimens are presented for all wall configurations in Table 4.5.

The average LSD factor of safety for the reversed cyclic tests was found to be 1.7. With respect to the AB244 specimens a value of 1.7 was also determined. The AB244 factor of safety for use with ASD is therefore 2.3. Both LSD and ASD factors of safety for the reversed cyclically loaded wall specimens are presented for all wall configurations in Table 4.6.

According to the 2000 International Building Code (*ICC, 2000*) design guidelines, the allowable capacity of light gauge steel frame shear walls should be designed with a factor of safety of 2.5. The 2000 IBC handbook (*Ghosh and Chittenden, 2001*) indicates that a factor of safety of 2.0 is adequate when determining the allowable capacity of light gauge steel frame shear walls subject to lateral wind loading. The factors of safety for allowable stress design determined for the specimens tested were comparable to these values. These factors of safety are even further increased when compared to the NBCC 1995 (*NRCC, 1995*). The NBCC 2005 requires designers to calculate wind loads according to a 50 year return period, rather than the previous version that required a less stringent 30 year return period.

While analyzing the data of the wall specimens tested, it was observed that the ultimate wall resistance attained during the positive cycle was greater than that which occurred during the corresponding negative cycle. Furthermore, during the testing the peak ultimate resistance of the positive cycles was reached prior to that of the negative cycles; therefore it was decided that the ultimate resistance measured for the positive cycles would be used for the factor of safety calculations.

Only FS values based on wind loading have been presented. Factors of safety are not used in seismic design mainly because the performance of the wall is dependant on the ductility of the wall system during inelastic cyclic loading. Since R_o and R_d values greater than 1.0 are recommended it is expected that a shear wall would reach its ultimate shear capacity during a design level seismic event. Seismic resistance is therefore dealt with using capacity based design principles, as outlined in Section 4.4.

Table 4.5: Factor of Safety Inherent in Design for Monotonic Test Specimens

Test	Panel Type	Plywood Manufacturer	Fastener Schedule	Ultimate Resistance (S_u) kN/m	Yield Load (S_y) kN/m Table 5.5	Factored Resistance (S_r) Φ = 0.7	Factor of Safety (LSD) S_u/S_r	Factor of Safety (ASD) S_u/S_r x 1.4
35A	CSP	BC 055	152/305	10.9	9.4	6.6	1.66	2.32
35B	CSP	BC 055	152/305	12.5	9.4	6.6	1.89	2.65
35C	CSP	BC 055	152/305	11.6	9.4	6.6	1.76	2.47
35D	CSP	BC 462	152/305	12.3	9.4	6.6	1.87	2.61
35E	CSP	AB 244	152/305	10.3	9.4	6.6	1.57	2.20
35F	CSP	AB 244	152/305	11.9	9.4	6.6	1.80	2.52
AVERAGE	**CSP**		**152/305**	**11.6**	**9.4**	**6.6**	**1.76**	**2.46**
AVERAGE AB 244	**CSP**		**152/305**	**11.1**	**9.4**	**6.6**	**1.68**	**2.36**
37A	CSP	BC 055	102/305	16.4	13.1	9.2	1.79	2.51
37B	CSP	BC 055	102/305	17.9	13.1	9.2	1.95	2.73
37C	CSP	BC 055	102/305	16.2	13.1	9.2	1.77	2.48
37D	CSP	BC 462	102/305	16.9	13.1	9.2	1.84	2.58
37E	CSP	AB 244	102/305	14.7	13.1	9.2	1.61	2.25
37F	CSP	AB 244	102/305	14.3	13.1	9.2	1.57	2.19
AVERAGE	**CSP**		**102/305**	**16.1**	**13.1**	**9.2**	**1.76**	**2.46**
AVERAGE AB 244	**CSP**		**102/305**	**14.5**	**13.1**	**9.2**	**1.59**	**2.22**
39A	CSP	BC 055	75/305	22.3	15.8	11.1	2.01	2.82
39B	CSP	AB 244	75/305	17.4	15.8	11.1	1.57	2.20
39C	CSP	AB 244	75/305	17.4	15.8	11.1	1.57	2.20
AVERAGE	**CSP**		**75/305**	**19.0**	**15.8**	**11.1**	**1.72**	**2.41**
AVERAGE AB 244	**CSP**		**75/305**	**17.4**	**15.8**	**11.1**	**1.57**	**2.20**
						AVERAGE	**1.75**	**2.45**
						STD. DEV	**0.15**	**0.21**
						CoV	**0.09**	**0.09**
						AVERAGE AB 244	**1.62**	**2.26**
						STD. DEV	**0.09**	**0.13**
						CoV	**0.06**	**0.06**

Table 4.6: Factor of Safety Inherent in Design for Reversed Cyclic Test Specimens

Test	Panel Type	Plywood Manufacturer	Fastener Schedule	Ultimate Resistance (S_u) kN/m	Yield Load (S_y) kN/m Table 5.5	Factored Resistance (S_r) Φ = 0.7	Factor of Safety (LSD) S_u/S_r	Factor of Safety (ASD) S_u/S_r x 1.4
36A	CSP	AB 244	152/305	9.7	9.4	6.6	1.47	2.05
36B	CSP	AB 244	152/305	10.8	9.4	6.6	1.64	2.29
36C	CSP	AB 244	152/305	10.9	9.4	6.6	1.65	2.32
AVERAGE	**CSP**		**152/305**	**10.5**	**9.4**	**6.6**	**1.59**	**2.22**
AVERAGE AB 244	**CSP**		**152/305**	**10.5**	**9.4**	**6.6**	**1.59**	**2.22**
38A	CSP	AB 244	102/305	15.4	13.1	9.2	1.68	2.36
38B	CSP	AB 244	102/305	14.9	13.1	9.2	1.63	2.28
38C	CSP	AB 244	102/305	15.9	13.1	9.2	1.73	2.42
AVERAGE	**CSP**		**102/305**	**15.4**	**13.1**	**9.2**	**1.68**	**2.35**
AVERAGE AB 244	**CSP**		**102/305**	**15.4**	**13.1**	**9.2**	**1.68**	**2.35**
40A[1]	CSP	BC 462	75/305	22.1	15.8	11.1	2.00	2.80
40B	CSP	AB 244	75/305	19.5	15.8	11.1	1.76	2.47
40C	CSP	BC 055	75/305	14.7	15.8	11.1	1.33	1.87
40D	CSP	BC 462	75/305	19.9	15.8	11.1	1.80	2.52
AVERAGE[2]	**CSP**		**75/305**	**20.5**	**15.8**	**11.1**	**1.85**	**2.59**
AVERAGE AB 244	**CSP**		**75/305**	**19.5**	**15.8**	**11.1**	**1.76**	**2.47**
						AVERAGE	**1.67**	**2.34**
						STD. DEV	**0.28**	**0.39**
						CoV	**0.17**	**0.17**
						AVERAGE AB 244	**1.65**	**2.31**
						STD. DEV	**0.22**	**0.37**
						CoV	**0.13**	**0.16**

[1]Test 40A capacity governed by 2.5% inelastic drift limit
[2]The data from Test 40C is not included in any design value averages

4.4 Capacity Based Design

In order to meet the requirements for seismic capacity based design, the engineer must designate an element in the lateral force resisting system as a “fuse” that will dissipate the seismic energy in a ductile manner. If light gauge steel frame / wood panel shear walls are chosen to dissipate this energy, the sheathing-to-framing connections can typically be relied on to fail in a ductile manner, and therefore this type of lateral load resisting system meets the fuse element criterion. Capacity based design not only requires a fuse element; in addition, all other structural elements that transfer the seismic load to the base of the structure must be designed to resist the loads defined by the true capacity of the fuse element, including any overstrength. This includes the chord studs, holddowns, foundation, etc.

It is the local bearing deformation of the wood sheathing around the sheathing-to-framing screw connections that allows the shear wall to dissipate the seismic energy in a ductile manner. Failure of the screws in shear or buckling of the compression chord studs will decrease the level of resistance, as well as ductility that the shear wall system can achieve. It is necessary, therefore, that all other components of the shear wall be designed to resist the probable capacity of the wall when a sheathing connection failure mode takes place. It should also be noted that the selection of the sheathing-to-framing screw connections as the fuse element of this type of shear wall itself was made to reserve the capacity of the gravity load-resisting steel frame in order to prevent loss of life due to collapse of the structure under combined gravity and seismic loading. In short, the steel frame remains essentially undamaged such that it is able to carry all loads due to lateral loading and all forces due to gravity both during and after an earthquake.

It was therefore necessary to evaluate the shear wall test data such that an overstrength value could be recommended. The overstrength of each test wall was calculated as the ratio of the ultimate shear resistance (S_u) to the yield resistance (S_y) as expressed in Equation 4-12.

$$overstrength = \frac{S_u}{S_y} \tag{4-12}$$

where,

S_u = Ultimate resistance of shear wall test specimen
S_y = Yield resistance of shear wall

The ultimate resistance value for each specimen was obtained from Tables 3.1, 3.2 and 3.3, while the nominal yield resistance (shear strength) for each wall configuration is listed in Table 4.4. The relationship between the wall overstrength and the ultimate and nominal yield resistances is illustrated in Figure 4.2.

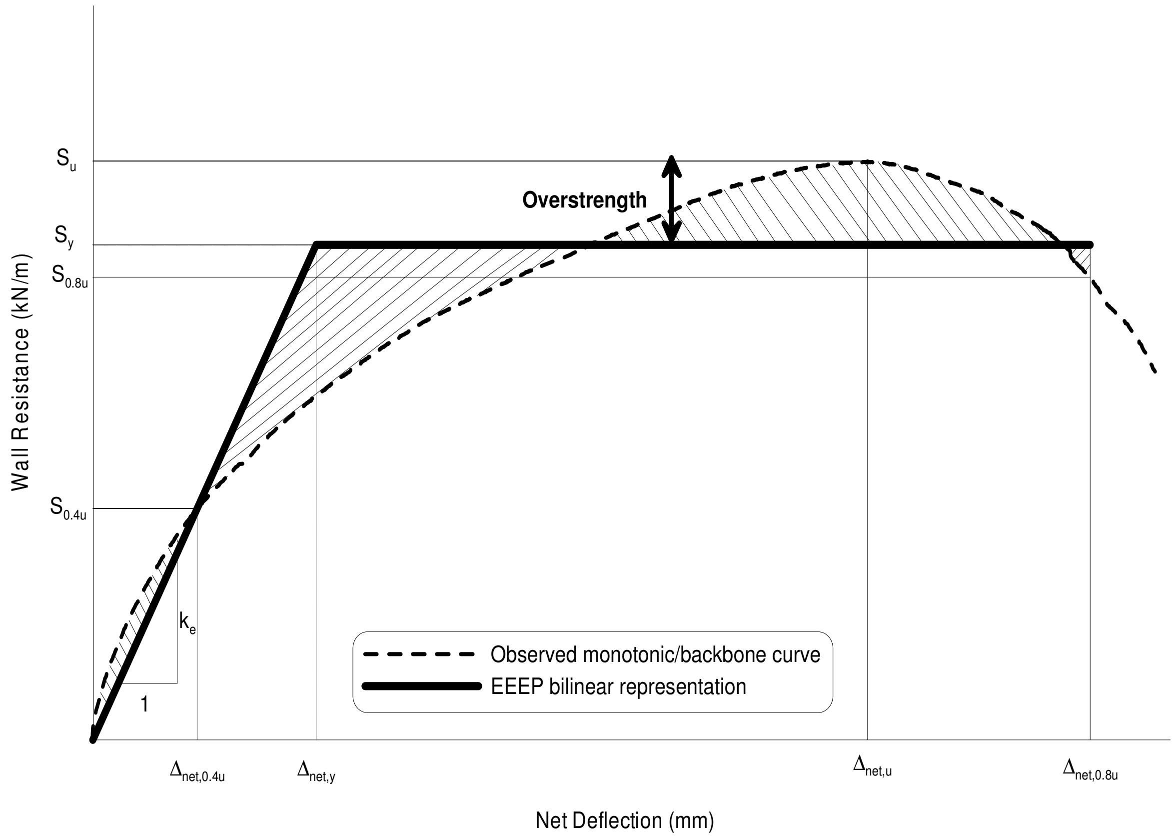

Figure 4.2: Overstrength Relationship with Ultimate and Nominal Yield Resistances (*Branston, 2004*)

The average overstrength for the monotonic tests was found to be 1.22. The overstrength values for the monotonically loaded wall specimens are presented for all wall configurations in Table 4.7.

A second overstrength value of 1.30 was calculated using the average ultimate resistance value of the BC CSP sheathed walls since the possibility exists that one may design a shear wall using the lower bound strengths based on a wall with AB244 sheathing (Table 4.4), while the contractor could then install a BC sheathing with a higher yield and ultimate resistance. The maximum ultimate resistances for the monotonic tests were calculated as the average of the BC 055 and BC 462 sheathed specimens. The overstrength values are found in Table 4.8.

The maximum ultimate resistance of the walls sheathed with BC CSP was then used to calculate a third overstrength value for the monotonic tests. The overstrength values calculated by this method are found in Table 4.9. A value of 1.36 represents the maximum overstrength achieved by the walls tested in this body of research.

The average calculated overstrength for the reversed cyclic tests was 1.17. The overstrength values for the reversed cyclically loaded wall specimens are presented for all wall configurations in Table 4.10.

As with the monotonic tests, overstrength values using the average ultimate resistance of the BC CSP sheathed walls, and using the maximum ultimate resistance of the walls sheathed with BC CSP were calculated. These values were calculated for only the 75/305 fastener schedules because AB 244 sheathing was used to construct all of the wall specimens for the 152/305 and 102/305 fastener schedules. Since there were no cyclic test specimens with these two connection patterns constructed using BC CSP panels a comparison was not possible. The overstrength values with respect to the average ultimate and the maximum ultimate resistance of the BC CSP walls are 1.33 and 1.40, respectively and can be found in Table 4.11.

It is recommended that the designer use the average BC CSP overstrength values (Tables 4.8 and 4.11), which include S_y values based on the AB244 specimens, for capacity design calculations of all non-fuse elements that are part of the lateral load resisting system. An overstrength value of 1.30 is recommended when a capacity based approach is used to design light gauge steel frame / wood panel shear walls. This value is higher than the 1.2 overstrength as determined by Branston (*2004*) for 12.5 mm CSP and 11.0 mm OSB walls. Further testing of cyclically loaded walls with BC CSP sheathing for the 152/305 and 102/305 fastener schedules is necessary before the BC CSP cyclic overstrength values can be considered.

It should be noted that while the overall overstrength value of 1.3 was determined using the average overstrength values of the BC CSP sheathed walls, not the maximum ultimate resistance. It is possible that the overstrength may actually reach as high as 1.36 or 1.40 as shown in Tables 4.9 and 4.11.

Table 4.7: Overstrength Inherent in Design for Monotonic Test Values

Test	Panel Type	Plywood Manufacturer	Fastener Schedule	Ultimate Resistance (S_u) kN/m	Yield Load (S_y) kN/m	Overstrength S_u/S_y
35A	CSP	BC 055	152/305	10.9	9.4	1.16
35B	CSP	BC 055	152/305	12.5	9.4	1.33
35C	CSP	BC 055	152/305	11.6	9.4	1.23
35D	CSP	BC 462	152/305	12.3	9.4	1.31
35E	CSP	AB 244	152/305	10.3	9.4	1.10
35F	CSP	AB 244	152/305	11.9	9.4	1.26
AVERAGE			**152/305**	**11.6**	**9.4**	**1.23**
AVERAGE AB 244			**152/305**	**11.1**	**9.4**	**1.18**
37A	CSP	BC 055	102/305	16.4	13.1	1.25
37B	CSP	BC 055	102/305	17.9	13.1	1.37
37C	CSP	BC 055	102/305	16.2	13.1	1.24
37D	CSP	BC 462	102/305	16.9	13.1	1.29
37E	CSP	AB 244	102/305	14.7	13.1	1.13
37F	CSP	AB 244	102/305	14.3	13.1	1.10
AVERAGE			**102/305**	**16.1**	**13.1**	**1.23**
AVERAGE AB 244			**102/305**	**14.5**	**13.1**	**1.11**
39A	CSP	BC 055	75/305	22.3	15.8	1.41
39B	CSP	AB 244	75/305	17.4	15.8	1.10
39C	CSP	AB 244	75/305	17.4	15.8	1.10
AVERAGE			**75/305**	**19.0**	**15.8**	**1.20**
AVERAGE AB 244			**75/305**	**17.4**	**15.8**	**1.10**
					AVERAGE	**1.22**
					STD. DEV	**0.10**
					CoV	**0.09**

Table 4.8: Overstrength Inherent in Design with Respect to the Average BC Sheathing Strength for Monotonic Test Values

Test	Fastener Schedule	Ultimate Resistance ($S_{u\ BC\ avg}$) kN/m	Yield Load (S_y) kN/m	Overstrength $S_{u\ max}/S_y$
AVERAGE TESTS 35 A, B, C, D, E, F	152/305	11.8	9.4	1.26
AVERAGE AB 244 TESTS 35 E, F	152/305	11.8	9.4	1.26
AVERAGE TESTS 37 A, B, C, D, E, F	102/305	16.8	13.1	1.29
AVERAGE AB 244 TESTS 37 E, F	102/305	16.8	13.1	1.29
AVERAGE TESTS 39 A, B, C	75/305	22.3	15.8	1.41
AVERAGE AB 244 TESTS 39 B, C	75/305	22.3	15.8	1.41
			AVERAGE	**1.30**
			STD. DEV	**0.06**
			CoV	**0.04**

Table 4.9: Overstrength Inherent in Design with Respect to the Maximum BC Sheathing Strength for Monotonic Test Values

Test	Fastener Schedule	Ultimate Resistance ($S_{u\ BC\ avg}$) kN/m	Yield Load (S_y) kN/m	Overstrength $S_{u\ max}/S_y$
AVERAGE TESTS 35 A, B, C, D, E, F	152/305	12.5	9.4	1.33
AVERAGE AB 244 TESTS 35 E, F	152/305	12.5	9.4	1.33
AVERAGE TESTS 37 A, B, C, D, E, F	102/305	17.9	13.1	1.37
AVERAGE AB 244 TESTS 37 E, F	102/305	17.9	13.1	1.37
AVERAGE TESTS 39 A, B, C	75/305	22.3	15.8	1.41
AVERAGE AB 244 TESTS 39 B, C	75/305	22.3	15.8	1.41
			AVERAGE	**1.36**
			STD. DEV	**0.03**
			CoV	**0.02**

Table 4.10: Overstrength Inherent in Design for Cyclic Test Values

Test	Panel Type	Plywood Manufacturer	Fastener Schedule	Ultimate Resistance (S_u) kN/m	Yield Load (S_y) kN/m (Table 4.4)	Overstrength S_u/S_y
36A	CSP	AB 244	152/305	9.7	9.4	1.03
36B	CSP	AB 244	152/305	10.8	9.4	1.15
36C	CSP	AB 244	152/305	10.9	9.4	1.16
AVERAGE			**152/305**	**10.5**	**9.4**	**1.11**
AVERAGE AB 244			**152/305**	**10.5**	**9.4**	**1.11**
38A	CSP	AB 244	102/305	15.4	13.1	1.18
38B	CSP	AB 244	102/305	14.9	13.1	1.14
38C	CSP	AB 244	102/305	15.9	13.1	1.21
AVERAGE			**102/305**	**15.4**	**13.1**	**1.18**
AVERAGE AB 244			**102/305**	**15.4**	**13.1**	**1.18**
40A[1]	CSP	BC 462	75/305	22.1	15.8	1.40
40B	CSP	AB 244	75/305	19.5	15.8	1.23
40C	CSP	BC 055	75/305	14.7	15.8	0.93
40D	CSP	BC 462	75/305	19.9	15.8	1.26
AVERAGE[2]			**75/305**	**20.5**	**15.8**	**1.21**
AVERAGE AB 244			**75/305**	**19.5**	**15.8**	**1.23**
					AVERAGE	**1.17**
					STD. DEV	**0.13**
					CoV	**0.11**

[1]Test 40A capacity governed by 2.5% inelastic drift limit

[2]The data from Test 40C is not included in any design value averages

Table 4.11: Overstrength Inherent in Design with Respect to the Maximum and Average BC Sheathing Strengths for 75/305 Cyclic Test Values

Test	Fastener Schedule	Ultimate Resistance kN/m	Yield Load (S_y) kN/m (Table 4.4)	Overstrength
With respect to average BC sheathing		**$S_{u\ BC\ avg}$**		**$S_{u\ BC\ avg}/S_y$**
AVERAGE TESTS 40 A, B, D	75/305	21.0	15.8	1.33
AVERAGE AB 244 TEST 40 B	75/305	21.0	15.8	1.33
With respect to maximum BC sheathing		**$S_{u\ max}$**		**$S_{u\ max}/S_y$**
AVERAGE TESTS 40 A, B, D	75/305	22.1	15.8	1.40
AVERAGE AB 244 TEST 40 B	75/305	22.1	15.8	1.40

4.5 Seismic Force Modification Factors

As previously outlined in Equation 4-9, both the ductility-related and overstrength-related force modification factors are necessary to calculate the minimum lateral earthquake base shear according to the NBCC 2005. A summary of the approach used to determine values for these variables is given in this Section. A more comprehensive description of the calculation procedure is provided by Boudreault (*2005*) and Boudreault *et al*. (*2006*). The R_o and R_d values obtained from the shear wall tests described in this report will be compared with the values recommended by Boudreault (*2005*), Branston (*2004*) and Chen (*2004*), which were based on the test results of shear walls sheathed with 12.7 mm plywood and 11 mm OSB.

4.5.1 Ductility-Related Force Modification Factor (R_d)

The relationship between the ductility-related force modification factor (R_d) and the ductility ratio (μ) of a particular shear wall system as presented by Newmark and Hall (1982) is expressed as:

$$R_d = \mu \qquad \text{for } T > 0.5 \text{ sec} \qquad (4\text{-}13)$$

$$R_d = (2\mu - 1)^{1/2} \qquad \text{for } 0.1 < T < 0.5 \text{ sec} \qquad (4\text{-}14)$$

$$R_d = 1 \qquad \text{for } T < 0.03 \text{ sec} \qquad (4\text{-}15)$$

where,

T = Natural period of the structure

R_d = Ductility-related force modification factor

μ = Ductility ratio of shear wall (Tables 3.1, 3.2 and 3.3)

It was determined by Boudreault (*2005*) that the natural period for most light-framed buildings is greater than 0.03 seconds, but typically would not exceed the upper bound of 0.5 seconds, as expressed in Equation 4-13. Therefore, R_d was conservatively calculated following Equation 4-14. The ductility ratio (μ) is as defined in Section 3.2.

The average ductility-related force modification factor for the monotonic tests was found to be 2.96. The average ductility-related force modification factor for the AB244 specimens was found to be 2.93. The R_d values for the monotonically loaded wall specimens are presented for all wall configurations in Table 4.12.

The average ductility-related force modification factor for the reversed cyclic tests was found to be 2.81. The average ductility-related force modification factor for the AB244 specimens was found to be 3.02. The R_d values for the reversed cyclically loaded wall specimens are presented for all wall configurations in Table 4.13.

Boudreault (*2005*) concluded that an R_d value of 2.5 should be used for walls with a maximum aspect ratio of 2:1. This value is lower than the average values calculated from both the monotonic and cyclic tests of the 9.5 mm sheathing specimens, and can therefore be conservatively used for designing shear walls of the type tested for this project.

Table 4.12: Ductility and R_d for Monotonic Test Specimens

Test	Panel Type	Plywood Manufacturer	Fastener Schedule	Ductility (μ)	R_d[1]
35A	CSP	BC 055	152/305	5.43	3.14
35B	CSP	BC 055	152/305	5.14	3.05
35C	CSP	BC 055	152/305	5.33	3.11
35D	CSP	BC 462	152/305	5.23	3.08
35E	CSP	AB 244	152/305	6.86	3.57
35F	CSP	AB 244	152/305	6.28	3.40
AVERAGE			**152/305**	**5.71**	**3.22**
AVERAGE AB 244			**152/305**	**6.57**	**3.48**
37A	CSP	BC 055	102/305	4.39	2.79
37B	CSP	BC 055	102/305	4.46	2.81
37C	CSP	BC 055	102/305	5.31	3.10
37D	CSP	BC 462	102/305	4.90	2.97
37E	CSP	AB 244	102/305	4.85	2.95
37F	CSP	AB 244	102/305	5.08	3.03
AVERAGE			**102/305**	**4.83**	**2.94**
AVERAGE AB 244			**102/305**	**4.97**	**2.99**
39A	CSP	BC 055	75/305	4.23	2.73
39B	CSP	AB 244	75/305	3.51	2.45
39C	CSP	AB 244	75/305	2.83	2.16
AVERAGE			**75/305**	**3.52**	**2.45**
AVERAGE AB 244			**75/305**	**3.17**	**2.31**
				AVERAGE	**2.96**
				STD. DEV	**0.34**
				CoV	**0.12**

[1] $R_d = (2\mu - 1)^{1/2}$

Table 4.13: Ductility and R_d for Reversed Cyclic Test Specimens

Test	Panel Type	Plywood Manufacturer	Fastener Schedule	Ductility[4] (μ)	R_d[1]
36A	CSP	AB 244	152/305	5.31	3.10
36B	CSP	AB 244	152/305	5.05	3.02
36C	CSP	AB 244	152/305	5.85	3.27
AVERAGE			**152/305**	**5.40**	**3.13**
AVERAGE AB 244			**152/305**	**5.40**	**3.13**
38A	CSP	AB 244	102/305	5.57	3.18
38B	CSP	AB 244	102/305	4.93	2.97
38C	CSP	AB 244	102/305	4.88	2.96
AVERAGE			**102/305**	**5.12**	**3.04**
AVERAGE AB 244			**102/305**	**5.12**	**3.04**
40A[2]	CSP	BC 462	75/305	3.90	2.61
40B	CSP	AB 244	75/305	4.01	2.65
40C	CSP	BC 055	75/305	2.51	2.00
40D	CSP	BC 462	75/305	3.34	2.38
AVERAGE[3]			**75/305**	**3.44**	**2.41**
AVERAGE AB 244			**75/305**	**4.01**	**2.65**
				AVERAGE	**2.81**
				STD. DEV	**0.40**
				CoV	**0.14**

[1] $R_d = (2\mu - 1)^{1/2}$

[2] Test 40A capacity governed by 2.5% inelastic drift limit

[3] The data from Test 40C is not included in any design value averages

[4] The ductility value shown in this table is the average of the positive and negative cycle ductility values

4.5.2 Overstrength-Related Force Modification Factor (R_o)

In order to account for the overstrength of the lateral load resisting system, the overstrength-related force modification factor (R_o) is calculated as proposed by Mitchell *et al.* (*2003*):

$$R_o = R_{size} \, R_{\Phi} \, R_{yield} \, R_{sh} \, R_{mech} \qquad (4\text{-}16)$$

where,

R_o = Overstrength-related force modification factor
R_{size} = Factor due to member dimension rounding and size limitations
$R_{\Phi} = 1 / \Phi$ Factor due to factoring of member resistances
$R_{yield} = S_u / S_y$ Factor due to underestimation of potential yield strength
S_u = Ultimate strength of wall specimen
S_y = Yield strength of wall specimen
R_{sh} = Factor due to strain hardening
R_{mech} = Factor due to collapse mechanism

The value of R_{size} was determined to be 1.05 to account for designers selecting a sheathing-to-frame connection spacing smaller than that required to resist the design loads. It was recommended in Section 4.1 of this report that a resistance factor of 0.7 be used for determination of the factored shear capacity of light gauge steel frame / wood panel shear walls. Using this value, R_{Φ} is found to be 1 / 0.7 = 1.43. The values for R_{yield} were averaged from the S_u / S_y values listed in Tables 4.7 and 4.10 of this report. These S_u / S_y values ranged from 0.93 to 1.41. The shear walls are assumed to be unaffected by strain hardening, therefore, the R_{sh} value was set equal to unity. Considering that a design method which accounts for collapse mechanisms has not yet been established for these types of shear walls, R_{mech} was also set to unity.

The overstrength-related force modification factor for all of the tests was found to be 1.79. The overstrength-related force modification factor for the AB244 specimens was found to be 1.72. The R_o values and their respective overstrength factors are presented in Table 4.14.

Boudreault (*2005*) concluded that an R_o value of 1.8 should be used for walls with a maximum aspect ratio of 2:1. This value is greater than the proposed values calculated from both the monotonic and cyclic tests of the 9.5 mm sheathing specimens, and therefore less conservative. It is therefore recommended that an R_o value of 1.7 be used for walls with these configurations, as well as walls constructed with thicker sheathing and with OSB sheathing.

Table 4.14: Overstrength-related Force Modification Factors for Steel Frame / Wood Panel Shear Walls

	Calculation of R_o						Proposed R_o (NBCC)
	R_{size}	R_ϕ	R_{yield}	R_{sh}	R_{mech}	R_o	
All tests[1]	1.05	1.43	1.20	1.00	1.00	1.79	**1.7**
AB 244	1.05	1.43	1.14	1.00	1.00	1.72	**1.7**

[1]The data from Test 40C is not included in any design values

4.5.3 Effect of Over-driven Sheathing to Framing Screws

Upon completing the construction of wall specimen 40C, it was observed that the majority of the sheathing to framing screws were over-driven by approximately 20 to 30% (Figure 2.6). The effects of over-driving the sheathing to framing screws can be seen by comparing the wall resistance versus deflection curve of test specimen 40C with that of a typical specimen as shown in Figures 4.3 and 4.4, respectively.

When comparing the performance of test specimen 40C with that of the cyclically loaded walls having the same 75 mm / 305 mm fastener schedule (specimens 40A, B and D), the following observations were made: respective ultimate shear resistances of 14.7 and 20.5 (kN/m) (Table 14.10) show a 28.3 % decrease; respective; respective ductility values of 2.51 and 3.44 (Table 4.13) indicate a 27% decrease; and respective ductility-related force modification factors (R_d) of 2.0 and 2.41 (Table 4.13) show a 17 % decrease.

It is therefore advised to pay special attention not to overdrive the sheathing screws when constructing this type of shear wall. CSA O86-01 (*2001*) indicates that sheathing to framing connectors must not be over-driven more than 15 percent of the panel thickness. Given the measured response of wall 40C it is recommended that a similar limit be placed on the installation of screw sheathing fasteners for cold-formed steel frame / wood panel shear walls.

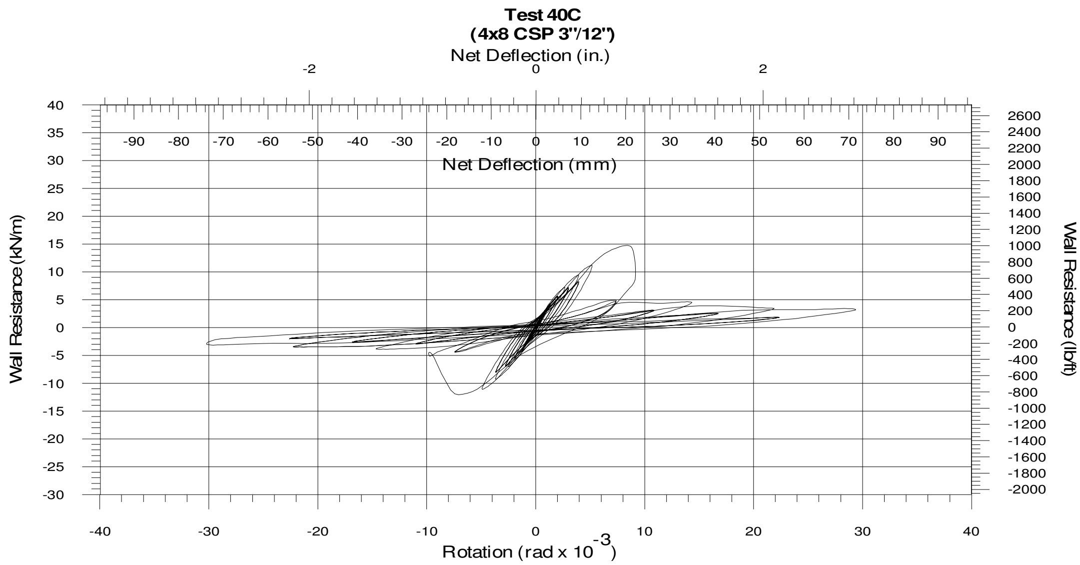

Figure 4.3: Wall Resistance versus Deflection Curve of Test Specimen 40C Under Reversed Cyclic Loading

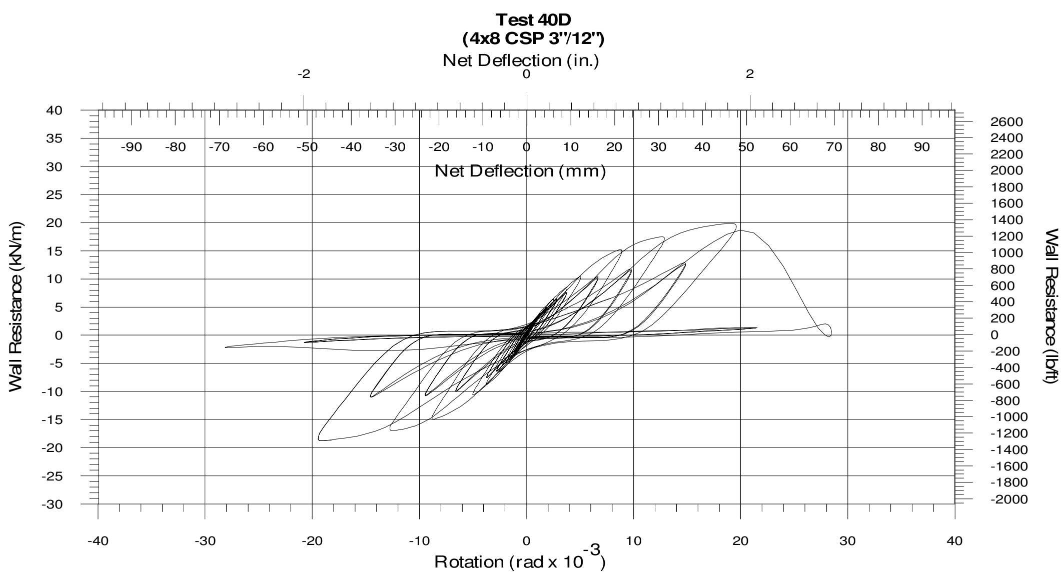

Figure 4.4: Wall Resistance versus Deflection Curve of Typical Shear Wall Under Reversed Cyclic Loading

CHAPTER 5 CONCLUSIONS AND RECOMMENDATIONS

Conclusions

The testing of light gauge steel frame / wood panel shear walls was performed in order to determine design capacity and stiffness parameters for walls with 9.5 mm (3/8") CSP sheathing and various screw spacing configurations, i.e. 75 mm (3"), 102 mm (4"), and 152 mm (6"). A total of 25 tests were carried out, 15 loaded monotonically and 10 reversed cyclic. The shear walls were constructed of 1.09 mm (0.043") nominal thickness cold-formed steel framing members sheathed with 9.5 mm (3/8") CSA 0151M Exterior Canadian Softwood Plywood (CSP). The intent of completing these tests was to add to the database of light gauge steel frame / wood panel shear wall design parameters, which prior to the completion of this report consisted of walls sheathed with thicker plywood and OSB.

The shear wall test results were analyzed following the equivalent energy elastic-plastic (EEEP) method as recommended by Branston (*2004*). The design values obtained from the data reduction were also limited by the inelastic drift requirement as per the 2005 National Building Code of Canada. Design parameters were calculated including; elastic stiffness, nominal yield resistance, system ductility, resistance factor, factor of safety, overstrength, and the ductility-related and overstrength-related force modification factors. Comparison of these results was made with the findings of previous studies on shear wall design by Boudreault (*2005*), Boudreault *et al.* (*2006*), Branston (*2004*), Branston *et al.* (*2006a and 2006b*), Chen (*2004*) and Chen *et al.* (*2006*).

The interpretation of the test data has lead to the following conclusions:

1) Yield strength and elastic stiffness design values can be assigned to each of the three wall configurations (Table 4.4). These recommended design values are valid only for light gauge steel frame / wood panel shear walls with 9.5 mm (3/8") CSP sheathing, with an aspect ratio of less than 2:1, and which are constructed as outlined in Chapter 2 of this report.

2) The results of the test specimens constructed with AB244, spruce based plywood, sheathing were isolated and used for the final recommended design parameters. Due to the nature of the species makeup of plywood from this mill walls with AB244 panels form the lower bound for shear wall strength and stiffness. The AB244 test results were also used to develop the factor of safety, overstrength factor for capacity based design, ductility-related force modification factor and overstrength-related force modification factor.

3) A resistance factor (ϕ) of 0.7 should be used for limit states design calculations for walls subjected to wind or seismic loading as determined from the 2005 NBCC. This resistance factor is in agreement with the value recommended for 12.5 mm CSP and DFP, as well as 9 mm and 11 mm OSB sheathed shear walls.

4) A factor of safety of 1.6 was found to exist for the limit states design (LSD) method. With respect to the 2005 NBCC wind loading a factor of safety of 2.24 was obtained following an allowable stress design (ASD) method. This ASD factor of safety is within the acceptable range associated with light framed shear wall design.

5) An overstrength factor of 1.3 should be used for capacity design calculations of all non-fuse elements that are part of the seismic force resisting system.

6) A ductility-related force modification factor (R_d) of 2.93 was found based on the ductility measurements of the tested shear walls. However, for the calculation of seismic design forces using the 2005 NBCC it is recommended that a more conservative value be used, $R_d = 2.5$, as per the findings of Boudreault (*2005*).

7) An overstrength-related force modification factor for seismic design (R_o) of 1.7 was calculated from the shear wall test results. It is recommended that this value of R_o be used for seismic design, following the 2005 NBCC, of all light gauge steel frame / wood panel shear walls, including those sheathed with thicker

plywood, as well as OSB. This R_o value of 1.7 supersedes the R_o = 1.8 presented by Boudreault (*2005*).

8) When constructing walls, it is important pay special attention to limiting the depth of the sheathing to framing screws so that the fastener is driven until its head becomes flush with the surface of the sheathing. Over-driving the sheathing screws affects the performance of the wall.

Recommendations for Further Study

The design values presented in this report are based solely on wall specimens tested under lateral loading. It is the author's opinion that further testing should be carried-out on wall specimens of identical construction under combined vertical (gravity) and lateral loading. The results of these proposed tests should then be compared to those presented in this report to further understand the effects of combined loading.

As a minor point, during the construction of future test wall specimens with thin sheathing, a grid should be drawn over the complete outer face of the sheathing in order to better observe and record the shear buckling of the of the wood panel.

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APPENDIX I - TEST DATA SHEETS

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 35A

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 19, 2004 **TIME:** 11:00

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical

Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other MFR: Canfor, BC 055

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing:
- [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive

Hold downs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head

Loading Beam: A325 3/4" bolts 3 bolts [ ] 6 bolts [X] 12 bolts [ ]

Back-to-Back Chord Studs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [ ] 4"/12" [X] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C. [ ] Other:

TRACK: Web: 3-5/8" inches Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter

Wood:

Temp.: C

8.1	8.3		
9.3	6.3		
Nth	10.0		Sth

AVG: 8.40

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	14.29	14.54		
Wd=	13.57	13.86		
m.c.=	5.31	4.91		

AVG m.c. 5.11

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:

-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1-1/4 turn
(load cells used on both hold-downs)
-Ambient temperature 23 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 1.4mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 35B

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 19, 2004 **TIME:** 16:00

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical, Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Canfor, BC 055

SCREWS
Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [ ] 4"/12" [X] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK:
Web: 3-5/8" inches
Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

8.8	9.4		
6.8	9.6		
Nth	9.8		Sth

AVG: 8.88

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	16.16	16.62		
Wd=	15.49	15.86		
m.c.=	4.33	4.79		

AVG m.c. 4.56

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 0.998 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 35C

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 20, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other MFR: Canfor, BC 055

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
Loading Beam: A325 3/4" bolts 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
Back-to-Back
Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [ ] 4"/12" [X] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C. [ ] Other:

TRACK:
Web: 3-5/8" inches [X] 0.044" (1.12mm) 33ksi (230 MPa)
Flange: 1-3/16" inches [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

8.5	9.7		
7.9	6.2		
Nth	6.8		Sth

AVG: 7.82

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	14.65	14.36		
Wd=	14.00	13.75		
m.c.=	4.64	4.44		

AVG m.c. 4.54

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 1.599 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 35D

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, C. Blais

DATE: Tested: June 9, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical, Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Weldwood, BC 462, 03/04/07

SCREWS
- Sheathing:
  - [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
  - [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
  - [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))
- Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
- Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
- Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
- Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [ ] 4"/12" [X] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK: Web: 3-5/8" inches; Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

Nth / Sth — AVG: #DIV/0!

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=				
Wd=				
m.c.=				

AVG m.c. 0.00

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 0.497 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 35E

RESEARCHER: David Rokas **ASSISTANTS:** A Frattini, C. Blais

DATE: Tested: June 29, 2004 **TIME:** 15:45

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Alberta Plywood, AB244

SCREWS
Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing:
- [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive

Hold downs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head

Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]

Back-to-Back
Chord Studs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [ ] 4"/12" [X] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK:
Web: 3-5/8" inches
Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod — (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod — (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

Nth / Sth
AVG: #DIV/0!

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=				
Wd=				
m.c.=				

AVG m.c. 0.00

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 18 C
-Double chord studs used
-Square plate washers (2.5"x2.5") + circular ones in both corners of top track
-Initial load set to zero at beginning of test, displacement -0.077 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 35F

RESEARCHER: David Rokas **ASSISTANTS:** A Frattini, Lim

DATE: Tested: June 30, 2004 **TIME:** 10:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other MFR: Alberta Plywood, AB244

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
Loading Beam: A325 3/4" bolts 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
Back-to-Back
Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [ ] 4"/12" [X] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C. [ ] Other:

TRACK:
Web: 3-5/8" inches [X] 0.044" (1.12mm) 33ksi (230 MPa)
Flange: 1-3/16" inches [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: 21 C

Nth			Sth

AVG: #DIV/0!

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=				
Wd=				
m.c.=	#DIV/0!	#DIV/0!		

AVG m.c. #DIV/0!

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 18 C
-Double chord studs used
-Square plate washers (2.5"x2.5") + circular ones in both corners of top track
-Initial load set to zero at beginning of test, displacement -0.710 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 36A

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 25, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical, Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Alberta Plywood, AB244

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing:
- [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive

Hold downs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head

Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]

Back-to-Back Chord Studs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [ ] 4"/12" [X] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK: Web: 3-5/8" inches; Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [ ] Monotonic
- [X] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter

Wood:

Temp.: C

7.9	9.3		
11.0	10.8		
Nth	11.0		Sth

AVG: 10.00

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	14.55	14.60		
Wd=	13.60	13.66		
m.c.=	6.99	6.88		

AVG m.c. 6.93

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement (-7.904) mm
the displacement is incorrect (less than one mm) wall not zeroed at onset

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 36B

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 26, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other MFR: Alberta Plywood, AB244

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing:
- [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive

Hold downs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head

Loading Beam: A325 3/4" bolts 3 bolts [ ] 6 bolts [X] 12 bolts [ ]

Back-to-Back Chord Studs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [ ] 4"/12" [X] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK: Web: 3-5/8" inches; Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [ ] Monotonic
- [X] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter

Wood:
Temp.: C

10.2	11.4		
8.3	9.3		
Nth	10.8		Sth

AVG: 10.00

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	15.73	15.17		
Wd=	14.94	14.09		
m.c.=	5.29	7.67		

AVG m.c. 6.48

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement (15.942) mm
the displacement is incorrect (less than one mm) wall not zeroed at onset

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 36C

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 26, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
[ ] Plywood 15/32" APA Rated Exposure 1 (USA)
[ ] OSB 7/16" APA Rated Exposure 1 (USA)
[ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") CAN/PLY Exterior CSP
[X] Plywood (CSA O151M) CSP 9mm (3/8") CAN/PLY Exterior CSP
[ ] OSB (CSA O325) 9mm (3/8")
[ ] Other MFR: Alberta Plywood, AB244

SCREWS Sheathing:
[X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
[ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
[ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
Loading Beam: A325 3/4" bolts 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
Back-to-Back
Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [ ] 4"/12" [X] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
[X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
[X] Double chord studs used
[ ] Other

STUD SPACING:
[ ] 12" O.C.
[ ] 16" O.C.
[X] 24" O.C. [ ] Other:

TRACK:
Web: 3-5/8" inches [X] 0.044" (1.12mm) 33ksi (230 MPa)
Flange: 1-3/16" inches [ ] Other:

HOLD DOWNS:
[X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
[ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
[ ] Other

TEST PROTOCOL AND DESCRIPTION:
[ ] Monotonic
[X] Cyclic

LVDT MEASUREMENTS:
[X] Actuator LVDT [X] North Uplift [X] East Frame Brace
[X] North Slip [X] South Uplift [X] West Frame Brace
[X] South Slip [X] Top of Wall Lateral [X] Sheathing at Corners of Panels
[X] Panel Shear **TOTAL:** [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

10.5	9.6		
9.0	9.5		
Nth	10.8		Sth

AVG: 9.88

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	14.90	15.22		
Wd=	14.05	14.21		
m.c.=	6.05	7.11		

AVG m.c. 6.58

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement -0.144 mm (correct)

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 37A

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 20, 2004 **TIME:** 15:00

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Canfor, BC 055

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing:
- [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive

Hold downs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head

Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]

Back-to-Back Chord Studs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [X] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK: Web: 3-5/8" inches; Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

8.3	9.4		
8.4	10.2		
Nth	8.4		Sth

AVG: 8.94

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	14.47	14.12		
Wd=				
m.c.=	#DIV/0!	#DIV/0!		

AVG m.c. #DIV/0!

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 4.516 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 37B

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 21, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Canfor, BC 055

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing:
- [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive

Hold downs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head

Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]

Back-to-Back Chord Studs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [X] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK: Web: 3-5/8" inches; Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

8.7	8.0		
7.5	9.1		
Nth	8.0		Sth

AVG: 8.26

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	14.98	14.94		
Wd=	14.30	14.16		
m.c.=	4.76	5.51		

AVG m.c. 5.13

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 1.118 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 37C

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 21, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Canfor, BC 055

SCREWS
Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing:
- [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive

Hold downs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head

Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]

Back-to-Back Chord Studs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [X] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK:
Web: 3-5/8" inches
Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

8.9	8.6		
9.3	9.8		
Nth	9.2		Sth

AVG: 9.16

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	17.25	17.15		
Wd=	16.37	16.25		
m.c.=	5.38	5.54		

AVG m.c. 5.46

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 0.46 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 37D

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini, C Blais

DATE: Tested: June 10, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other MFR: Weldwood, BC 462, 03/04/07

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
Loading Beam: A325 3/4" bolts 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [X] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C. [ ] Other:

TRACK: Web: 3-5/8" inches Flange: 1-3/16" inches [X] 0.044" (1.12mm) 33ksi (230 MPa) [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

10.0	10.7		
10.0	9.8		
Nth	7.4		Sth

AVG: 9.58

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=				
Wd=				
m.c.=	#DIV/0!	#DIV/0!		

AVG m.c. #DIV/0!

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
North central hole in top track was drilled while wall was in testing frame
Plywood had curvature 34.11 mm when affixed to steel frame
-Initial load set to zero at beginning of test, displacement -0.366 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 37E

RESEARCHER: David Rokas **ASSISTANTS:** A. Frattini, Lim

DATE: Tested: June 30, 2004 **TIME:** 14:00

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Alberta Plywood, AB244

SCREWS
Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing:
- [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive

Hold downs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head

Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]

Back-to-Back Chord Studs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [X] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK:
Web: 3-5/8" inches
Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: 26C

10.0	10.7		
10.0	9.8		
Nth	7.4		Sth

AVG: 9.58

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=				
Wd=				
m.c.=	#DIV/0!	#DIV/0!		

AVG m.c. #DIV/0!

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") + circular ones in both corners of top track
-Initial load set to zero at beginning of test, displacement 2.263 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 37F

RESEARCHER: David Rokas **ASSISTANTS:** A. Frattini, Lim

DATE: Tested: June 30, 2004 **TIME:** 16:00

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical

Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other MFR: Alberta Plywood, AB244

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing:
- [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive

Hold downs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head

Loading Beam: A325 3/4" bolts 3 bolts [ ] 6 bolts [X] 12 bolts [ ]

Back-to-Back Chord Studs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [X] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK:
Web: 3-5/8" inches
Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: 26C

10.0	10.7		
10.0	9.8		
Nth	7.4		Sth

AVG: 9.58

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=				
Wd=				
m.c.=	#DIV/0!	#DIV/0!		

AVG m.c. #DIV/0!

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") + circular ones in both corners of top track
-Initial load set to zero at beginning of test, displacement 0.039 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 38A

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 26, 2004 **TIME:** 16:00

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other MFR: Alberta Plywood, AB244

SCREWS
- Sheathing:
  - [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
  - [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
  - [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))
- Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
- Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
- Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
- Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [X] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK:
- Web: 3-5/8" inches
- Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [ ] Monotonic
- [X] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels
- **TOTAL:** [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: 15C

9.5	9.6		
8.7	11.4		
Nth	9.4		Sth

AVG: 9.72

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	14.84	14.50		
Wd=				
m.c.=	#DIV/0!	#DIV/0!		

AVG m.c. #DIV/0!

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 1.578 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 38B

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 27, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical, Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Alberta Plywood, AB244

SCREWS
- Sheathing:
  - [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
  - [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
  - [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))
- Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
- Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
- Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
- Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [X] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK:
- Web: 3-5/8" inches
- Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [ ] Monotonic
- [X] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter

Wood:

Temp.: C

10.4	8.3		
11.8	10.1		
Nth	9.1		Sth

AVG: 9.94

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	14.88	14.59		
Wd=				
m.c.=	#DIV/0!	#DIV/0!		

AVG m.c. #DIV/0!

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
- -Shear anchors torqued for 10 s with impact wrench
- -North hold down anchor 1/2 turn from finger tight, south 1/2 turn (load cells used on both hold-downs)
- -Ambient temperature 20 C
- -Double chord studs used
- -Square plate washers (2.5"x2.5") used in all track connections
- -Initial load set to zero at beginning of test, displacement 2.056 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 38C

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 27, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other MFR: Alberta Plywood, AB244

SCREWS
Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
Loading Beam: A325 3/4" bolts 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
Back-to-Back
Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [ ] 3"/12" [X] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C. [ ] Other:

TRACK:
Web: 3-5/8" inches [X] 0.044" (1.12mm) 33ksi (230 MPa)
Flange: 1-3/16" inches [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [ ] Monotonic
- [X] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

10.0	9.6		
10.2	9.2		
Nth	8.9		Sth

AVG: 9.58

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	14.35	14.92		
Wd=				
m.c.=	#DIV/0!	#DIV/0!		

AVG m.c. #DIV/0!

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 0.841 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 39A

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 24, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical, Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Canfor, BC 055

SCREWS
- Sheathing:
  - [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
  - [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
  - [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))
- Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
- Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
- Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
- Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [X] 3"/12" [ ] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK:
- Web: 3-5/8" inches
- Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter

Wood:

Temp.: 20 C

7.7	7.5		
7.1	8.8		
Nth	8.0		Sth

AVG: 7.82

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	15.28	14.88		
Wd=	14.52	14.16		
m.c.=	5.23	5.08		

AVG m.c. 5.16

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
- -Shear anchors torqued for 10 s with impact wrench
- -North hold down anchor 1/2 turn from finger tight, south 1/2 turn (load cells used on both hold-downs)
- -Ambient temperature 20 C
- -Double chord studs used
- -Square plate washers (2.5"x2.5") used in all track connections
- -Initial load set to zero at beginning of test, displacement 0.159 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 39B

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 24, 2004 **TIME:** 15:00

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical, Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Alberta Plywood, AB244

SCREWS
- Sheathing:
  - [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
  - [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
  - [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))
- Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
- Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
- Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
- Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [X] 3"/12" [ ] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK:
- Web: 3-5/8" inches
- Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter

Wood:

Temp.: C

9.9	9.1		
9.9	10.5		
Nth	8.7		Sth

AVG: 9.62

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	13.65	13.89		
Wd=	12.84	13.07		
m.c.=	6.31	6.27		

AVG m.c. 6.29

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
- -Shear anchors torqued for 10 s with impact wrench
- -North hold down anchor 1/2 turn from finger tight, south 1/2 turn (load cells used on both hold-downs)
- -Ambient temperature 20 C
- -Double chord studs used
- -Square plate washers (2.5"x2.5") used in all track connections
- -Initial load set to zero at beginning of test, displacement -1.854 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 39C

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 25, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical, Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Alberta Plywood, AB244

SCREWS
- Sheathing:
  - [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
  - [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
  - [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))
- Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
- Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
- Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
- Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [X] 3"/12" [ ] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK:
- Web: 3-5/8" inches
- Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [X] Monotonic
- [ ] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels
- **TOTAL:** [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter

Wood:
Temp.: C

9.4	10.0		
10.8	9.8		
Nth	8.1		Sth

AVG: 9.62

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	12.86	14.15		
Wd=	12.21	13.25		
m.c.=	5.32	6.79		

AVG m.c. 6.06

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
- -Shear anchors torqued for 10 s with impact wrench
- -North hold down anchor 1/2 turn from finger tight, south 1/2 turn (load cells used on both hold-downs)
- -Ambient temperature 20 C
- -Double chord studs used
- -Square plate washers (2.5"x2.5") used in all track connections
- -Initial load set to zero at beginning of test, displacement 2.288 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 40A

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 27, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Weldwood, BC 462, 03/04/10

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing:
- [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive

Hold downs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head

Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]

Back-to-Back Chord Studs:
- [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [X] 3"/12" [ ] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK: Web: 3-5/8" inches; Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [ ] Monotonic
- [X] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

10.1	9.6		
9.8	9.7		
Nth	9.2		Sth

AVG: 9.68

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	15.79	16.33		
Wd=	14.68	15.16		
m.c.=	7.56	7.72		

AVG m.c. 7.64

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement -.804 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 40B

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 28, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical
Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other MFR: Alberta Plywood, AB244

SCREWS Sheathing:
- [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
- [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
- [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))

Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
Loading Beam: A325 3/4" bolts 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [X] 3"/12" [ ] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C. [ ] Other:

TRACK: Web: 3-5/8" inches; Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [ ] Monotonic
- [X] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: C

11.4	8.9		
12.2	11.0		
Nth	11.0		Sth

AVG: 10.90

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	15.12	15.64		
Wd=	14.02	14.46		
m.c.=	7.85	8.16		

AVG m.c. 8.00

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 1.481 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 40C

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, A. Frattini

DATE: Tested: May 28, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical, Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Canfor, BC 055

SCREWS
- Sheathing:
  - [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
  - [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
  - [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))
- Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
- Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
- Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
- Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [X] 3"/12" [ ] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C.
- [ ] Other:

TRACK: Web: 3-5/8" inches; Flange: 1-3/16" inches
- [X] 0.044" (1.12mm) 33ksi (230 MPa)
- [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [ ] Monotonic
- [X] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT
- [X] North Slip
- [X] South Slip
- [X] Panel Shear
- [X] North Uplift
- [X] South Uplift
- [X] Top of Wall Lateral
- [X] East Frame Brace
- [X] West Frame Brace
- [X] Sheathing at Corners of Panels

TOTAL: [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: 16 C

10.0	9.4		
9.0	9.4		
Nth	9.3		Sth

AVG: 9.42

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	15.11	14.77		
Wd=	14.22	13.86		
m.c.=	6.26	6.57		

AVG m.c. 6.41

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 1/2 turn from finger tight, south 1/2 turn
 (load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 0.804 mm

Cold Formed Steel Framed Shear Walls
McGill University, Montreal

TEST: 40D

RESEARCHER: David Rokas **ASSISTANTS:** K. Hikita, C. Blais

DATE: Tested: June 8, 2004 **TIME:** 11:30

DIMENSIONS OF WALL: 4 FT X 8 FT **PANEL ORIENTATION:** Vertical; Sheathing one side

SHEATHING:
- [ ] Plywood 15/32" APA Rated Exposure 1 (USA)
- [ ] OSB 7/16" APA Rated Exposure 1 (USA)
- [ ] Plywood (CSA 0151M) CSP 12.5mm (1/2") — CAN/PLY Exterior CSP
- [X] Plywood (CSA O151M) CSP 9mm (3/8") — CAN/PLY Exterior CSP
- [ ] OSB (CSA O325) 9mm (3/8")
- [ ] Other — MFR: Weldwood, BC 462, 03/04/07

SCREWS
- Sheathing:
  - [X] No.8 gauge 1.5" self-piercing Bugle head LOX drive (Grabber Superdrive)
  - [ ] No.8 gauge 1.0" self-piercing Bugle head (Flat socket head screw) (HD)
  - [ ] No.9 gauge 1.0" self-piercing Bugle head (HD = near hold-down (1 screw in track))
- Framing: [X] No.8 gauge 0.5" self-drilling wafer head (mod. Truss) Phillips drive
- Hold downs: [X] No.10 gauge 0.75" self-drilling Hex washer head
- Loading Beam: A325 3/4" bolts — 3 bolts [ ] 6 bolts [X] 12 bolts [ ]
- Back-to-Back Chord Studs: [X] No.10 gauge 0.75" self-drilling Hex washer head (2@12" O.C.)

SHEATHING FASTENER SCHEDULE: [ ] 2"/12" [X] 3"/12" [ ] 4"/12" [ ] 6"/12" [ ] Other:

EDGE PANEL DISTANCE: [ ] 3/8" [X] 1/2" [ ] Other:

STUDS:
- [X] 3-5/8"Wx1-5/8"Fx1/2"Lip 0.044" (1.12mm) 33ksi (230 MPa)
- [X] Double chord studs used
- [ ] Other

STUD SPACING:
- [ ] 12" O.C.
- [ ] 16" O.C.
- [X] 24" O.C. [ ] Other:

TRACK: Web: 3-5/8" inches; Flange: 1-3/16" inches — [X] 0.044" (1.12mm) 33ksi (230 MPa) [ ] Other:

HOLD DOWNS:
- [X] Simpson Strong-Tie S/HD10 7/8" Anchor Rod (# of screws): 33
- [ ] UCI 18" hold down 1/2" Anchor Rod (# of screws):
- [ ] Other

TEST PROTOCOL AND DESCRIPTION:
- [ ] Monotonic
- [X] Cyclic

LVDT MEASUREMENTS:
- [X] Actuator LVDT [X] North Uplift [X] East Frame Brace
- [X] North Slip [X] South Uplift [X] West Frame Brace
- [X] South Slip [X] Top of Wall Lateral [X] Sheathing at Corners of Panels
- [X] Panel Shear **TOTAL:** [ ]

MOISTURE CONTENT OF SHEATHING: Moisture Meter
Wood:
Temp.: 16 C

8.0	8.3		
8.9	9.7		
Nth	11.2		Sth
AVG:	9.22		

OVEN DRIED ACCORDING TO APA TEST METHOD P-6

	North	North	South	South
Ww=	15.25	14.84		
Wd=				
m.c.=	#DIV/0!	#DIV/0!		
AVG m.c.				#DIV/0!

DATA ACQ. RECORD RATE: 2 scan/sec **MONITOR RATE:** 50 scan/sec

COMMENTS:
-Shear anchors torqued for 10 s with impact wrench
-North hold down anchor 3/4 turn from finger tight, south 3/4 turn
(load cells used on both hold-downs)
-Ambient temperature 20 C
-Double chord studs used
-Square plate washers (2.5"x2.5") used in all track connections
-Initial load set to zero at beginning of test, displacement 0.607 mm

APPENDIX II - TEST OBSERVATION SHEETS

(note: tests 35D, 37D and 40D not included)

McGill

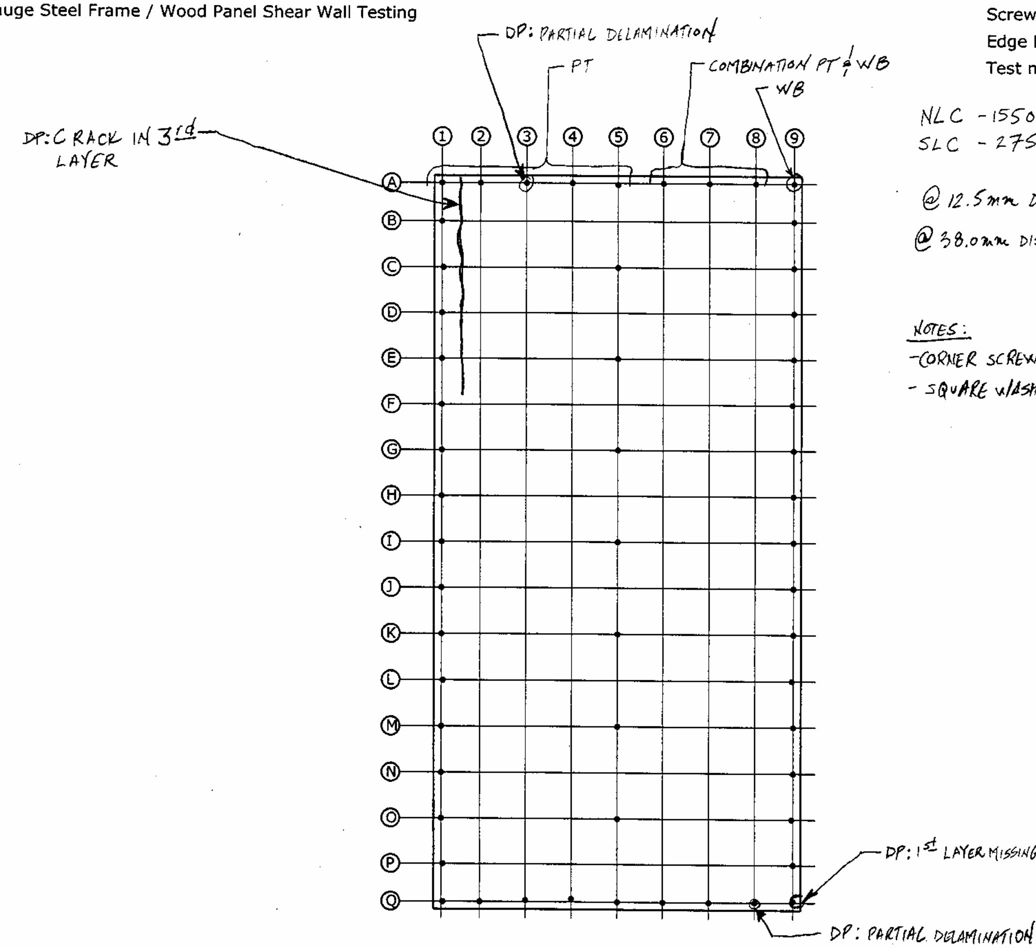
Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 35A
Date tested : MAY 19, 2004
Wall Size : 4' x 8'
Screw pattern : 6" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

NLC - 1550N
SLC - 275N

@ 12.5mm DISPLACEMENT : AXIAL FORCE = 6811 N
@ 38.0mm DISPLACEMENT : AXIAL FORCE = 11291 N
MAX = 13387N

NOTES:
- CORNER SCREWS PULLED THROUGH SHEATHING FIRST
- SQUARE WASHERS NOT PLACE ON SHEAR ANCHORS



Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

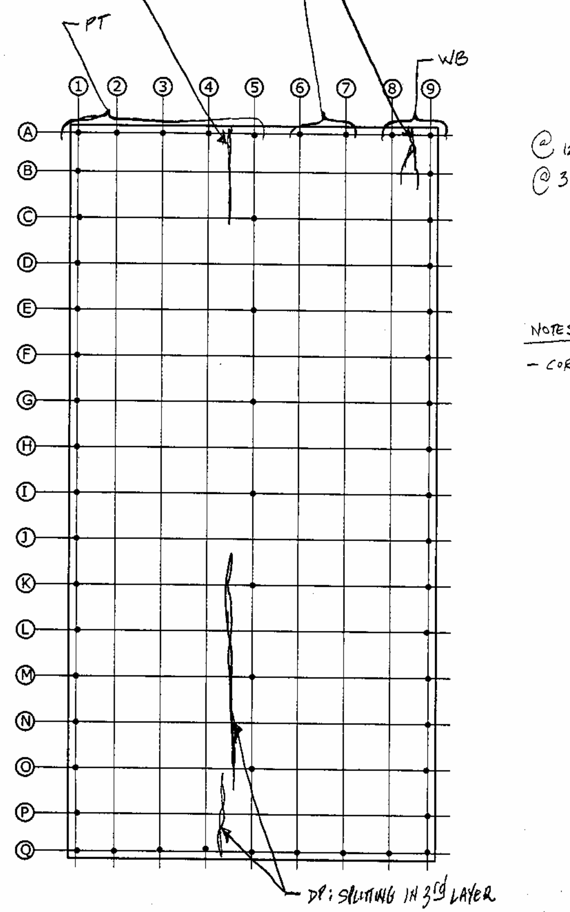
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 35B
Date tested : MAY 19, 2004
Wall Size : 4' x 8'
Screw pattern : 6" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

NLC - 1550 N
SLC - 275 N

@ 12.5mm displacement ; axial load = 7773 N
@ 38.0mm displacement : axial load = 13447 N
max axial load = 15288 N



NOTES:
- corner screws pulled through first

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 35C
Date tested : MAY 20, 2004
Wall Size : 4' x 8'
Screw pattern : 6" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

NLC -1550 N
SLC -275 N

@ 12.5mm DISPLACEMENT : AXIAL LOAD = 8316 N
@ 38.0mm DISPLACEMENT : AXIAL LOAD = 13172 N
MAX. AXIAL LOAD = 14213 N

SCREW SHEARED

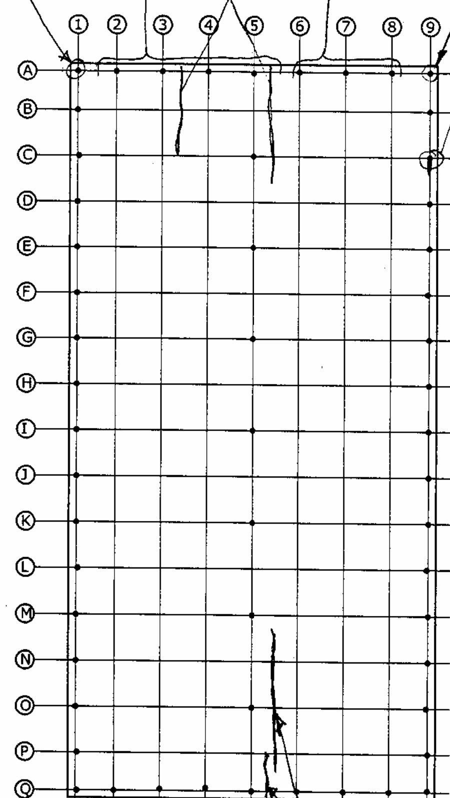
PT

DP: SPLITTING IN 3rd LAYER

COMBINATION PT & WB

DP: DEFECT (LOCAL) 2nd LAYER MISSING

WB



DP: SPLITTING IN 3rd LAYER

NOTES:
- NOISE HEARD AT ~ 57mm
- CORNER SCREWS PULLED THROUGH FIRST

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

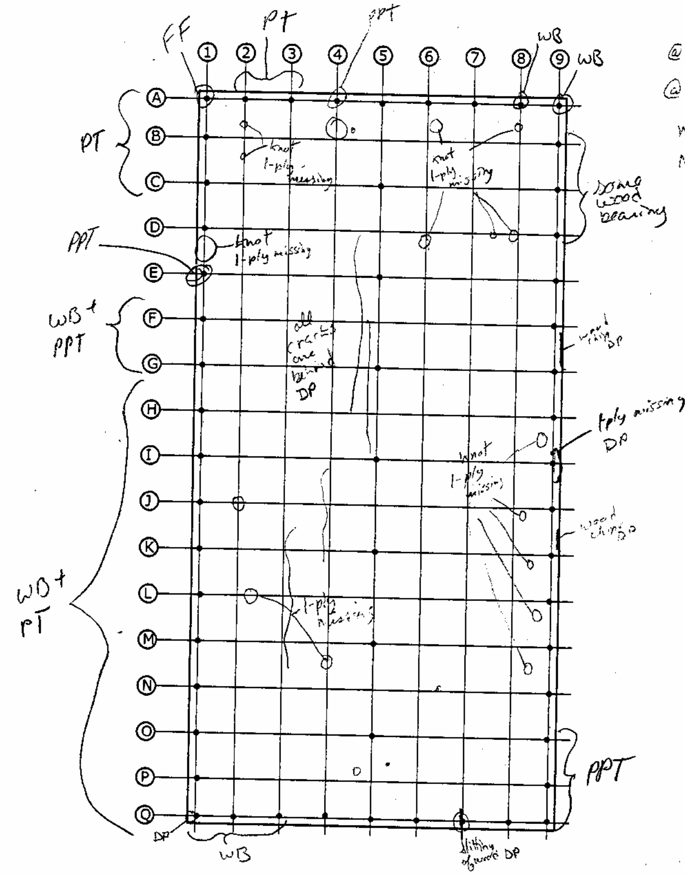
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

[4 2004]

Test name : 35E
Date tested : June 29 2004
Wall Size : 4' x 8'
Screw pattern : 6" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

@12.5 ⇒ load : 7804.2 N
@38.0 ⇒ load : 11951 N
MAX LOAD : 12645 N
MAX DISP. : ≈ 78 mm



Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

McGill

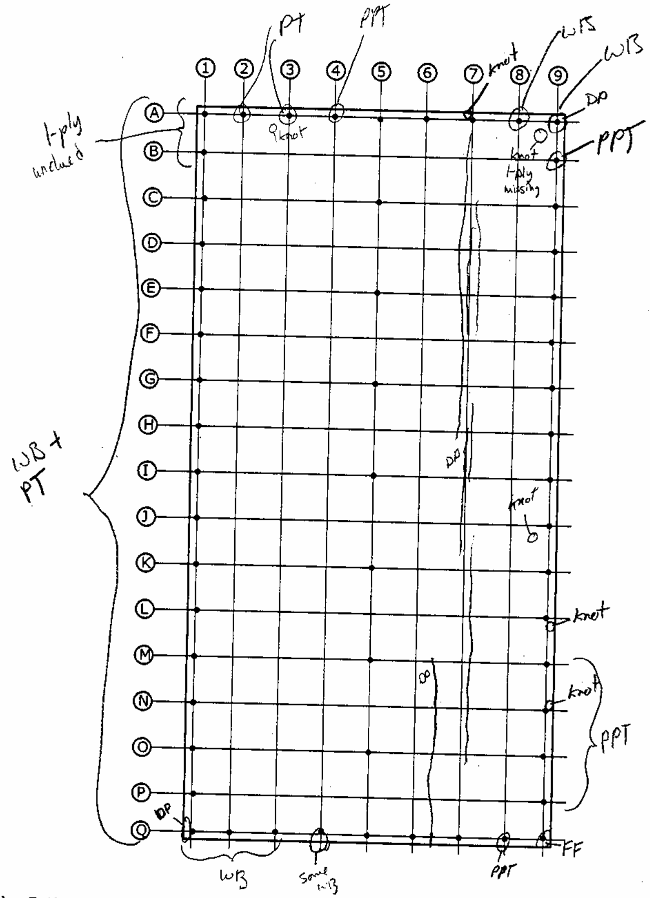
Light Gauge Steel Frame / Wood Panel Shear Wall Testing

[3 2004]

Test name : 35 F
Date tested : June 30 2004
Wall Size : 4' x 8'
Screw pattern : 6" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

@ 0.5mm : 8959,3 N
@ 32.0mm : 13 334 N

MAX LOAD => 14535 N
MAX DISP => ≈ 80mm

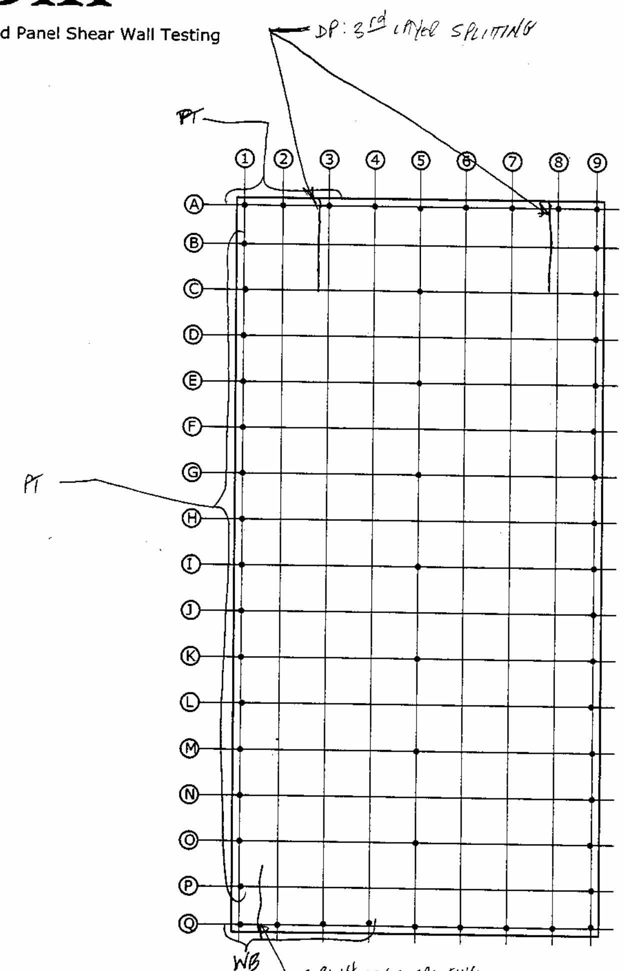


Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 36A
Date tested : MAY 25, 2004
Wall Size : 4' x 8'
Screw pattern : 6" / 12"
Edge Distance : 1/2"
Test mode : ☒ Cyclic ☐ Monotonic
NLC - 1550 N
SLC - 275 N



NOTES:
- NO PANEL LVDTs USED
- PLYWOOD PRODUCED IN ALBERTA

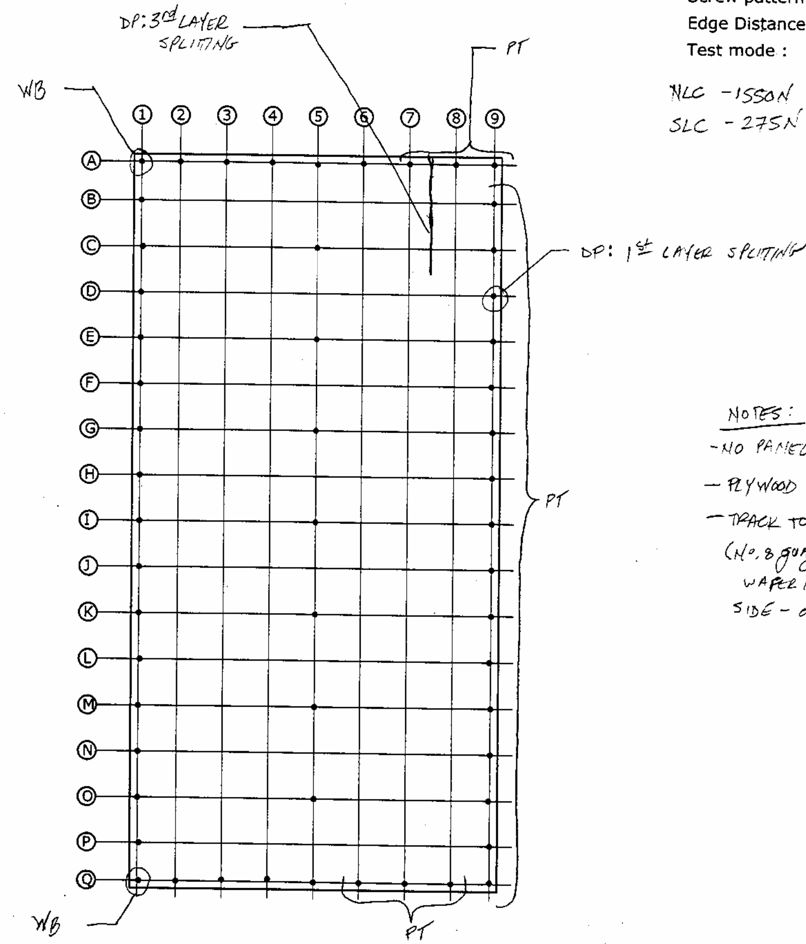
Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 36 B
Date tested : MAY 26, 2004
Wall Size : 4' x 8'
Screw pattern : 6" / 12"
Edge Distance : 1/2"
Test mode : ☒ Cyclic ☐ Monotonic

NLC - 1550N
SLC - 275N



NOTES:
- NO PANEL LVDTs USED.
- PLYWOOD PRODUCED IN ALBERTA.
- TRACK TO STUD SCREWS MISSING (No. 8 GUAGE 0.5" SELF DRILLING WAFER HEAD SCREWS) ON ONE SIDE - ON SHEATHING SIDE

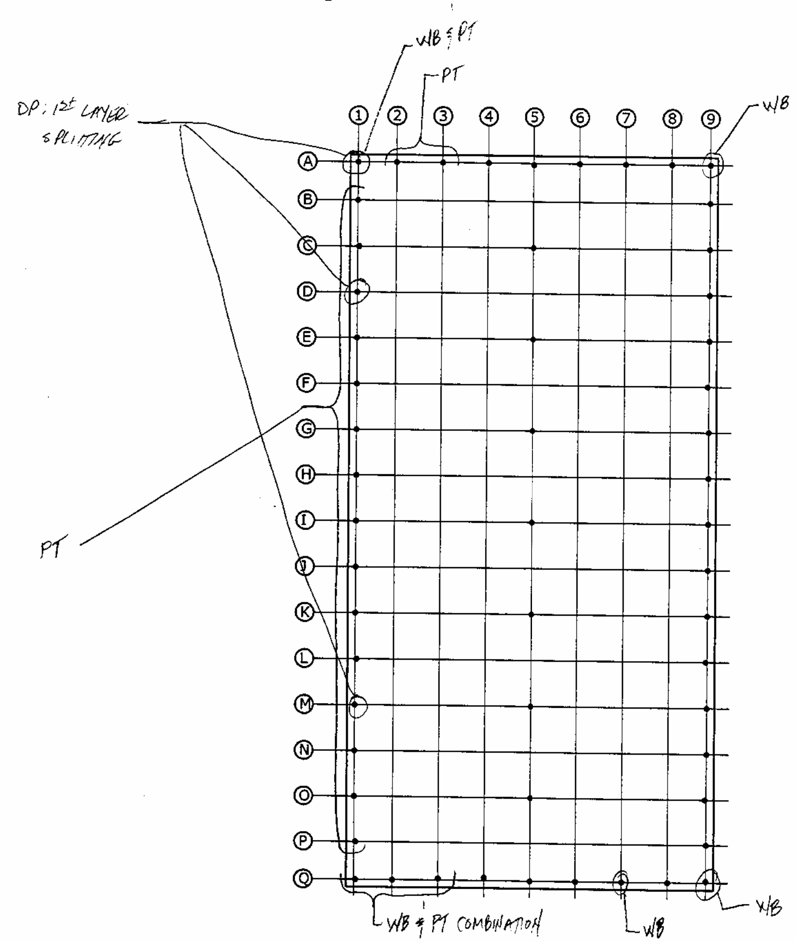
Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 36C
Date tested : MAY 26, 2006
Wall Size : 4' x 8'
Screw pattern : 6" / 12"
Edge Distance : 1/2"
Test mode : ☒ Cyclic ☐ Monotonic

HLC - 1550N
SLC - 275N



NOTES
- NO PANEL LVDTs
- PLYWOOD PRODUCED IN ALBERTA

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

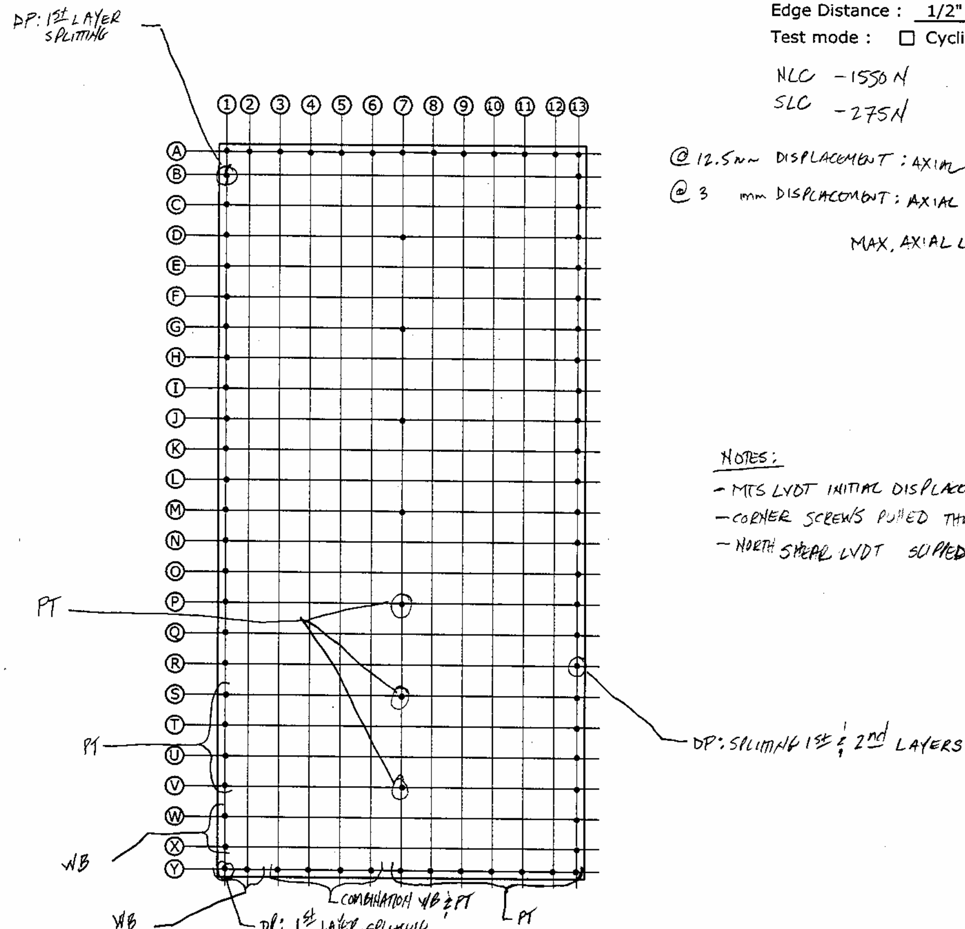
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 37 A
Date tested : MAY 26, 2004
Wall Size : 4' x 8'
Screw pattern : 4" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

NLC -1550 N
SLC -275 N

@ 12.5mm DISPLACEMENT : AXIAL LOAD = 10349 N
@ 3 mm DISPLACEMENT : AXIAL LOAD = 17515 N
MAX. AXIAL LOAD = 20067 N



NOTES:
- MTS LVDT INITIAL DISPLACEMENT = 0.051 mm
- CORNER SCREWS PULLED THROUGH FIRST
- NORTH SHEAR LVDT SLIPPED

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB) ; No Damage (ND)

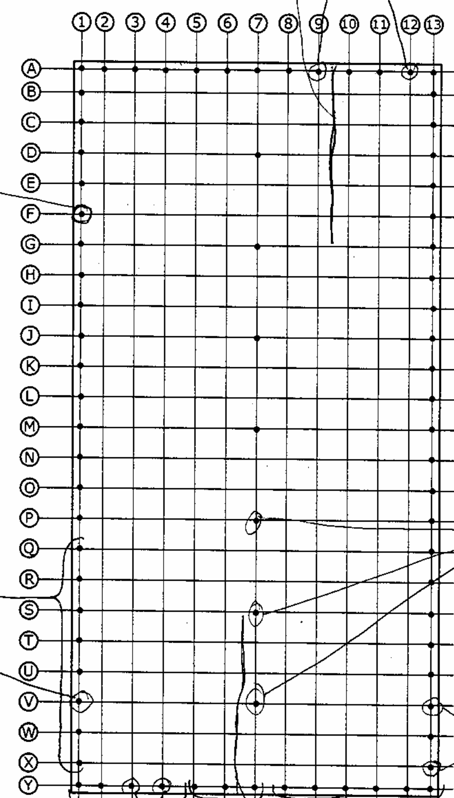
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 37-B
Date tested : MAY 21, 2004
Wall Size : 4' x 8'
Screw pattern : 4" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

NLC - 1550 N
SLC - 275 N

@12.5mm DISPLACEMENT : AXIAL LOAD = 10679 N
@38.0mm DISPLACEMENT : AXIAL LOAD = 18735 N
MAX. AXIAL LOAD =



NOTES:
- EXTENSIVE PANEL BUCKLING (ELASTIC) OBSERVED APPROX. 1 MIN. BEFORE FAILURE.
- CORNER SCREWS PULLED THROUGH FIRST

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB) ; No Damage (ND)

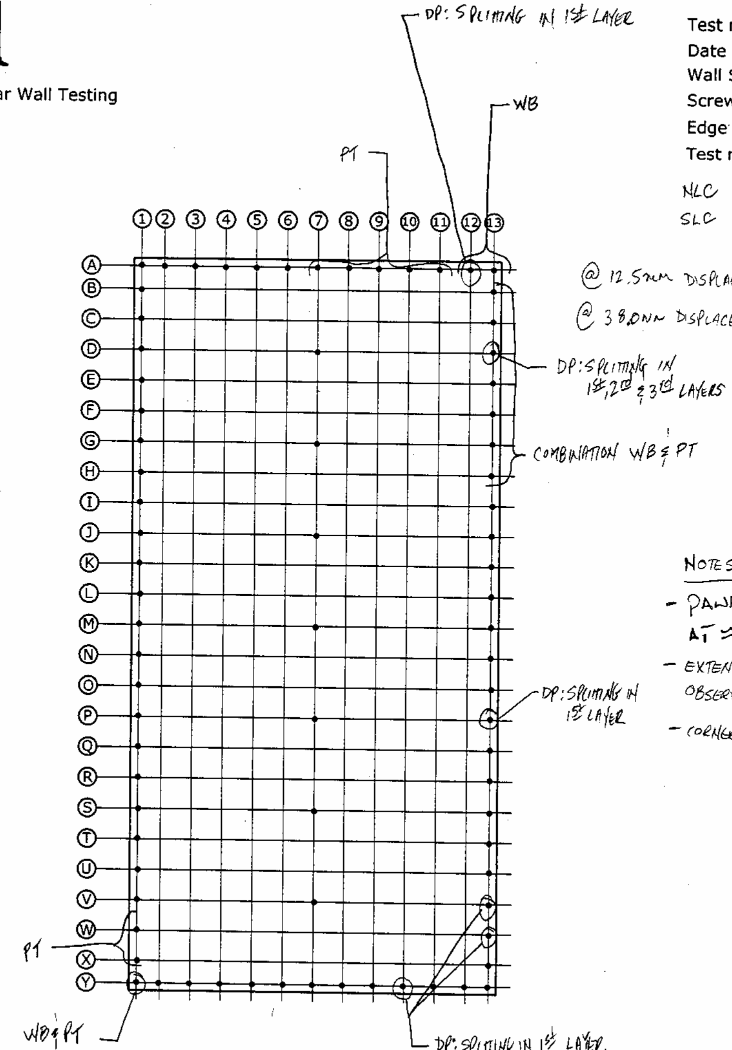
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 37C
Date tested : MAY 21, 2004
Wall Size : 4' x 8'
Screw pattern : 4" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

NLC -1550 N
SLC -275N

@ 12.5mm DISPLACEMENT : AXIAL LOAD = 10940 N
@ 38.0mm DISPLACEMENT : AXIAL LOAD = 17817
MAX AXIAL LOAD = 19926 N



NOTES:
- PANEL LUDTS REMOVED AT ≈ 18.5 KN
- EXTENSIVE PANEL BUCKLING (ELASTIC) OBSERVED BEFORE FAILURE.
- CORNER SCREWS PULLED THROUGH FIRST.

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB) ; No Damage (ND)

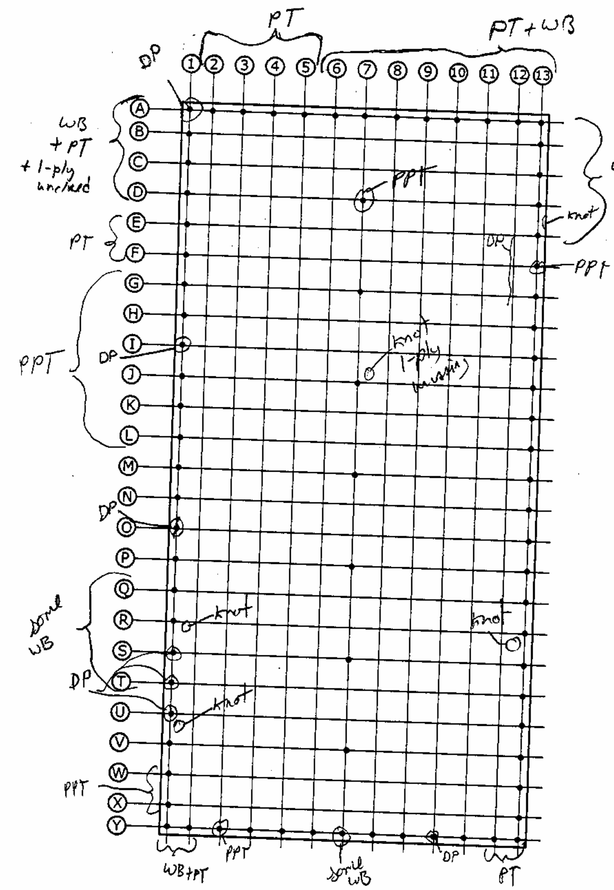
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

[3 2004]

Test name : 37E
Date tested : Jun 30, 2004
Wall Size : 4' x 8'
Screw pattern : 4" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

@ 125mm ⇒ 9202,9N
@ 380mm ⇒ 15281 N
MAX LOAD : 18016 N
MAX DISP. : 79.912 mm



Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB) ; No Damage (ND)

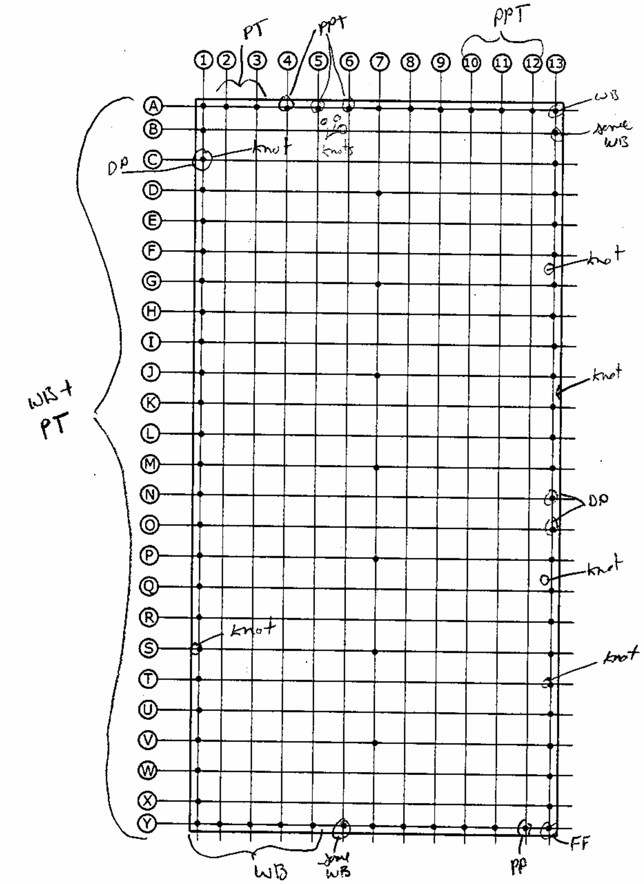
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

[01 2004]

Test name : 37F
Date tested : June 30, 2004
Wall Size : 4' x 8'
Screw pattern : 4" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

@ 12.5mm → 9870,4N
@ 38,0mm → 15757 N
MAX LOAD → 17543 N
MAX DISP → ≈ 82 mm



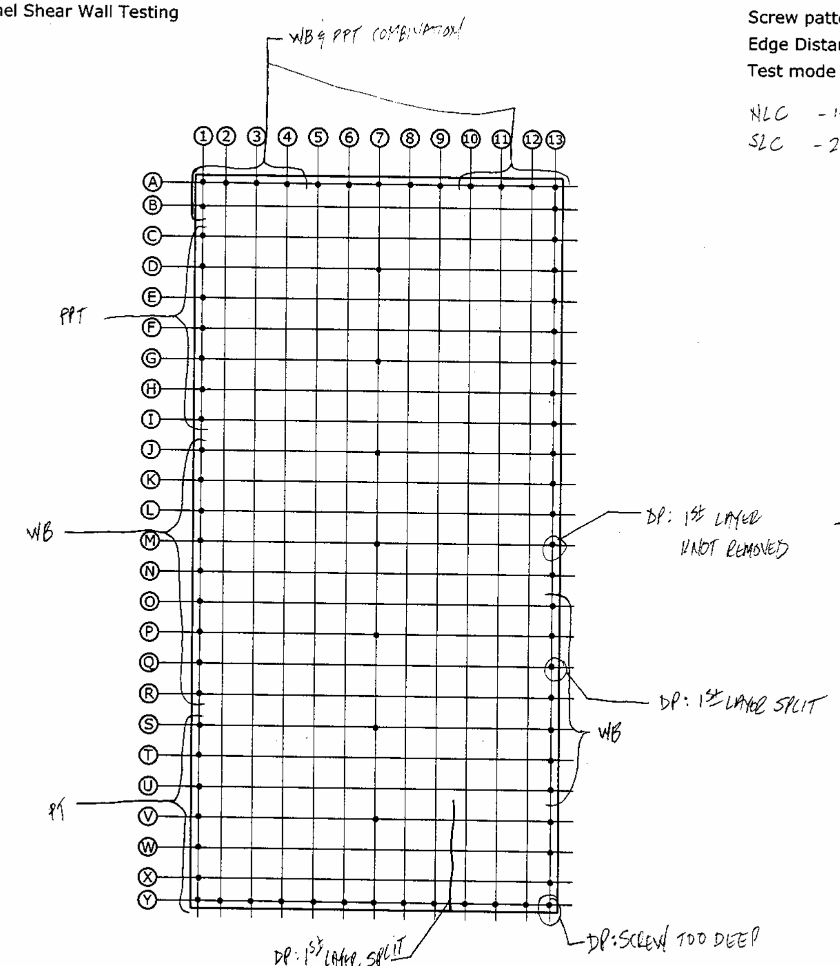
Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB) ; No Damage (ND)

McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 38A
Date tested : MAY 26, 2004
Wall Size : 4' x 8'
Screw pattern : 4" / 12"
Edge Distance : 1/2"
Test mode : ☒ Cyclic ☐ Monotonic

NLC - 1550N
SLC - 275N



NOTES :
- NO PANEL LVDTs USED.
- PLYWOOD PRODUCED IN ALBERTA.

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB) ; No Damage (ND)

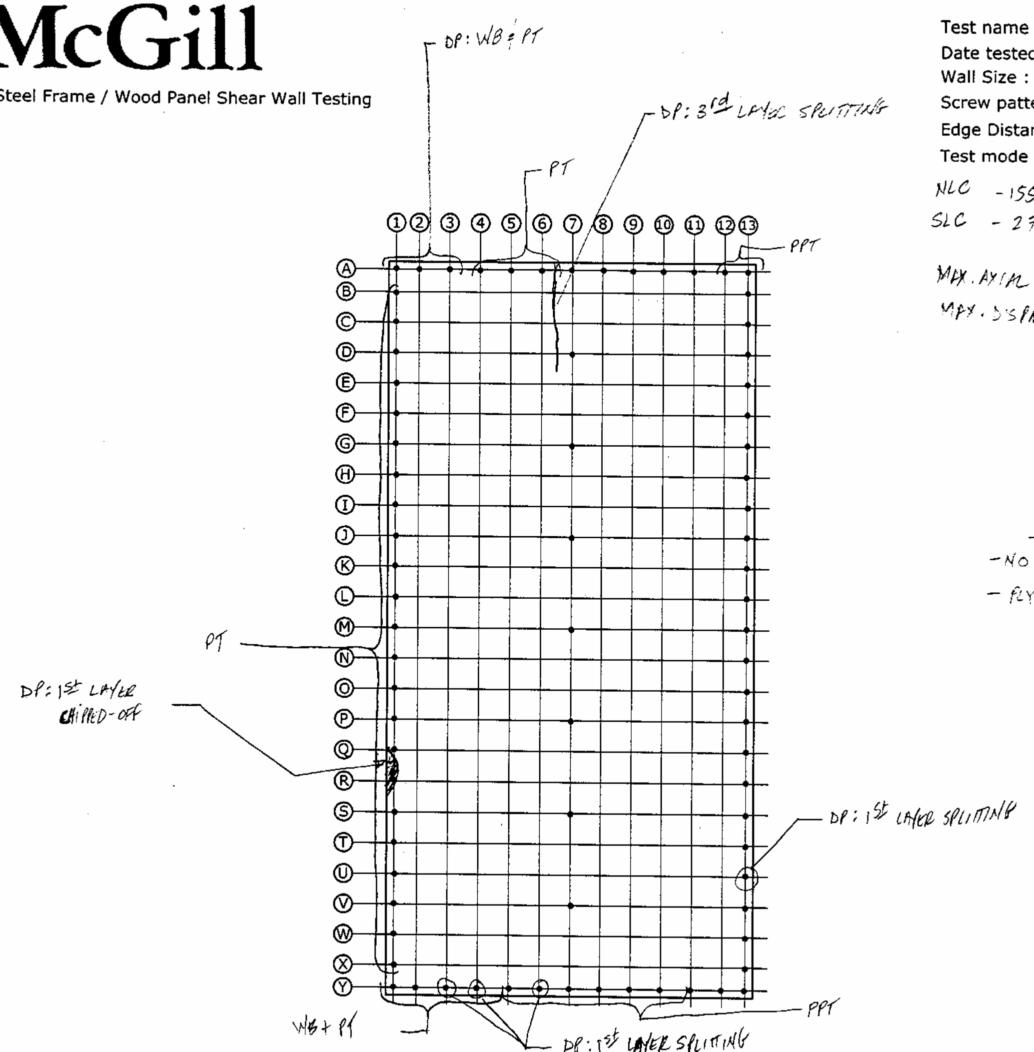
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 38B
Date tested : MAY 27, 2004
Wall Size : 4' x 8'
Screw pattern : 4" / 12"
Edge Distance : 1/2"
Test mode : ☒ Cyclic ☐ Monotonic

NLC - 1550N
SLC - 275N

MAX. AXIAL LOAD = 13369 N
MAX. DISPLACEMENT = 81.926mm.



NOTES :

- NO PANEL LOTS USED.
- PLYWOOD PRODUCED IN ALBERTA

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB) ; No Damage (ND)

McGill

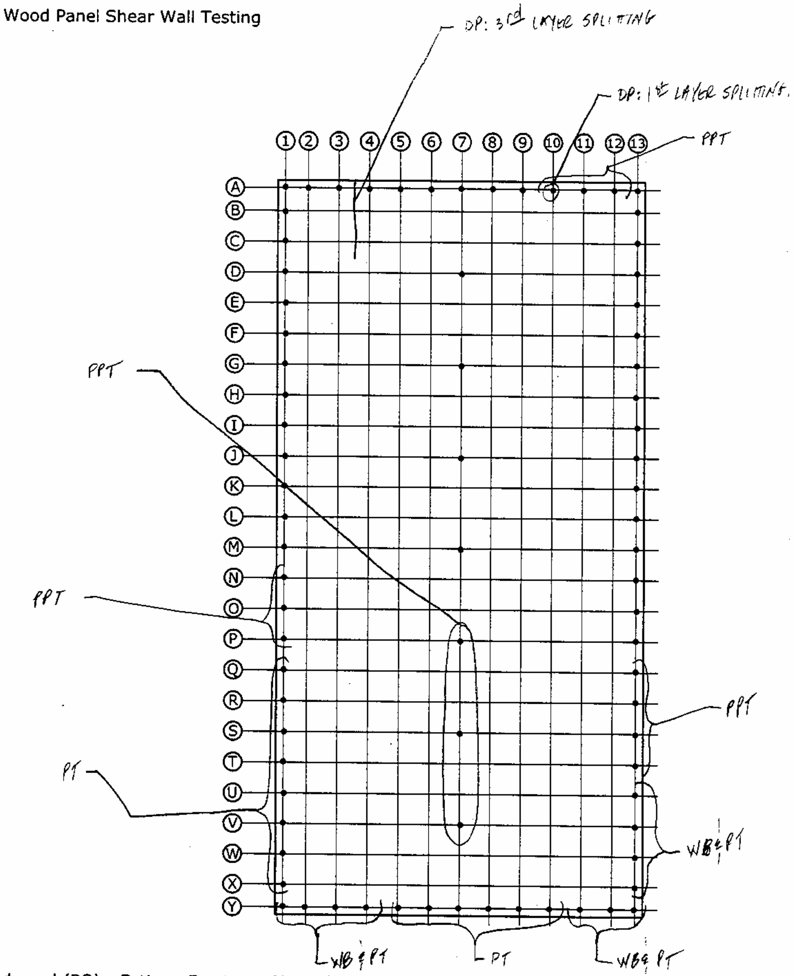
Light Gauge Steel Frame / Wood Panel Shear Wall Testing

INITIAL 0.84 mm

Test name : 38C
Date tested : MAY 27
Wall Size : 4' x 8'
Screw pattern : 4" / 12"
Edge Distance : 1/2"
Test mode : ☒ Cyclic ☐ Monotonic

NLC -1550N
SLC -275N

MAX. AXIAL LOAD = 19589 N
MAX. DISPLACEMENT = 84.9 mm



NOTES:
- NO PANEL LVDTs USED
- PLYWOOD PRODUCED IN ALBERTA.

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB) ; No Damage (ND)

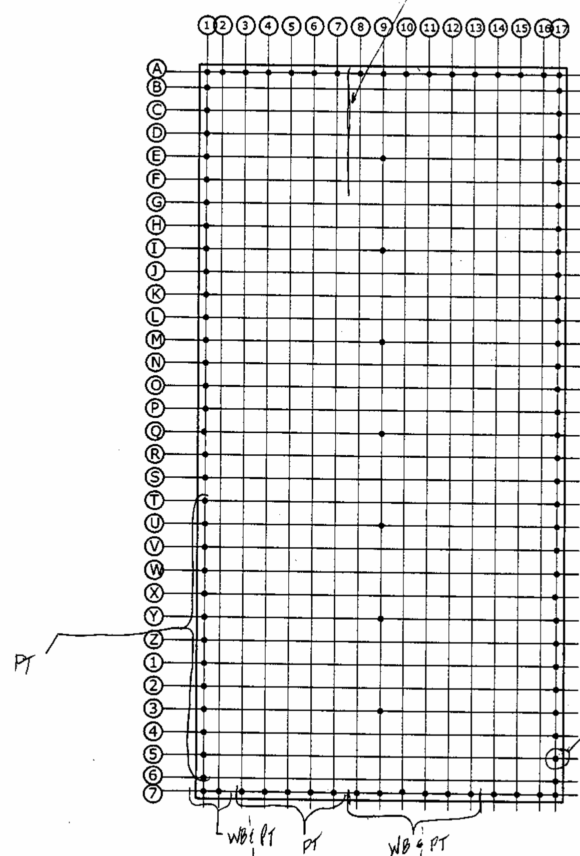
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 39A
Date tested : MAY 24, 2004
Wall Size : 4' x 8'
Screw pattern : 3" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

NLC - 1550 N
SLC - 275 N

DP: SPLITTING IN 3rd LAYER



DP: SPLITTING IN 1st LAYER

@ 12.5mm DISPLACEMENT : AXIAL LOAD = 13208 N
@ 38.0mm DISPLACEMENT : AXIAL LOAD = 23023 N
MAX. AXIAL LOAD = 27200 N

NOTES:
- PANEL LVDTs REMOVED AT ≃ 25 kN
- CORNER SCREWS PULLED THROUGH FIRST.
- EXTENSIVE PANEL BUCKLING (ELASTIC) OBSERVED BEFORE FAILURE

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

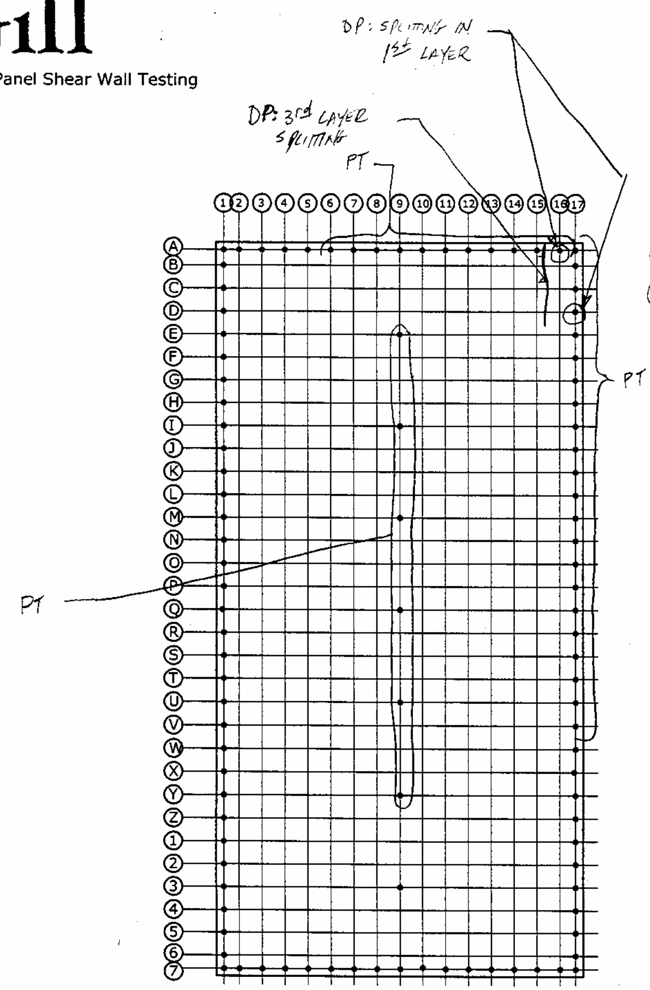
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 39B
Date tested : MAY 24, 2004
Wall Size : 4' x 8'
Screw pattern : 3" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

NLC -1550 N
SLC -275 N

@ 12.5mm DISPLACEMENT : AXIAL LOAD = 9886 N
@ 38.0mm DISPLACEMENT : AXIAL LOAD = 18086 N
MAX. AXIAL LOAD = 21929 N



NOTES:
- PLYWOOD PRODUCED IN ALBERTA
- PANEL & SHEAR LVDTS REMOVED AT ≈ 19 kN.

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

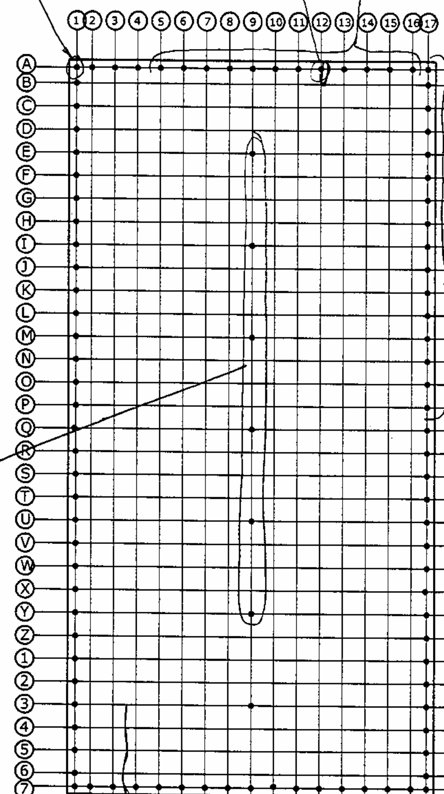
Test name : 39C
Date tested : MAY 25, 2004
Wall Size : 4' x 8'
Screw pattern : 3" / 12"
Edge Distance : 1/2"
Test mode : ☐ Cyclic ☒ Monotonic

NLC - 1550N
SLC - 275N

DP: 1st LAYER CHIPPED (LOCALLY)

DP. 1st LAYER SPLIT

PT



PT

PT

@ 12.5mm DISPLACEMENT : AXIAL LOAD = 10344 N
@ 38.0mm DISPLACEMENT : AXIAL LOAD = 18715 N
MAX. AXIAL LOAD = 21273 N

NOTES:

- PANEL & SHEAR LVDT: REMOVED AT ≃ 19KN
- PLYWOOD PRODUCED IN ALBERTA
- TEST WAS PAUSED WHEN SEVERE BUCKLING AND PULL THROUGH FAILURE OF I9, M9, Q9 & U9 SCREWS WAS OBSERVED.
- THE TEST WAS THEN RESUMED UNTIL FAILURE
- THE MAX. AXIAL LOAD OCCURED BEFORE THE TEST WAS PAUSED.

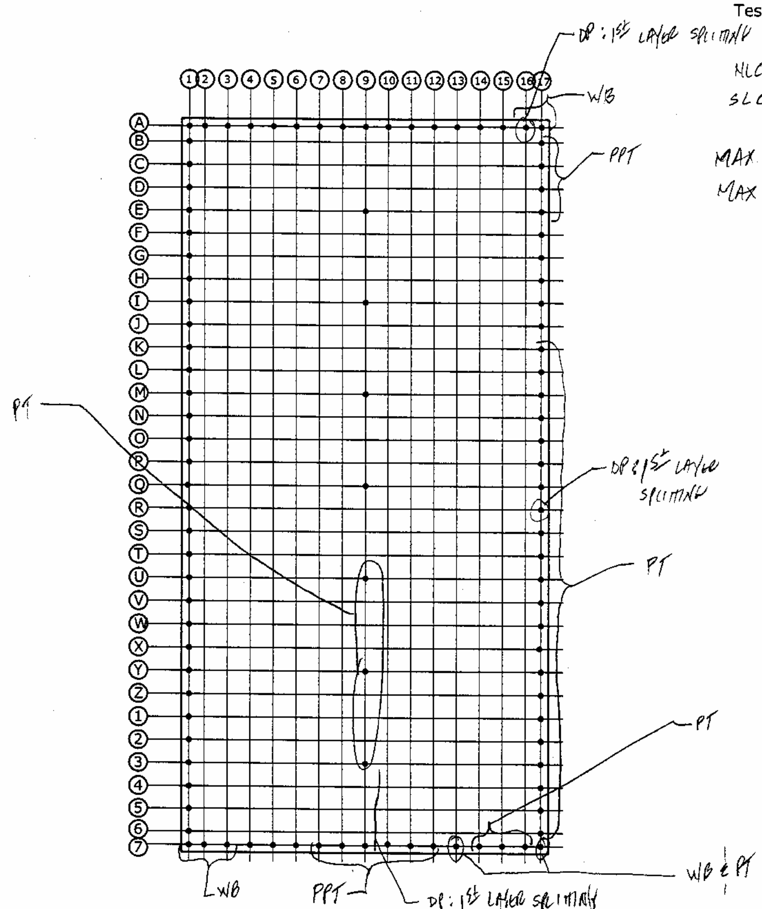
DP: SPLITTING IN 1st LAYER

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 40 A
Date tested : MAY 27, 2004
Wall Size : 4' x 8'
Screw pattern : 3" / 12"
Edge Distance : 1/2"
Test mode : ☒ Cyclic ☐ Monotonic



NLC - 1550N
SLC - 275N

MAX AXIAL LOAD =
MAX. DISPLACEMENT =

NOTES:

- BC "WELDWOOD" PLYWOOD USED.
- NO PANEL LVDTs USED.
- SOUTH SHEAR LVDT READINGS MAY NOT BE ACCURATE TOWARDS THE END OF THE TEST DUE TO A SLIP IN THE WIRE.

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

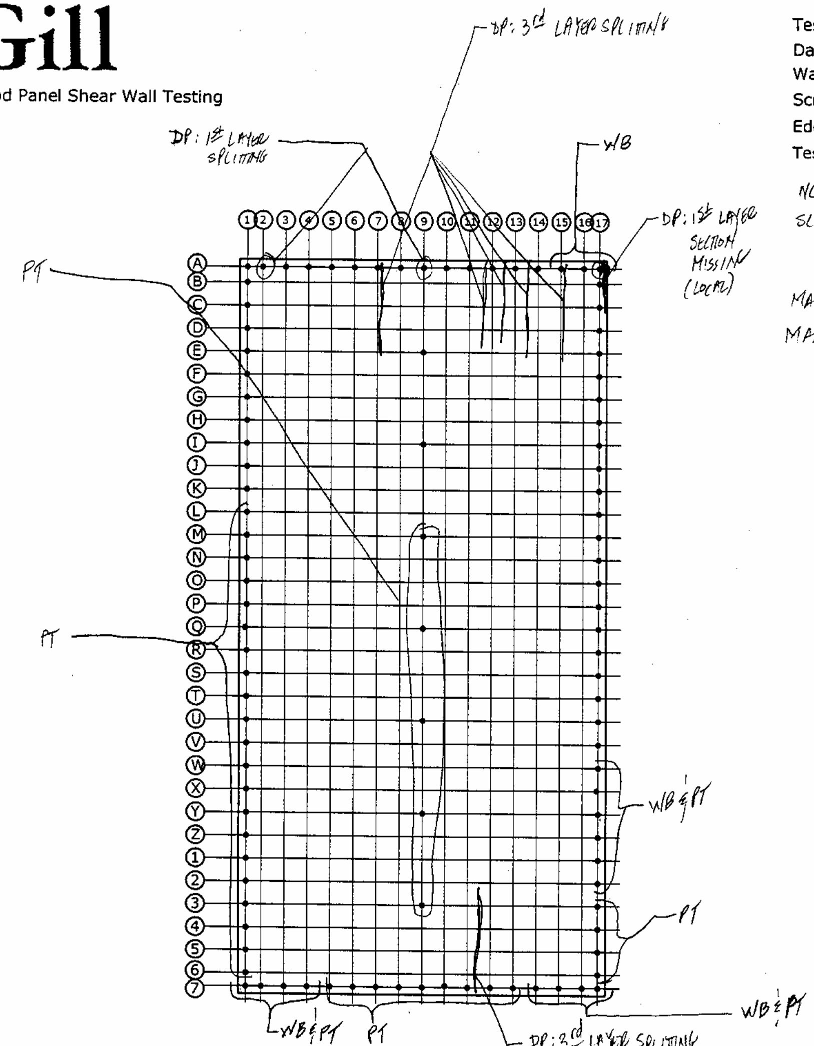
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 40B
Date tested : MAY 28, 2004
Wall Size : 4' x 8'
Screw pattern : 3" / 12"
Edge Distance : 1/2"
Test mode : ☒ Cyclic ☐ Monotonic

NLC - 1550 N
SLC - 275 N

MAX. AXIAL LOAD = 24108 N
MAX. DISPLACEMENT = 76.836 mm



NOTES:

- ALBERTA PLYWOOD USED. (AB 244)

- NO PANEL LVDTs USED.

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

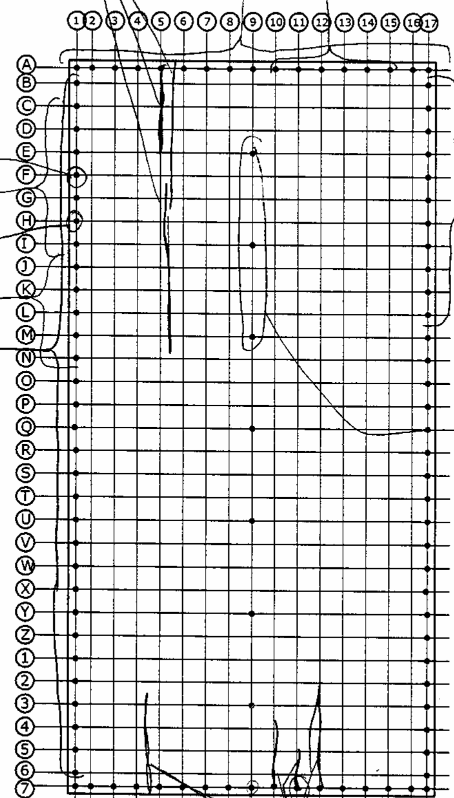
McGill

Light Gauge Steel Frame / Wood Panel Shear Wall Testing

Test name : 40C
Date tested : MAY 28, 2004
Wall Size : 4' x 8'
Screw pattern : 3" / 12"
Edge Distance : 1/2"
Test mode : ☒ Cyclic ☐ Monotonic

NLC - 1550 N
SLC - 275 N

MAX. AXIAL LOAD = 18278 N
MAX. DISPLACEMENT = 76.818 mm



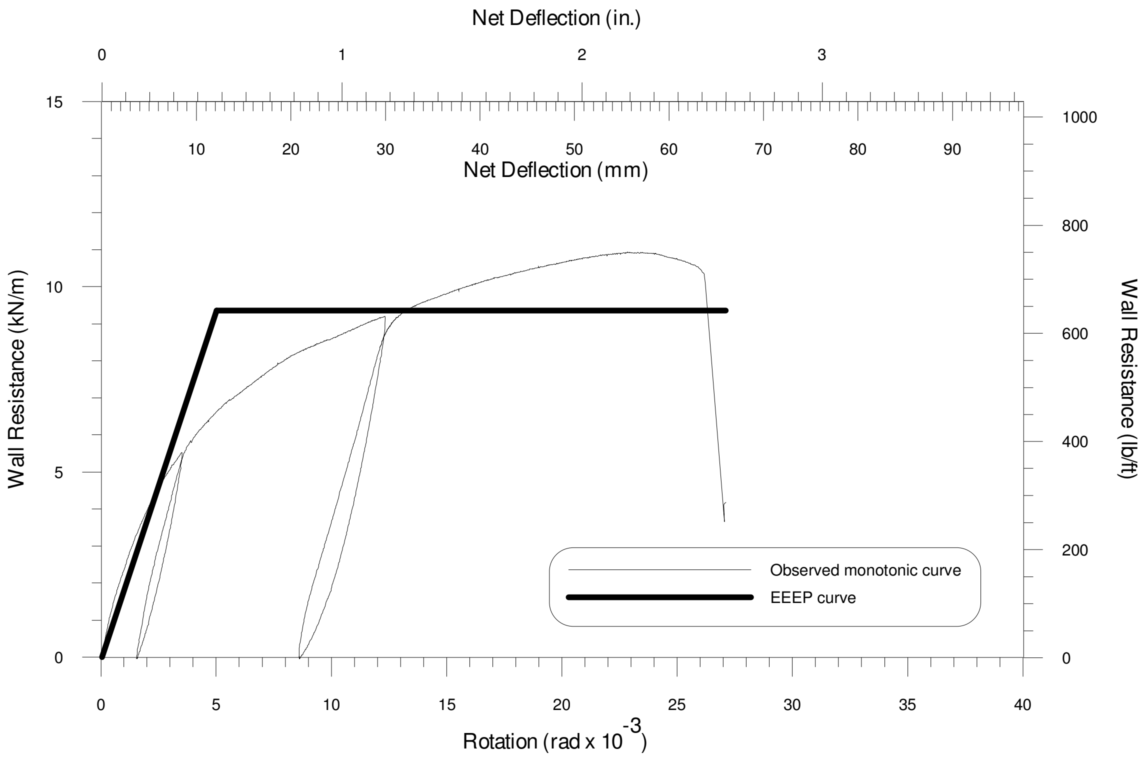
NOTES:

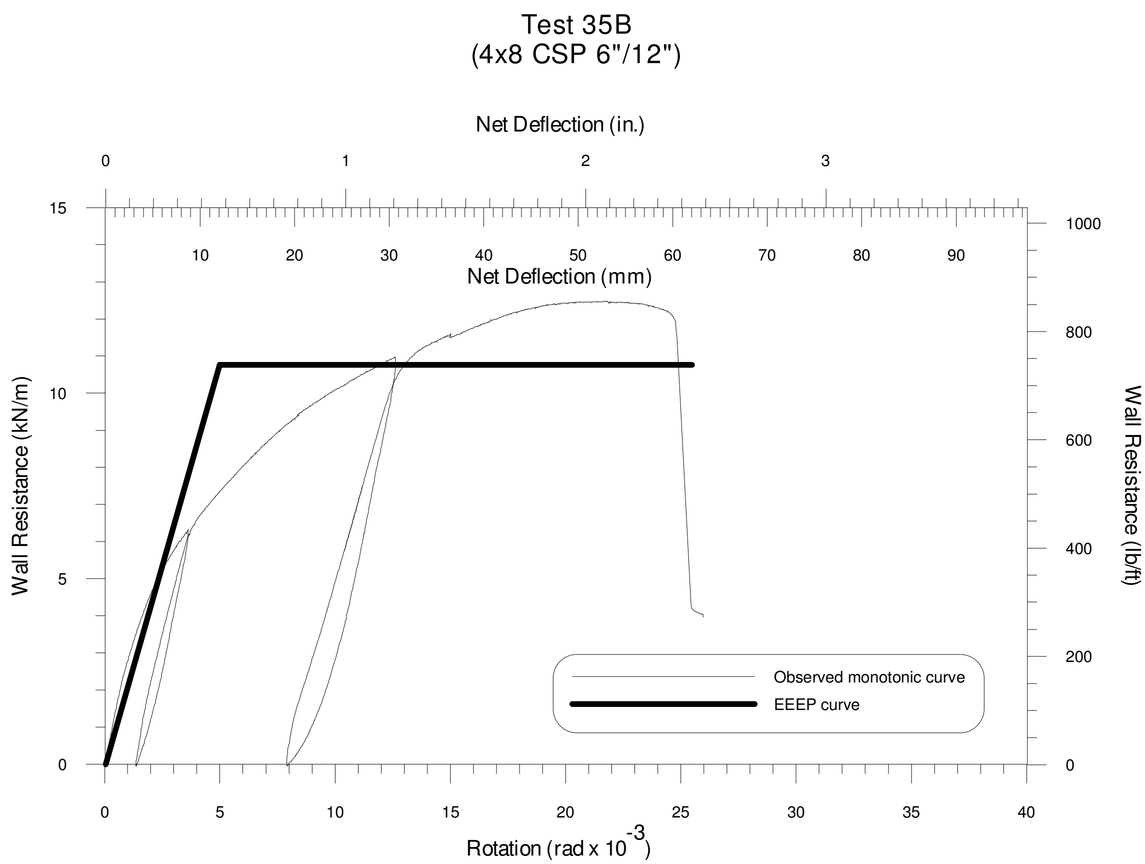
- NO PANEL LVDTs USED
- "CAN FOR" BC PLYWOOD USED (BC OSS)
- * LOWER RESISTANCE OF THIS WALL ASSUMED TO BE THE RESULT OF THE SCREWS ALONG THE "A" AXIS BEING OVER-DRIVEN.
- OVERDRIVEN BY 2mm.
- Screw 79 missing

Failure modes: Pullout, withdrawal (PO) ; Fatigue Fracture, Shear (FF) ; Pull through sheathing (PT) ; Damage prior to testing (DP)
Partial Pullthrough (PPT) ; Tearout of sheathing (TO) ; Wood Bearing Failure (WB)

APPENDIX III - RESPONSE CURVES FOR MONOTONIC TESTS

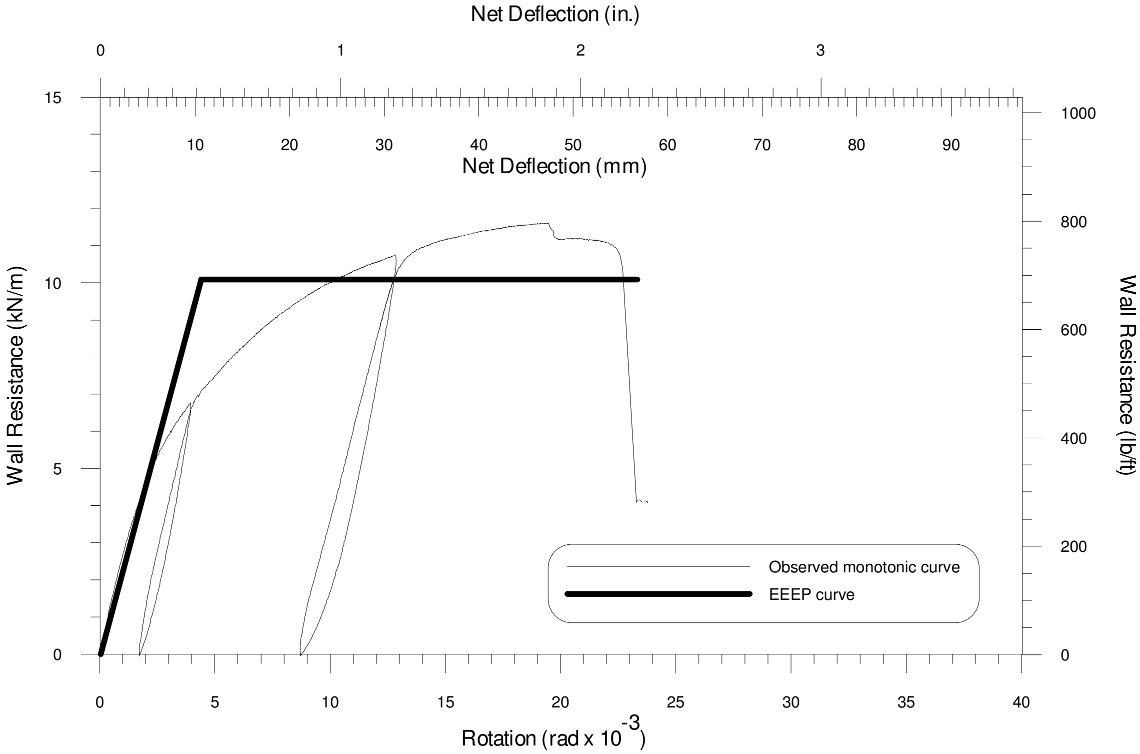
Test 35A
(4x8 CSP 6"/12")



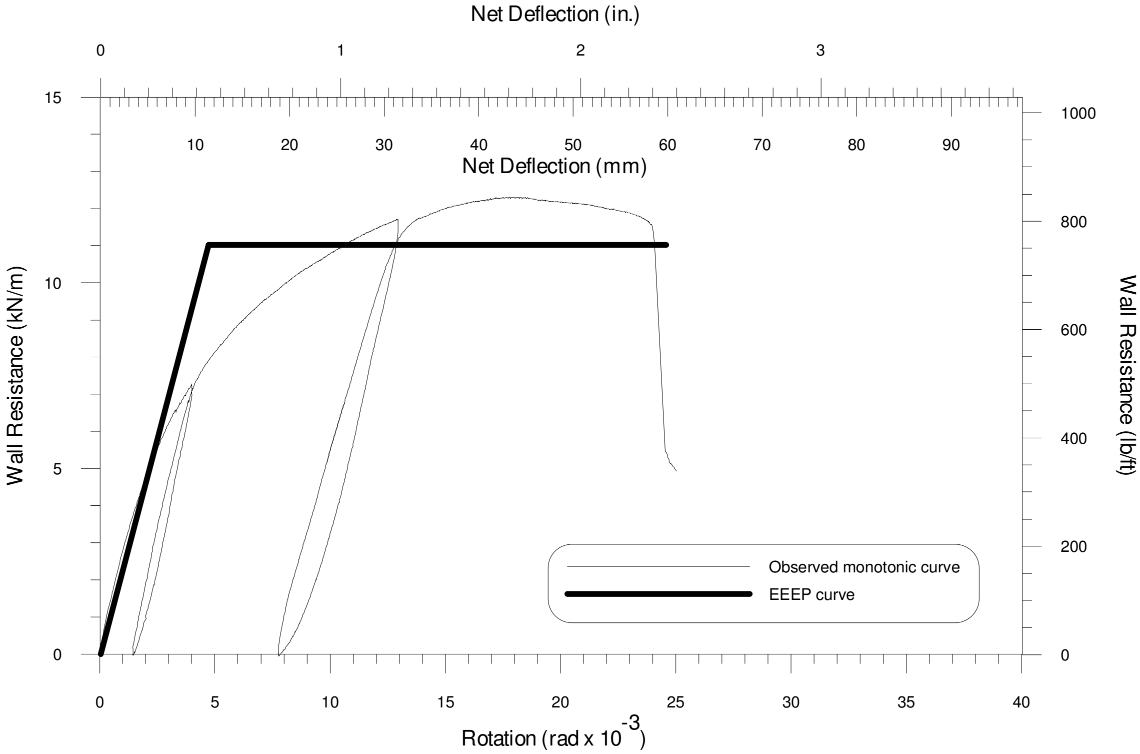


Test 35B
(4x8 CSP 6"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^{-3})
Observed monotonic curve
EEEP curve

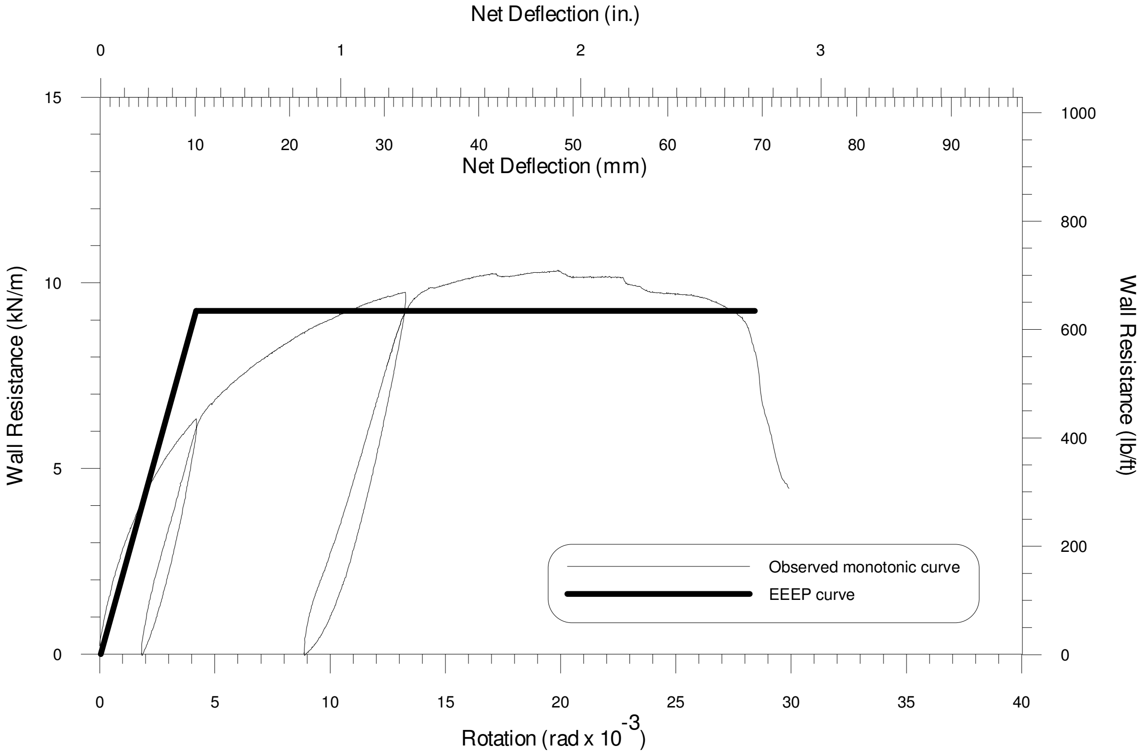
Test 35C
(4x8 CSP 6"/12")



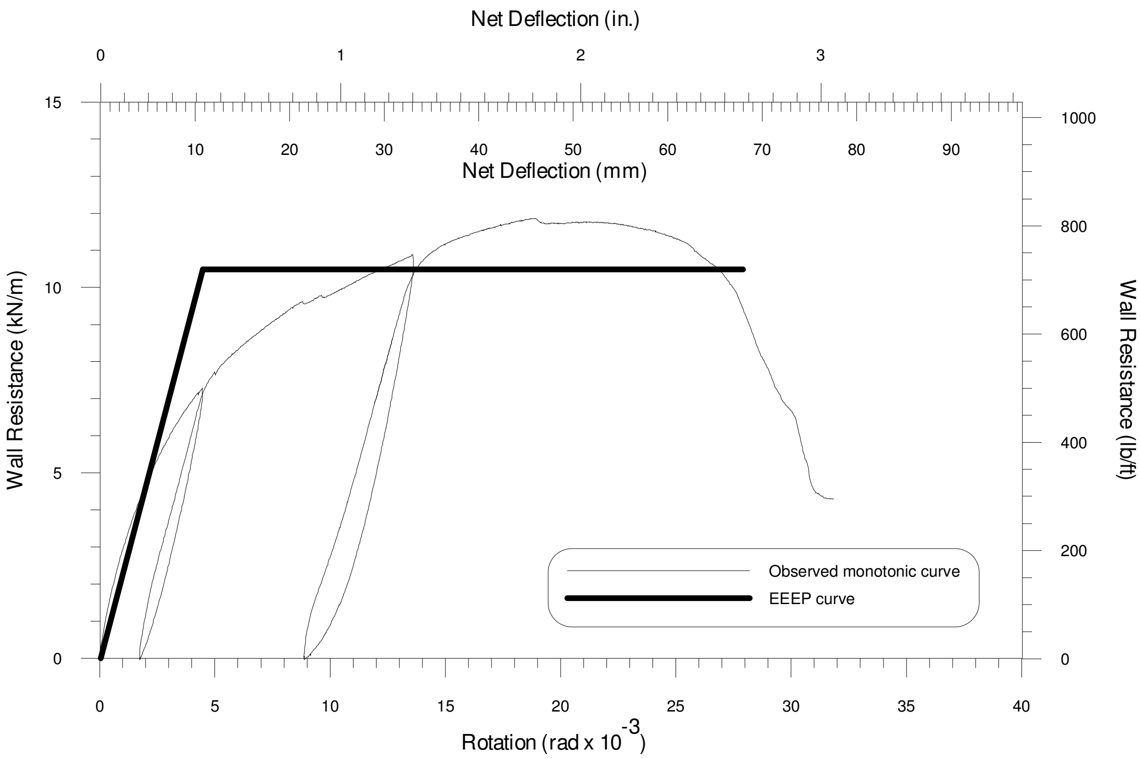
Test 35D
(4x8 CSP 6"/12")



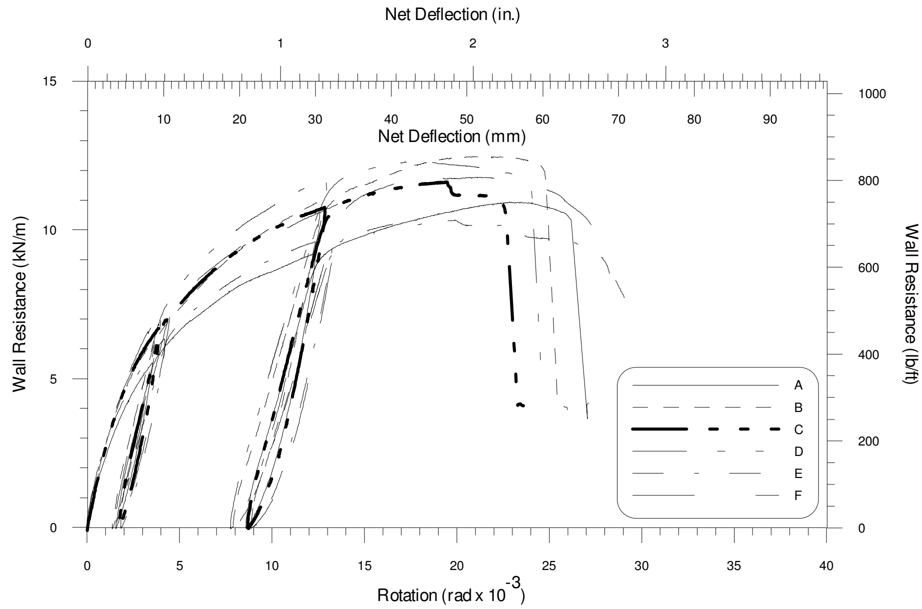
Test 35E
(4x8 CSP 6"/12")



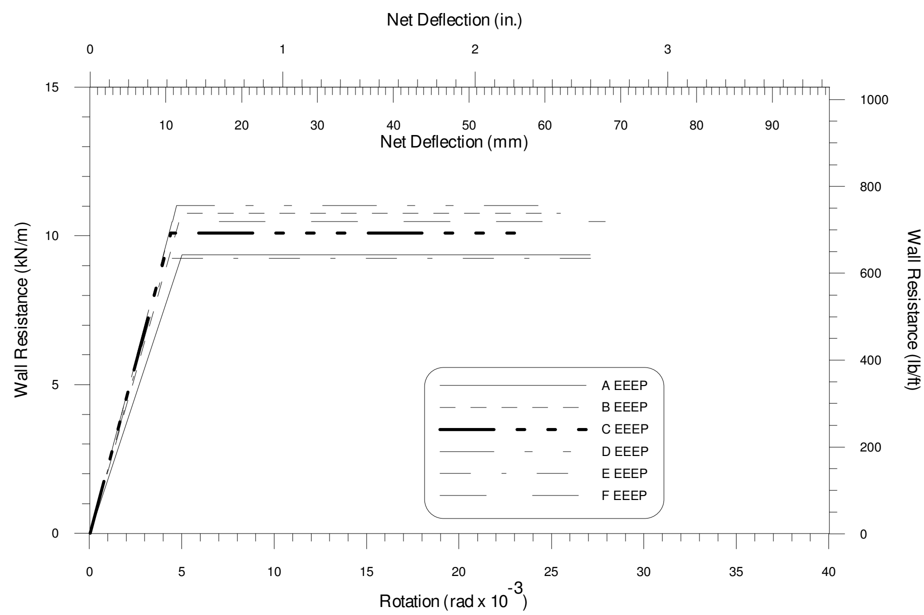
Test 35F
(4x8 CSP 6"/12")



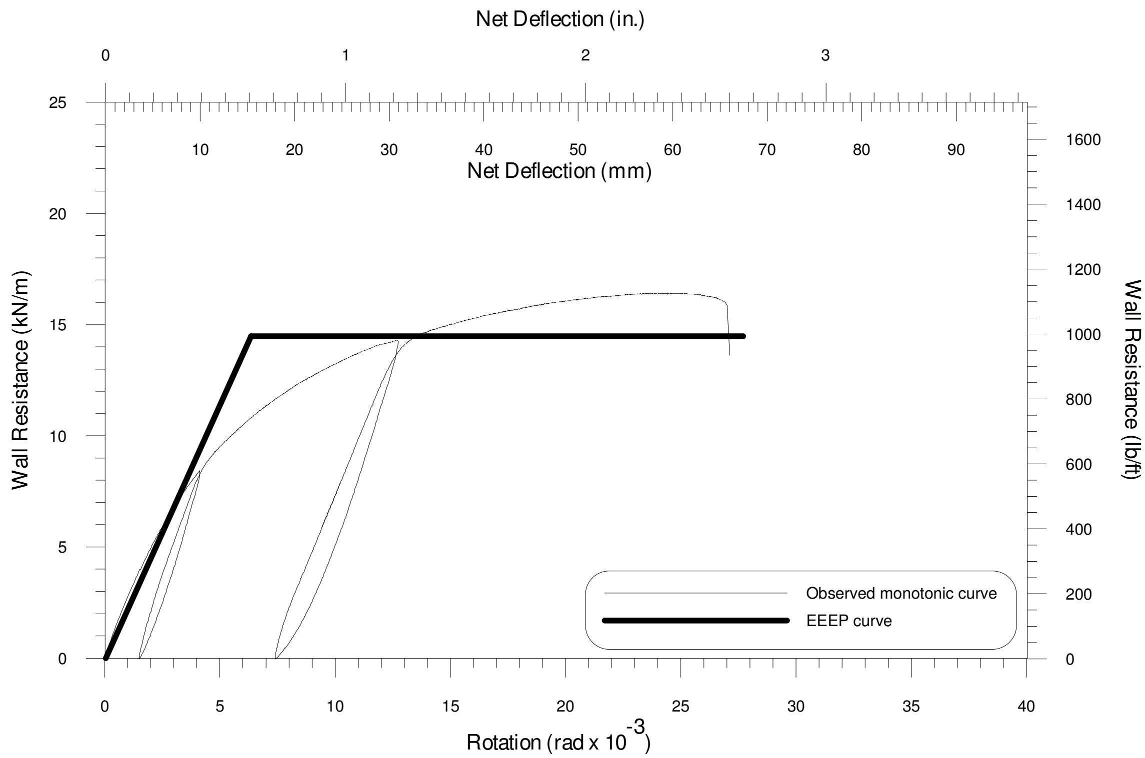
Test 35-A,B,C,D,E,F
(4x8 CSP 6"/12")



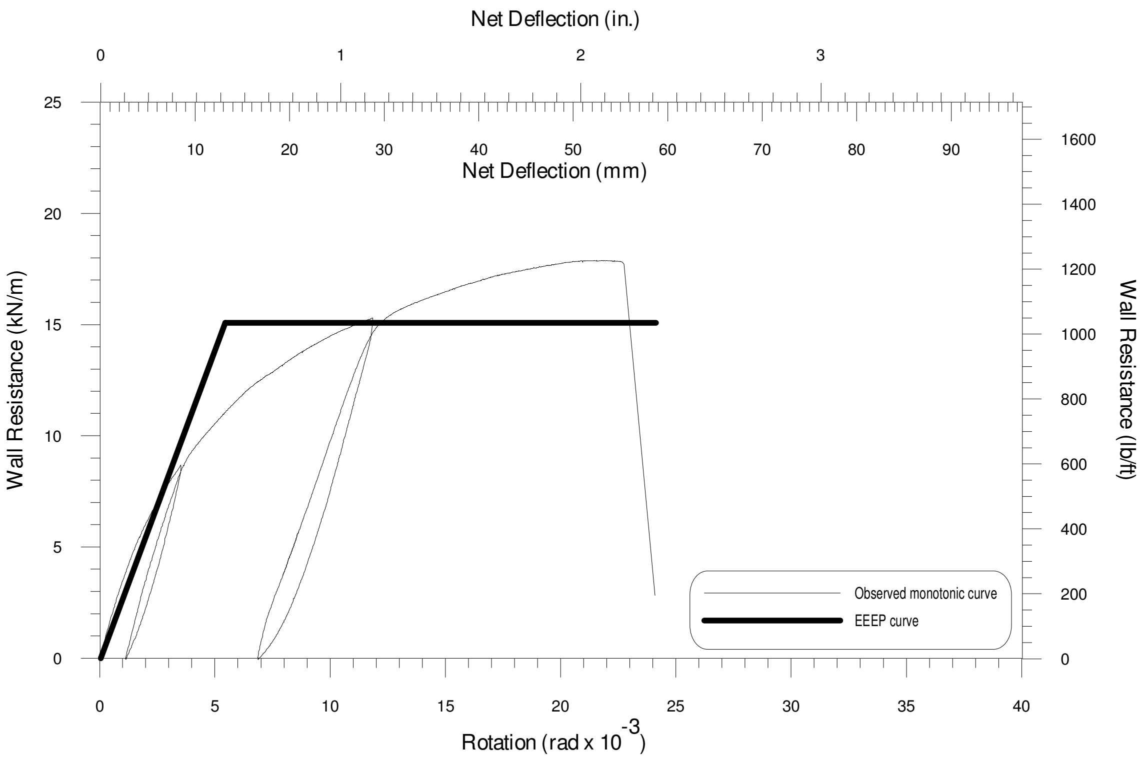
Test 35-A,B,C,D,E,F EEEP
(4x8 CSP 6"/12")



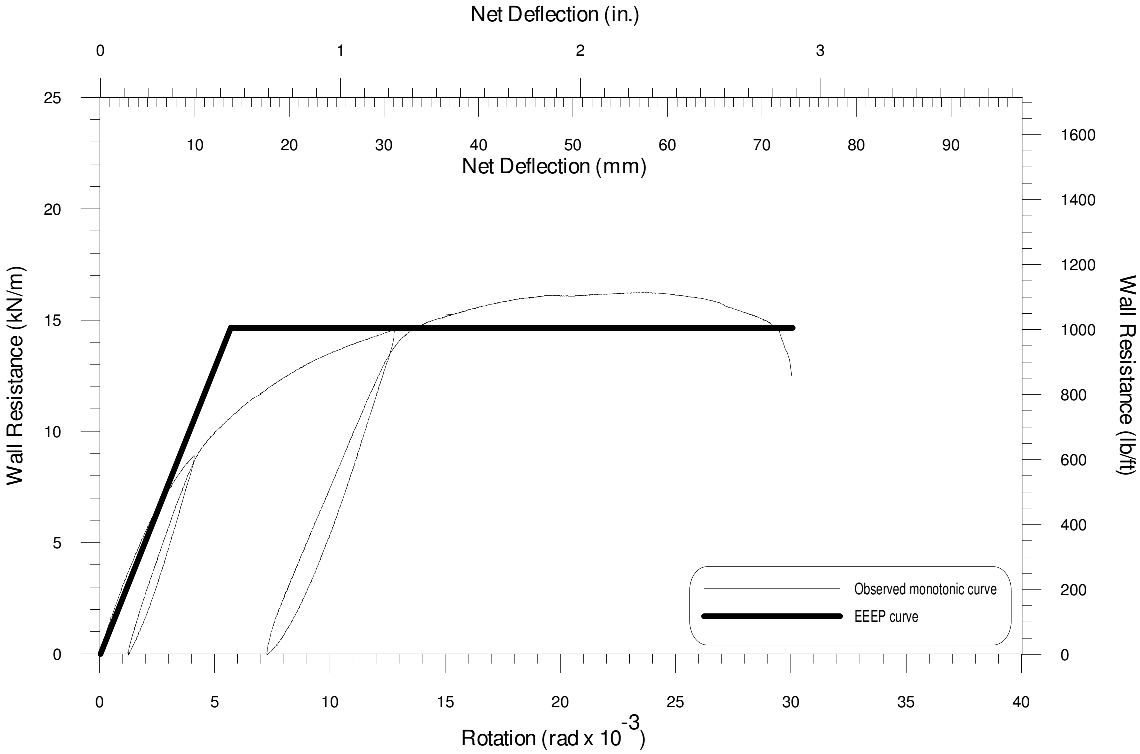
Test 37A
(4x8 CSP 4"/12")



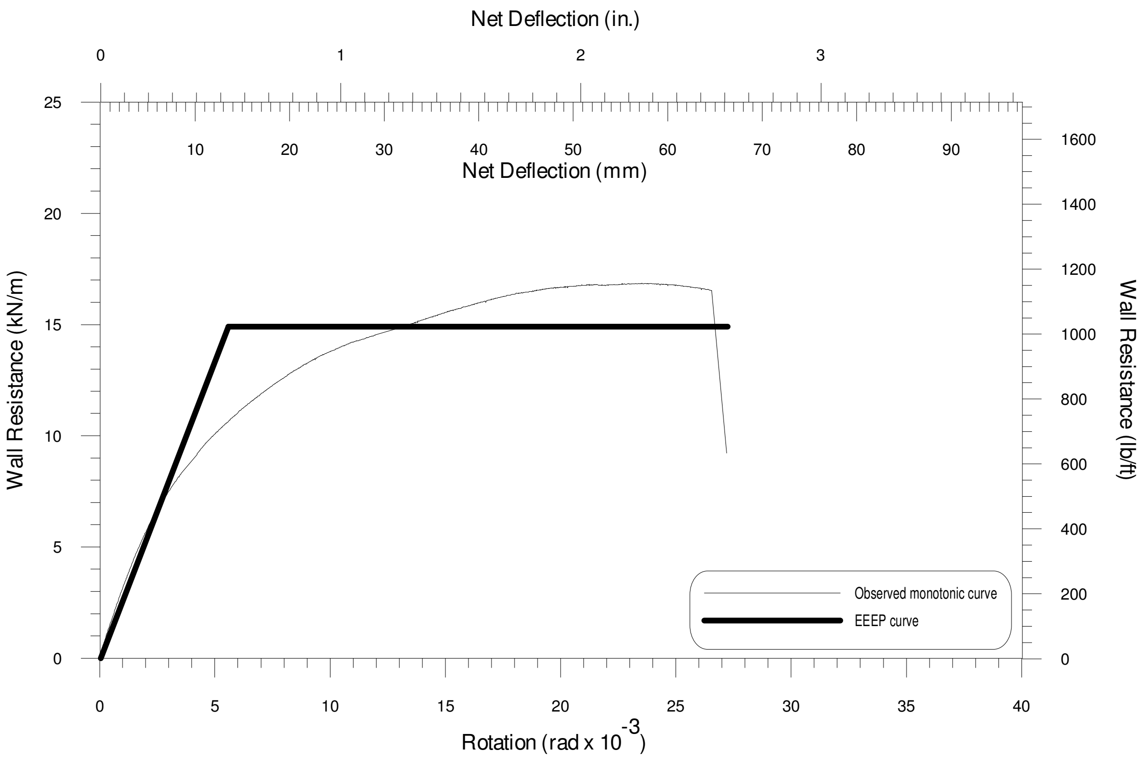
Test 37B
(4x8 CSP 4"/12")



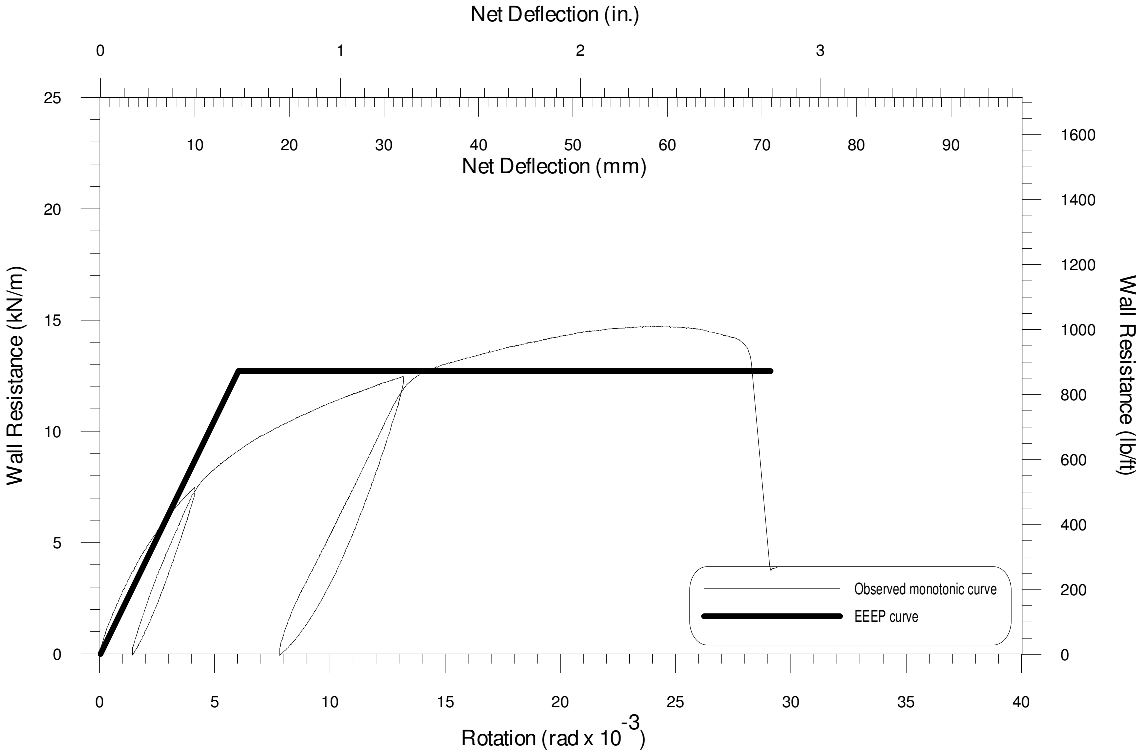
Test 37C
(4x8 CSP 4"/12")

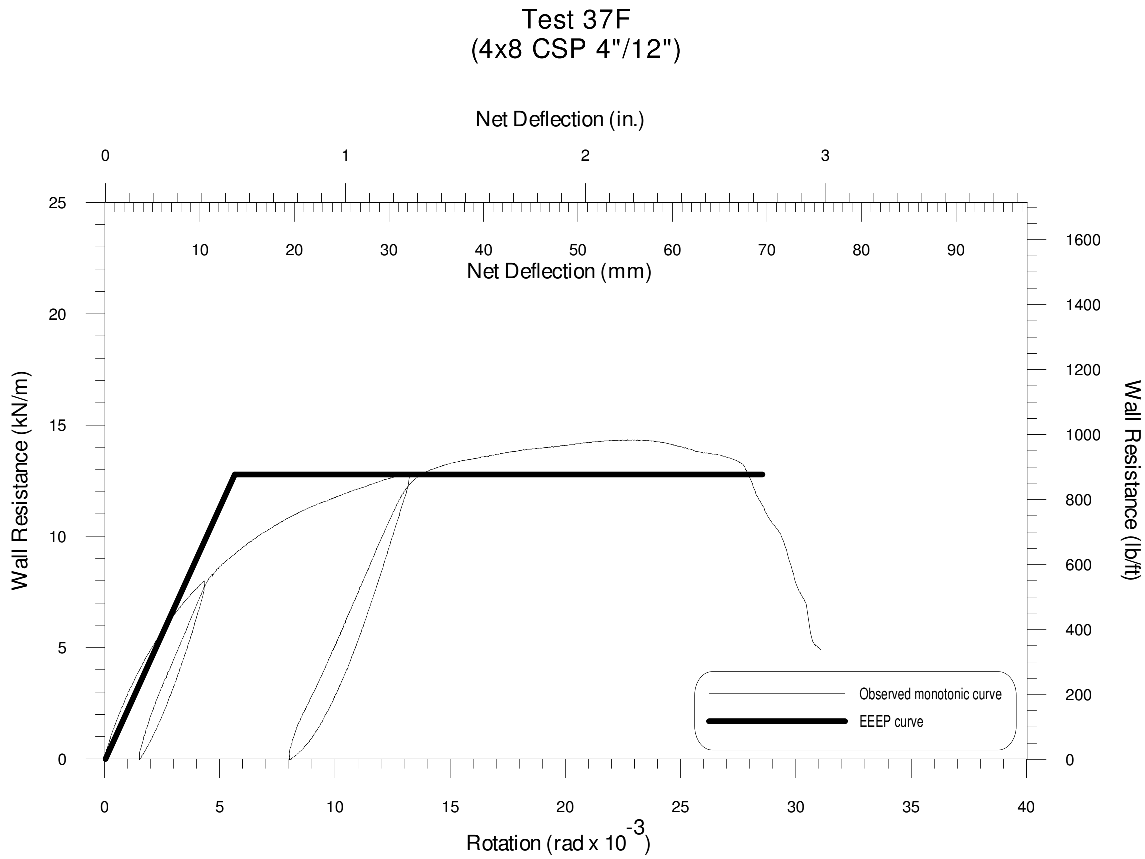


Test 37D
(4x8 CSP 4"/12")

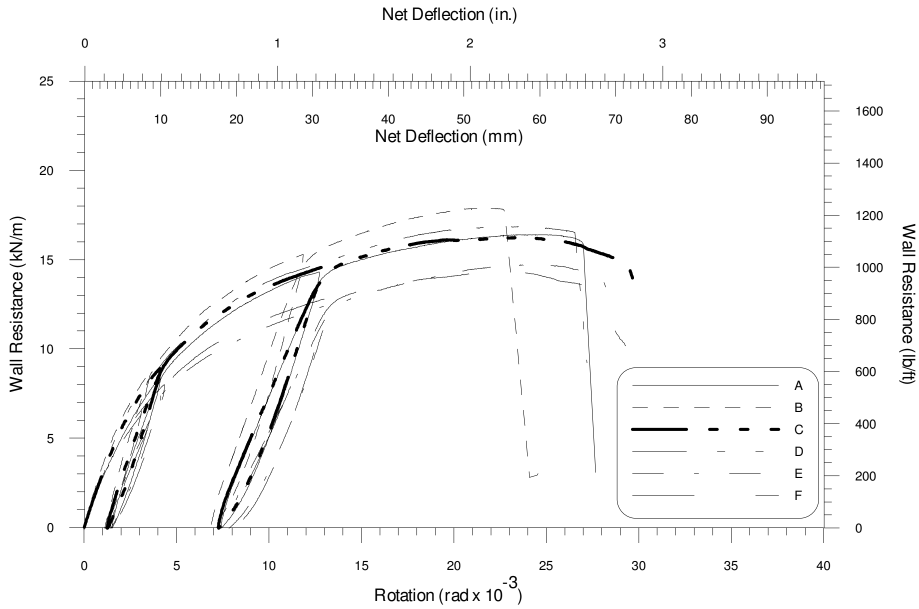


Test 37E
(4x8 CSP 4"/12")

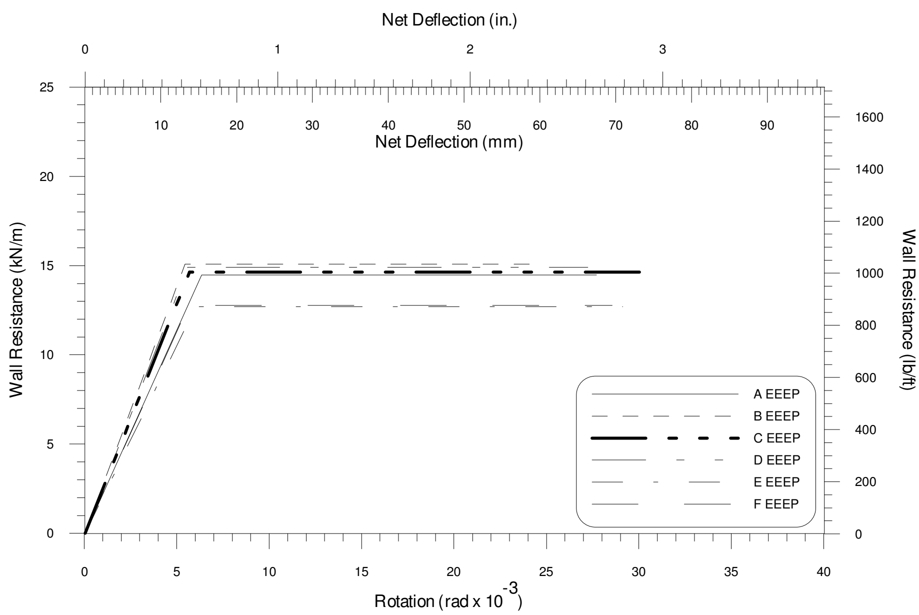



Test 37F
(4x8 CSP 4"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^{-3})
Observed monotonic curve
EEEP curve

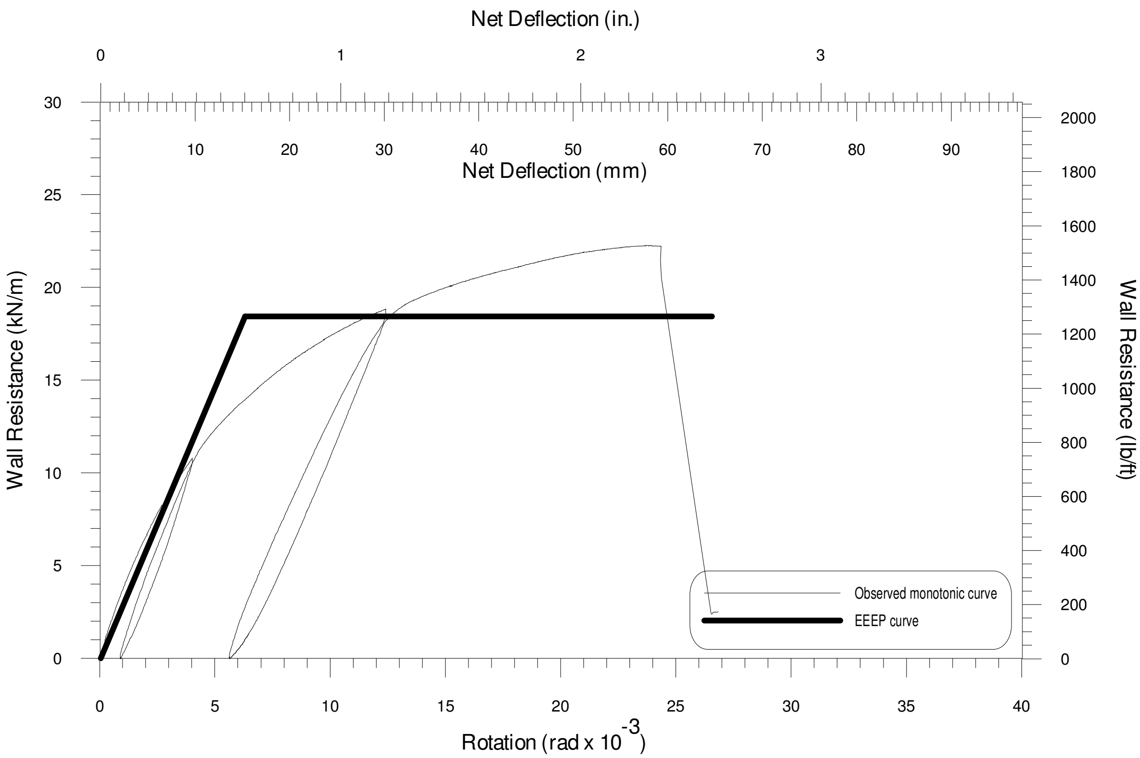
Test 37-A,B,C,D,E,F
(4x8 CSP 4"/12")



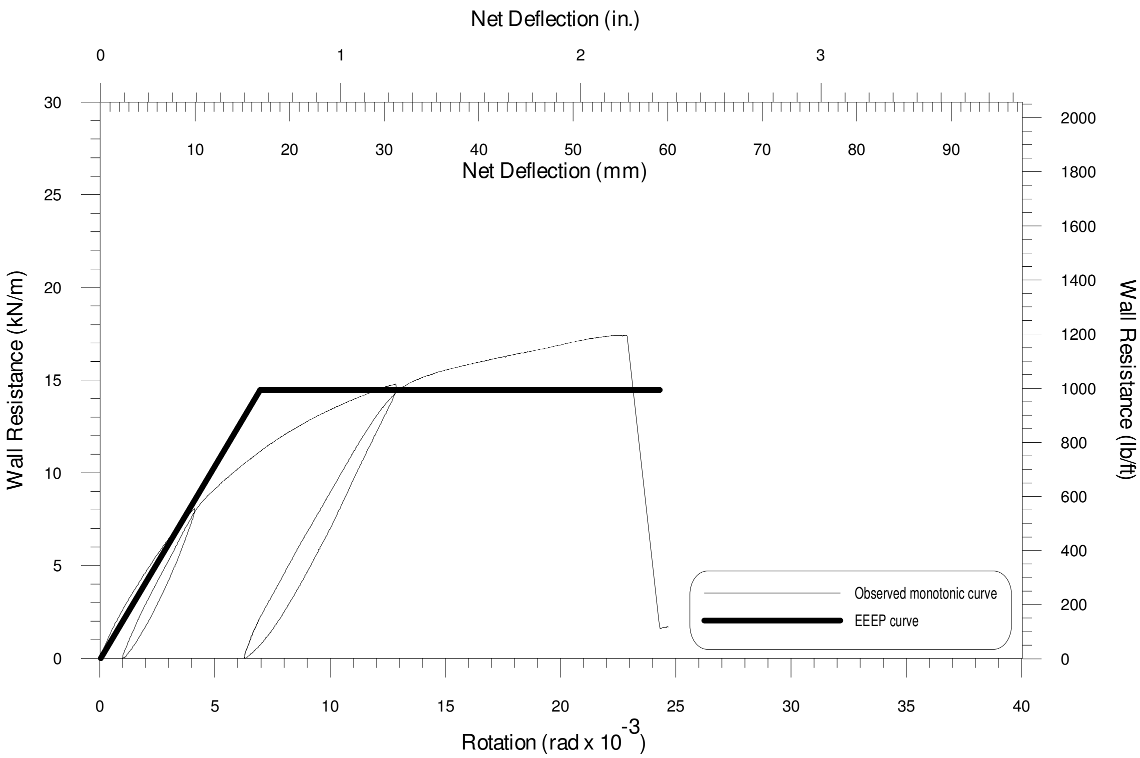
Test 37-A,B,C,D,E,F EEEP
(4x8 CSP 4"/12")



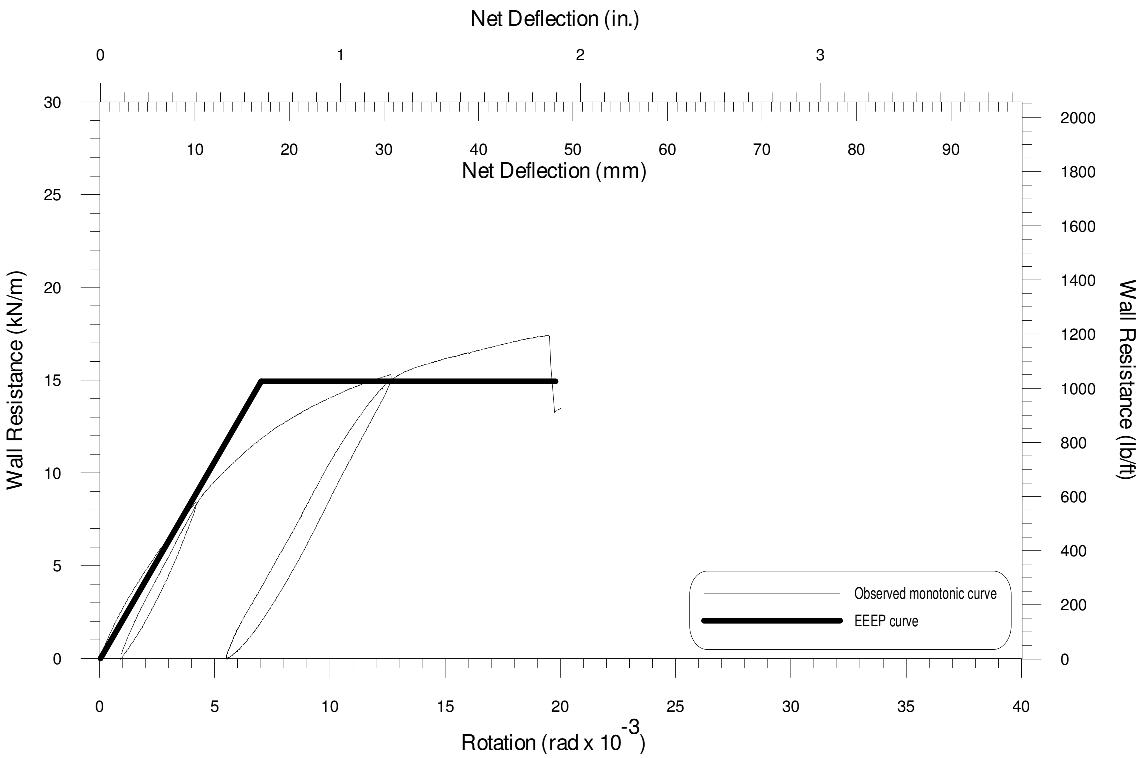
Test 39A
(4x8 CSP 3"/12")



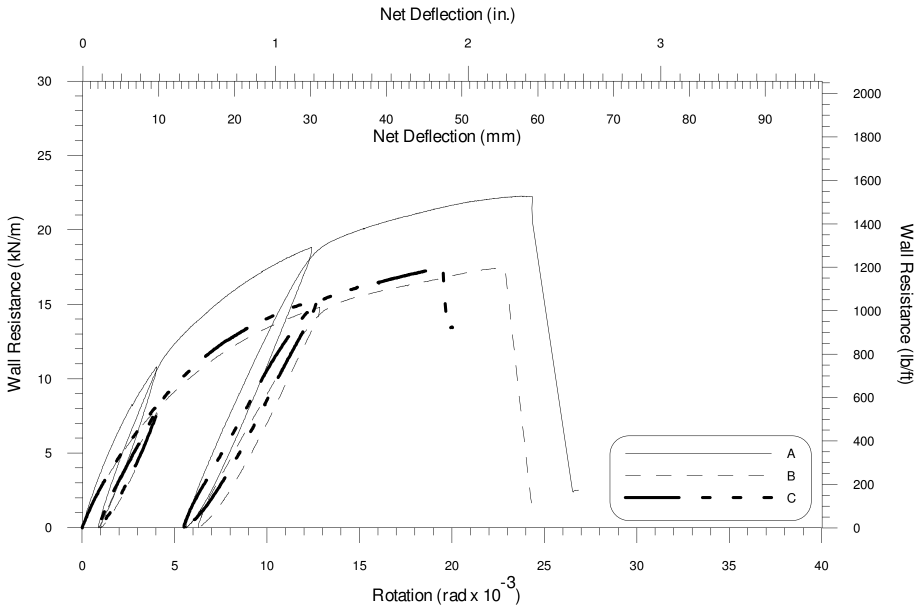
Test 39B
(4x8 CSP 3"/12")



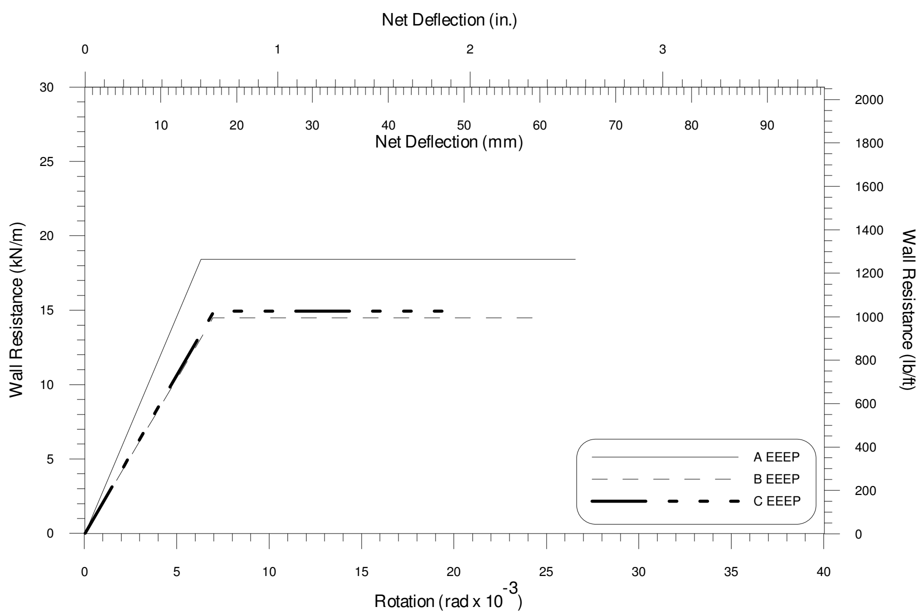
Test 39C
(4x8 CSP 3"/12")



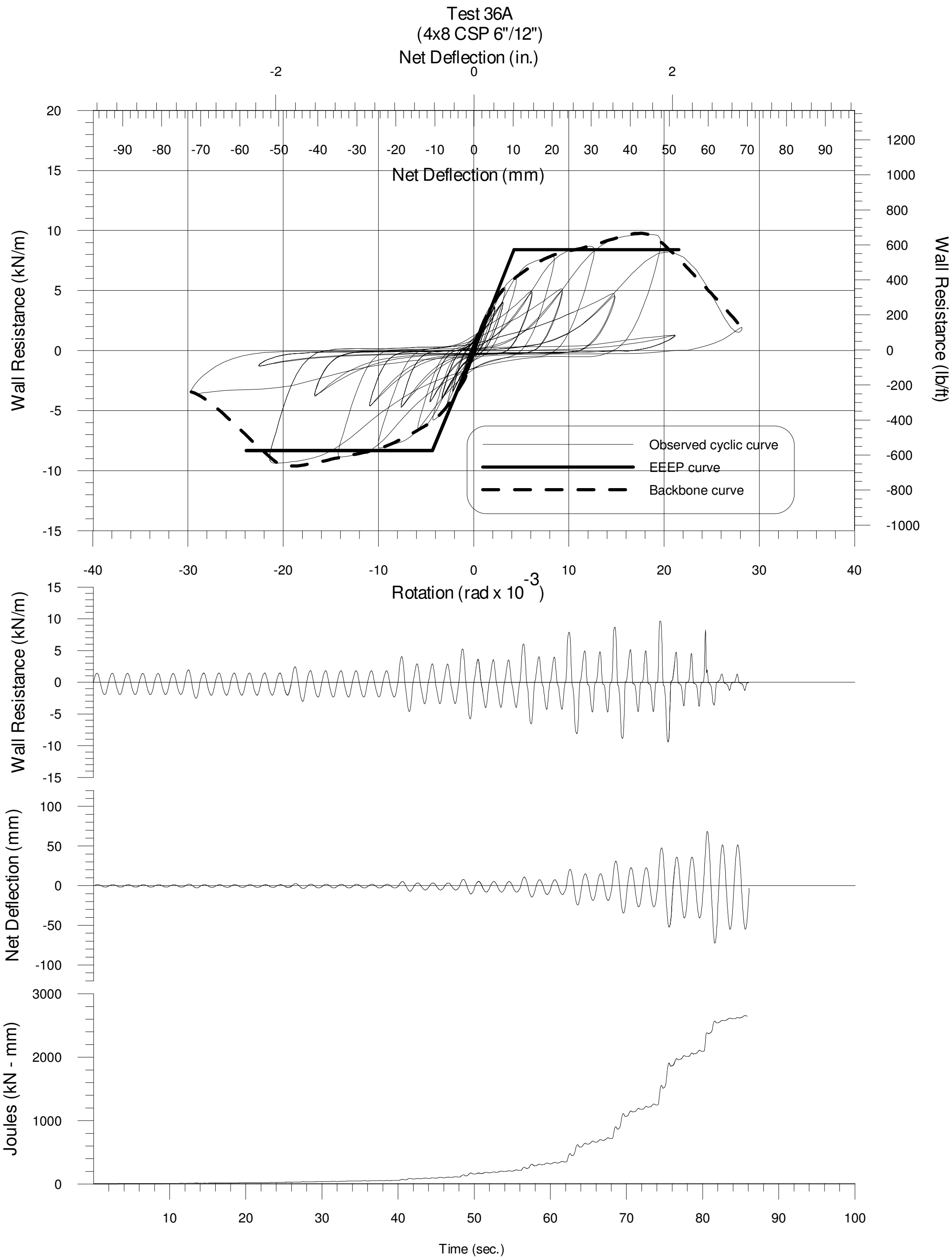
Test 39-A,B,C
(4x8 CSP 3"/12")

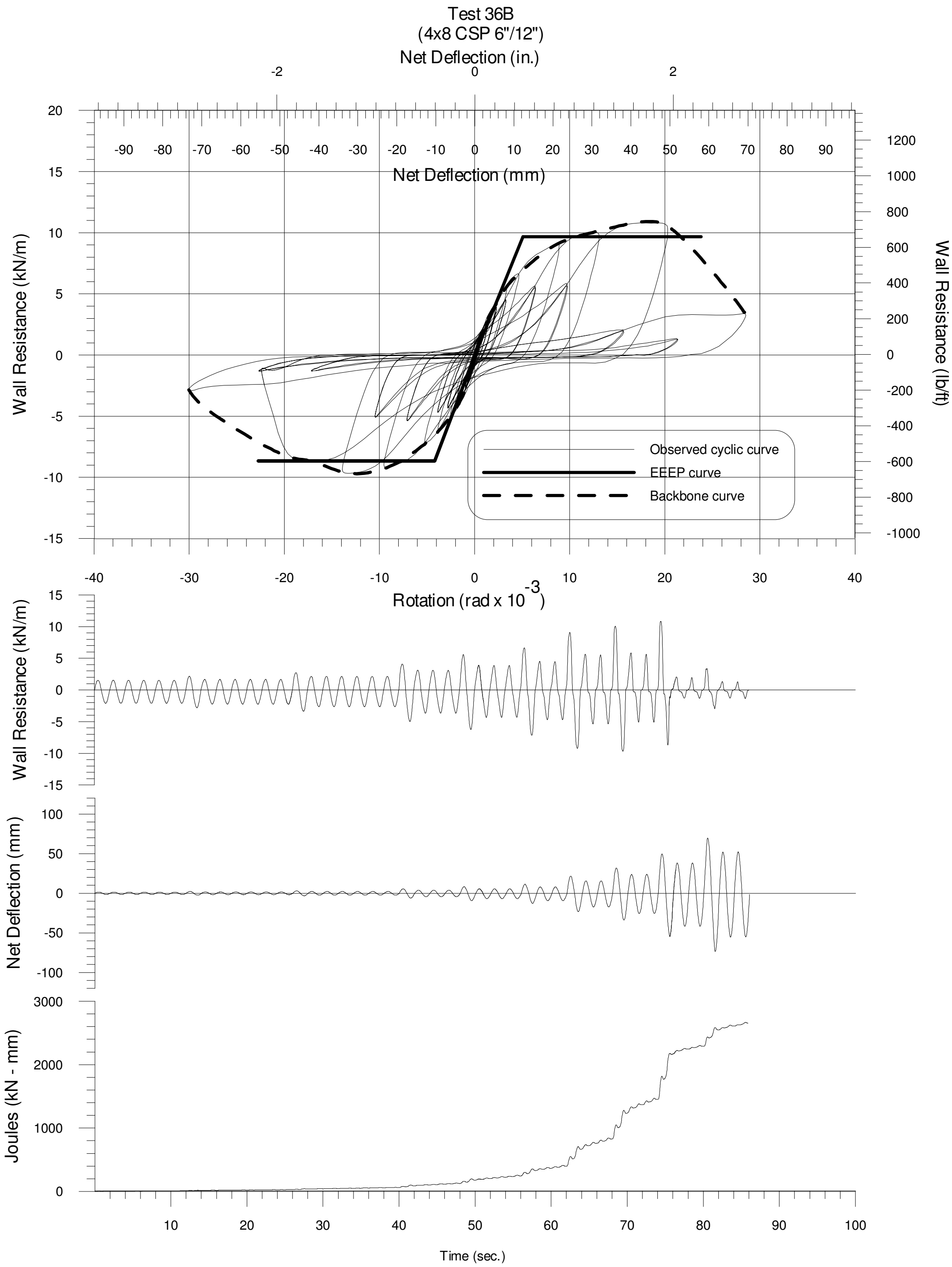


Test 39-A,B,C EEEP
(4x8 CSP 3"/12")

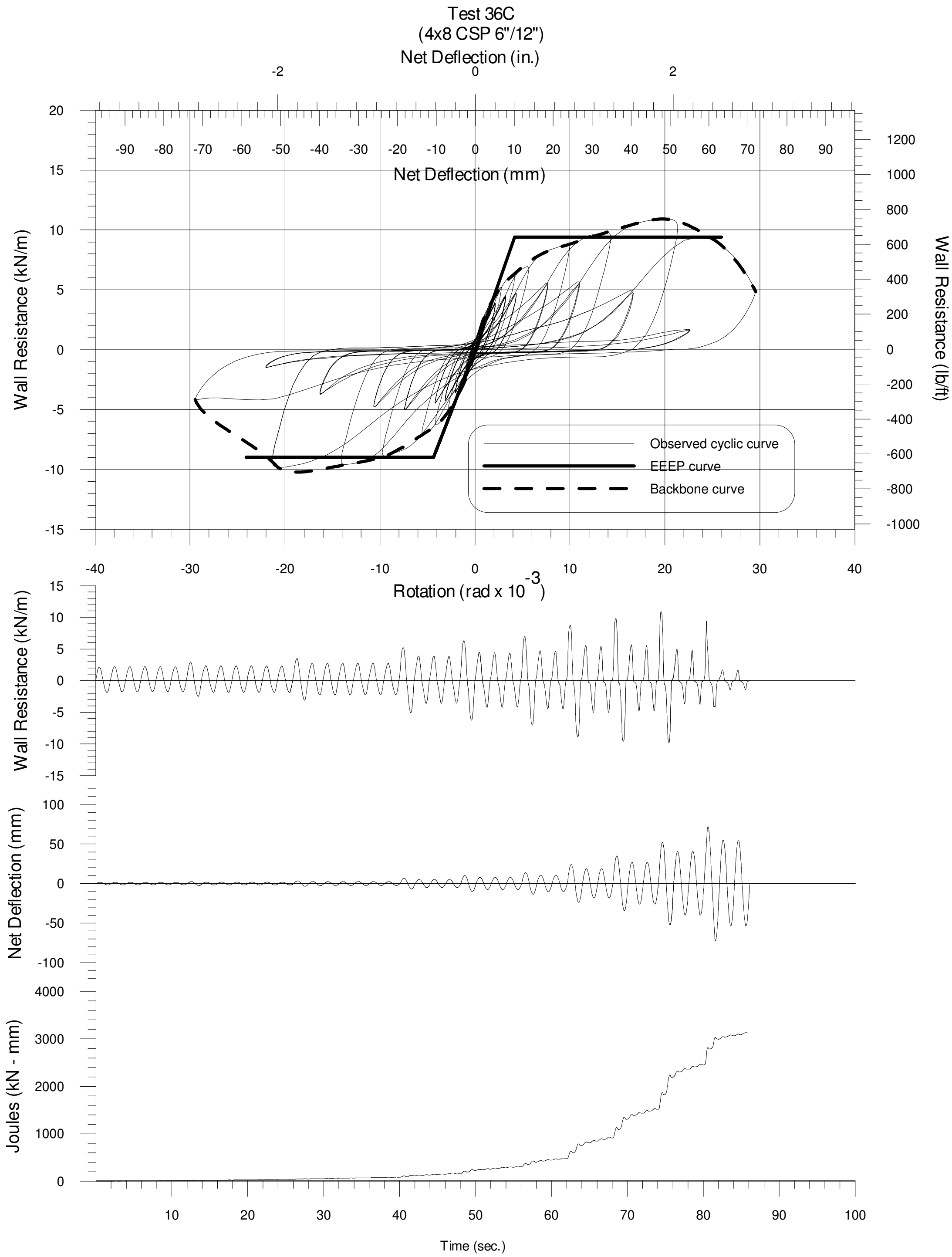


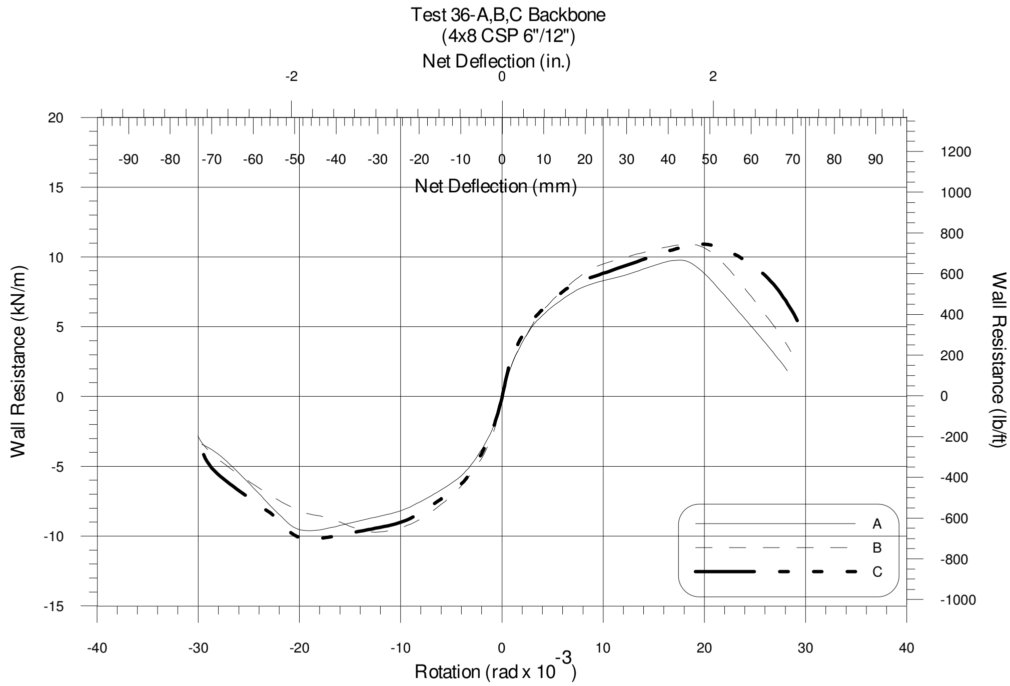
APPENDIX IV - RESPONSE CURVES, WALL RESISTANCE TIME HISTORIES AND DISPLACEMENT TIME HISTORIES FOR THE REVERSED CYCLIC TESTS


Test 36A
(4x8 CSP 6"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Observed cyclic curve
EEEP curve
Backbone curve
Rotation (rad x 10^-3)
Wall Resistance (kN/m)
Net Deflection (mm)
Joules (kN - mm)
Time (sec.)

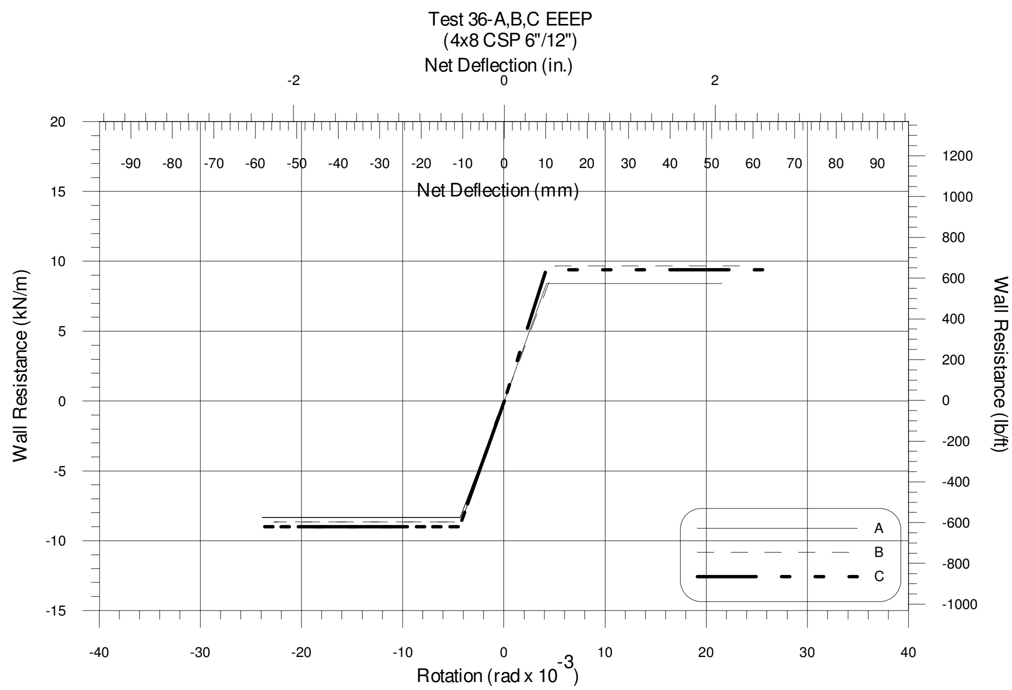


Test 36B
(4x8 CSP 6"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Observed cyclic curve
EEEP curve
Backbone curve
Rotation (rad x 10^-3)
Wall Resistance (kN/m)
Net Deflection (mm)
Joules (kN - mm)
Time (sec.)

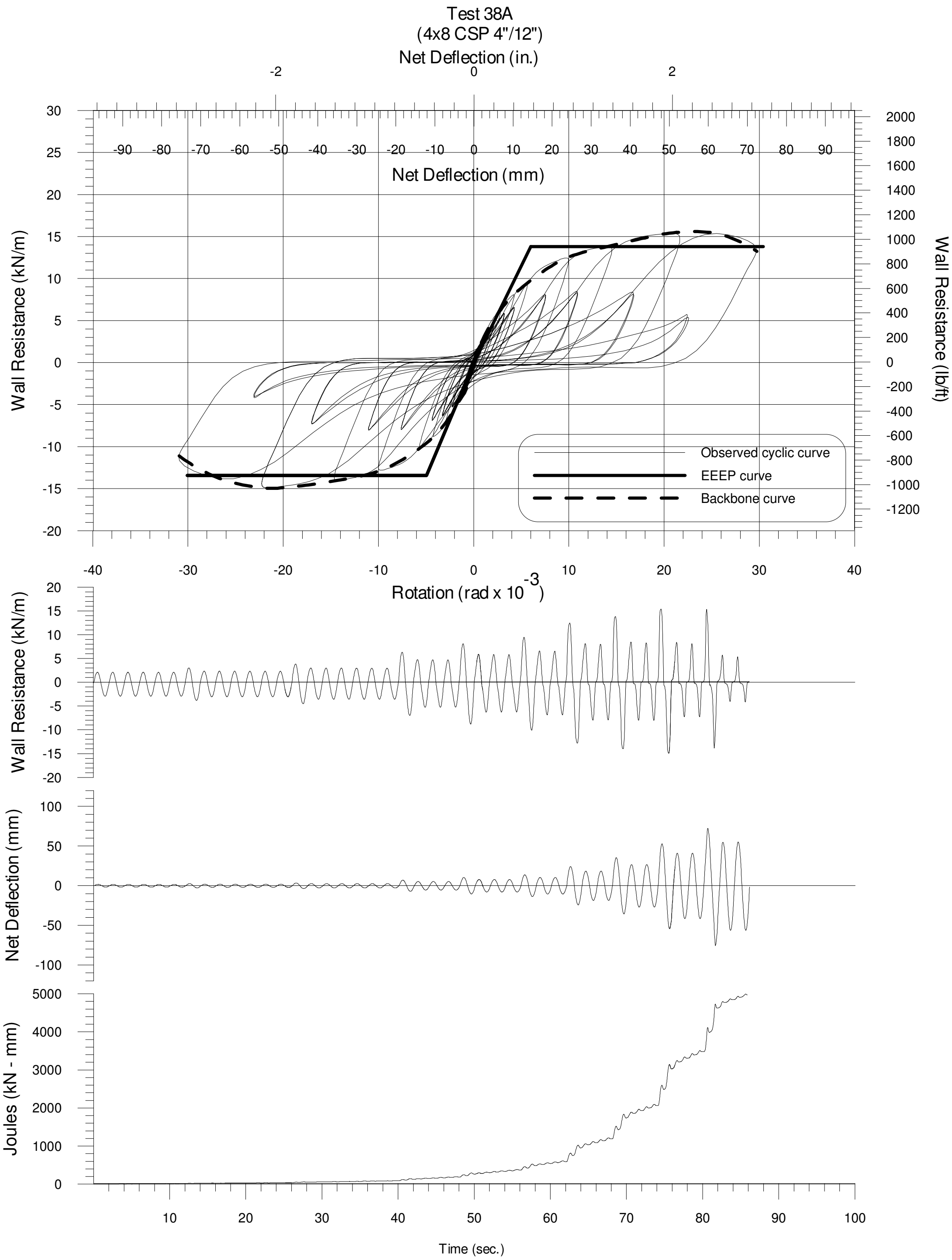

Test 36C
(4x8 CSP 6"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Observed cyclic curve
EEEP curve
Backbone curve
Rotation (rad x 10^{-3})
Net Deflection (mm)
Joules (kN - mm)
Time (sec.)

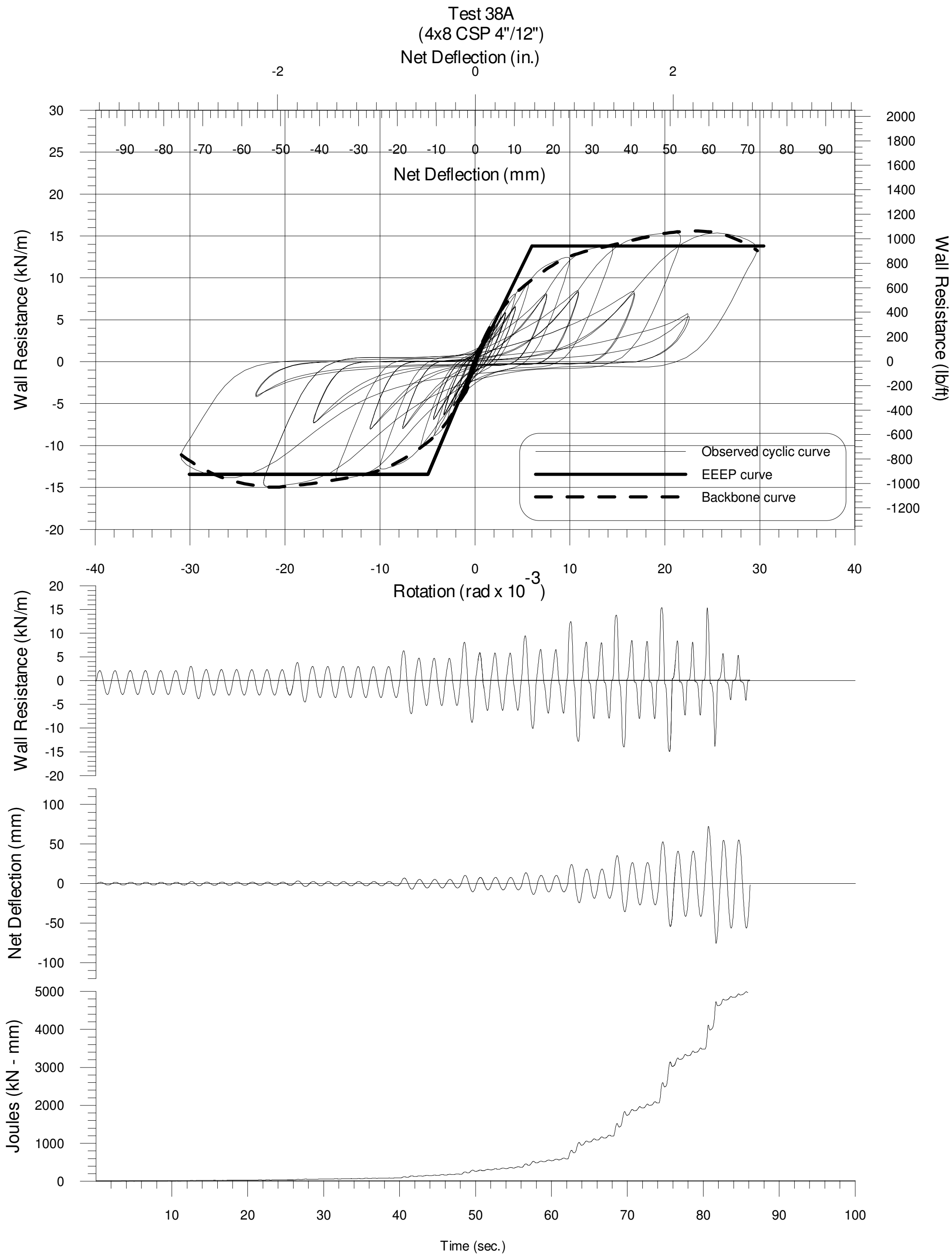


Test 36-A,B,C Backbone
(4x8 CSP 6"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^-3)
A
B
C

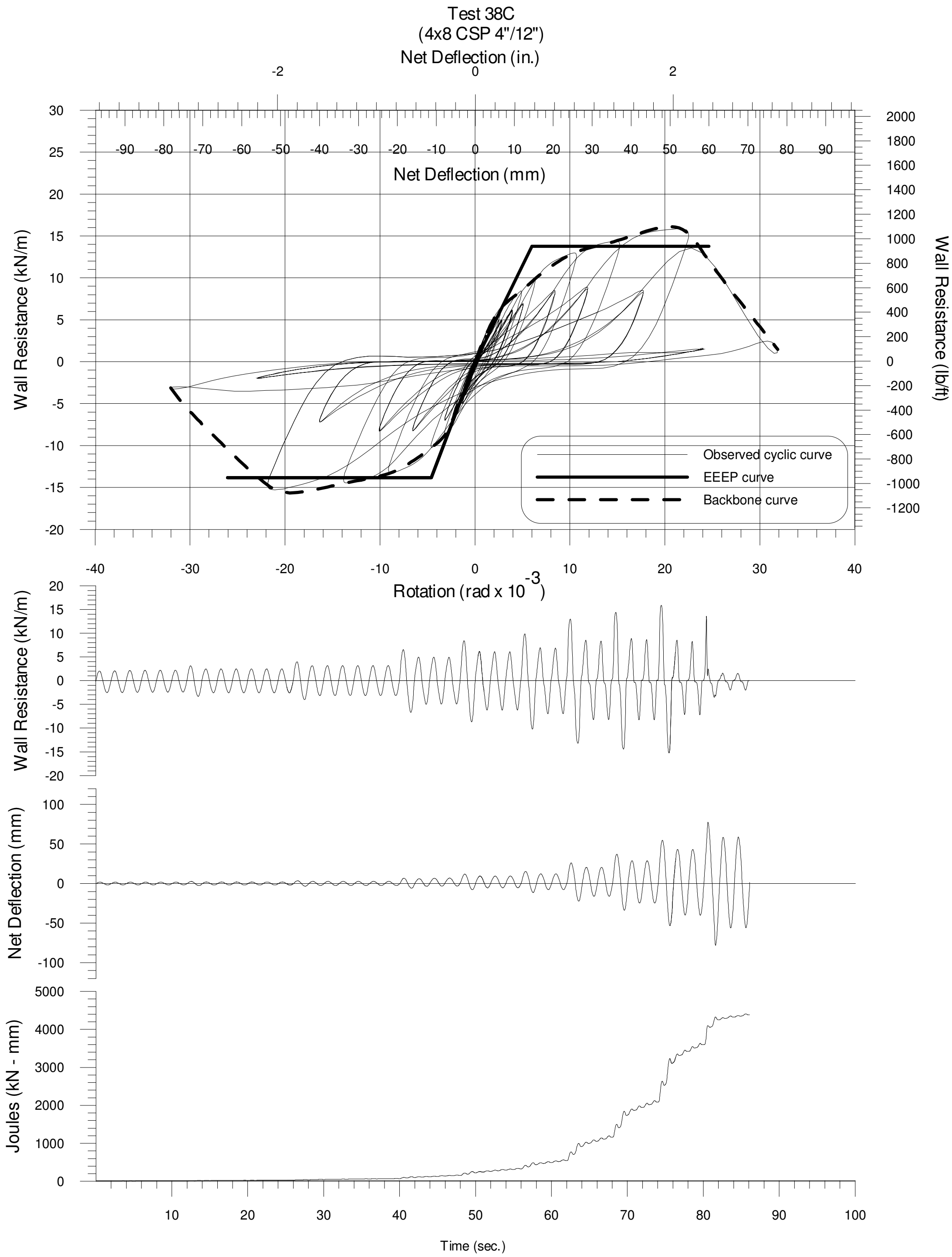


Test 36-A,B,C EEEP
(4x8 CSP 6"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^-3)
A
B
C

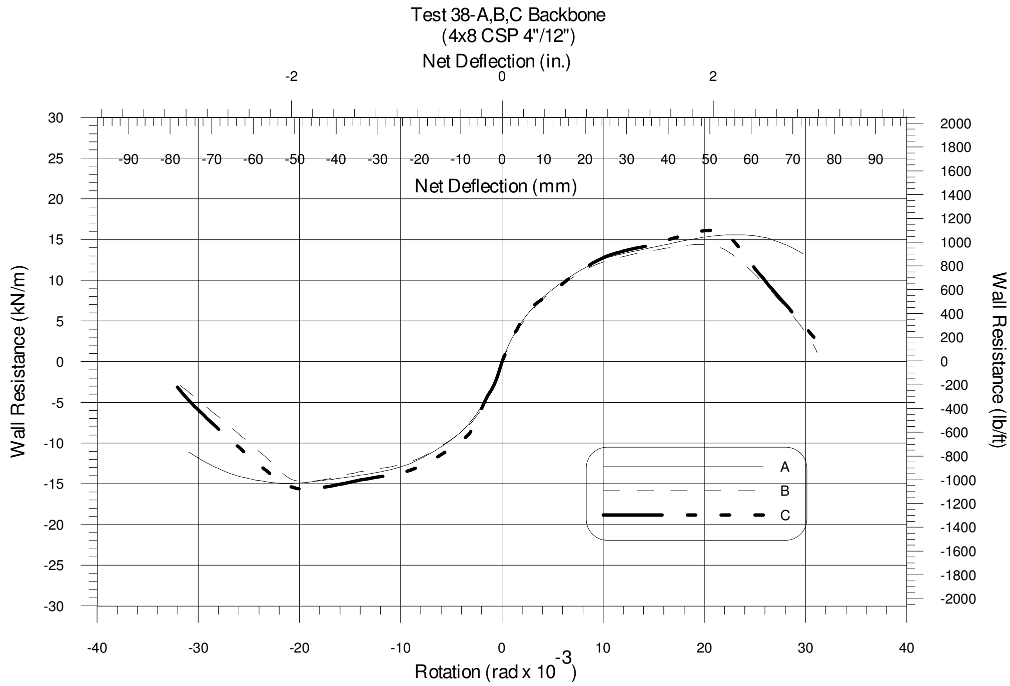

Test 38A
(4x8 CSP 4"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Observed cyclic curve
EEEP curve
Backbone curve
Rotation (rad x 10^-3)
Net Deflection (mm)
Joules (kN - mm)
Time (sec.)

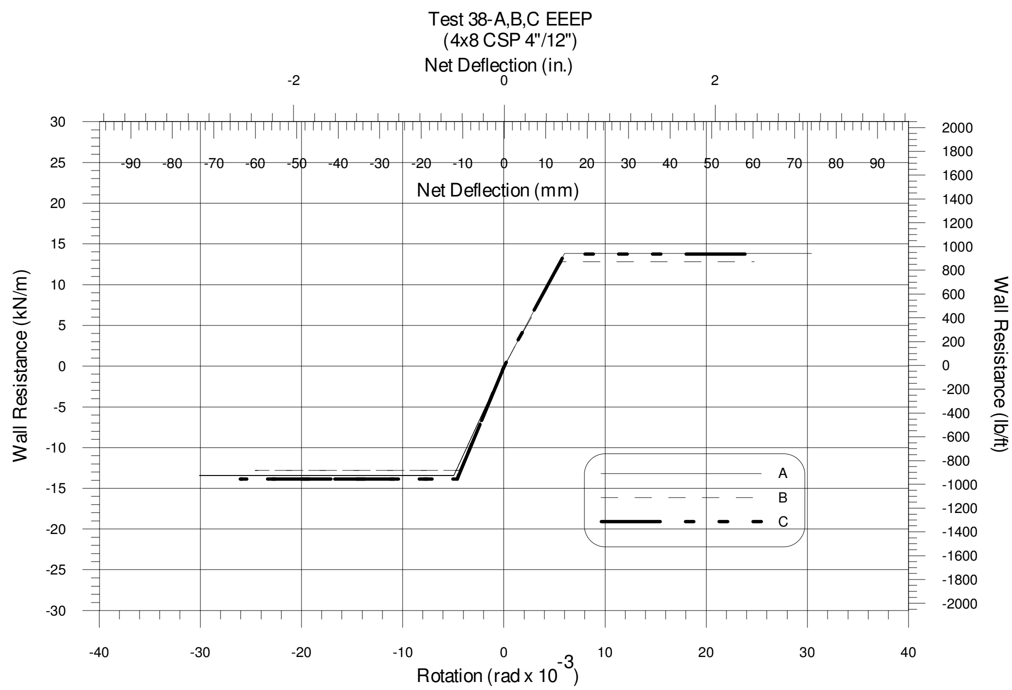


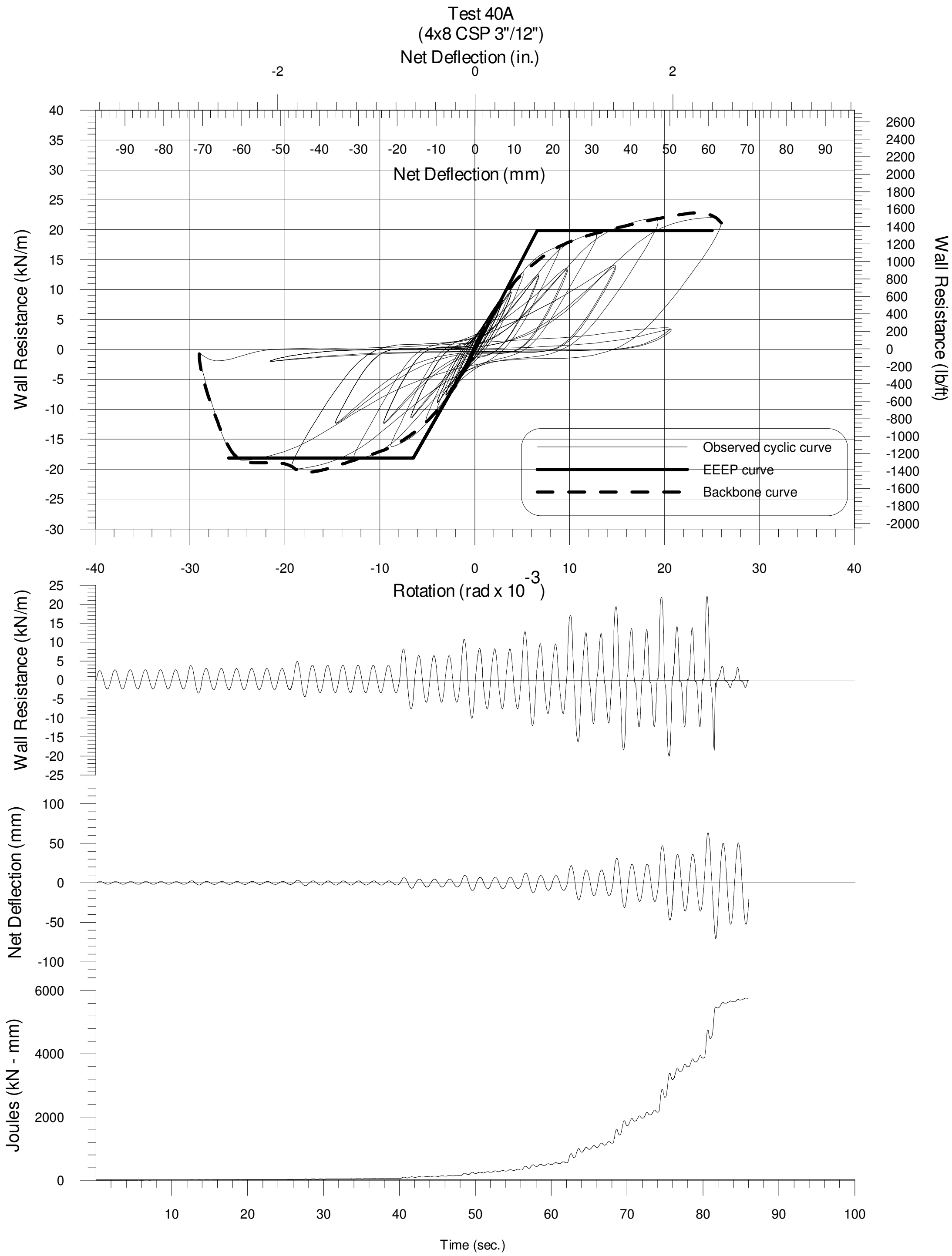
Test 38A
(4x8 CSP 4"/12")
Net Deflection (in.)
-2
0
2
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^-3)
Observed cyclic curve
EEEP curve
Backbone curve
Wall Resistance (kN/m)
Net Deflection (mm)
Joules (kN - mm)
Time (sec.)



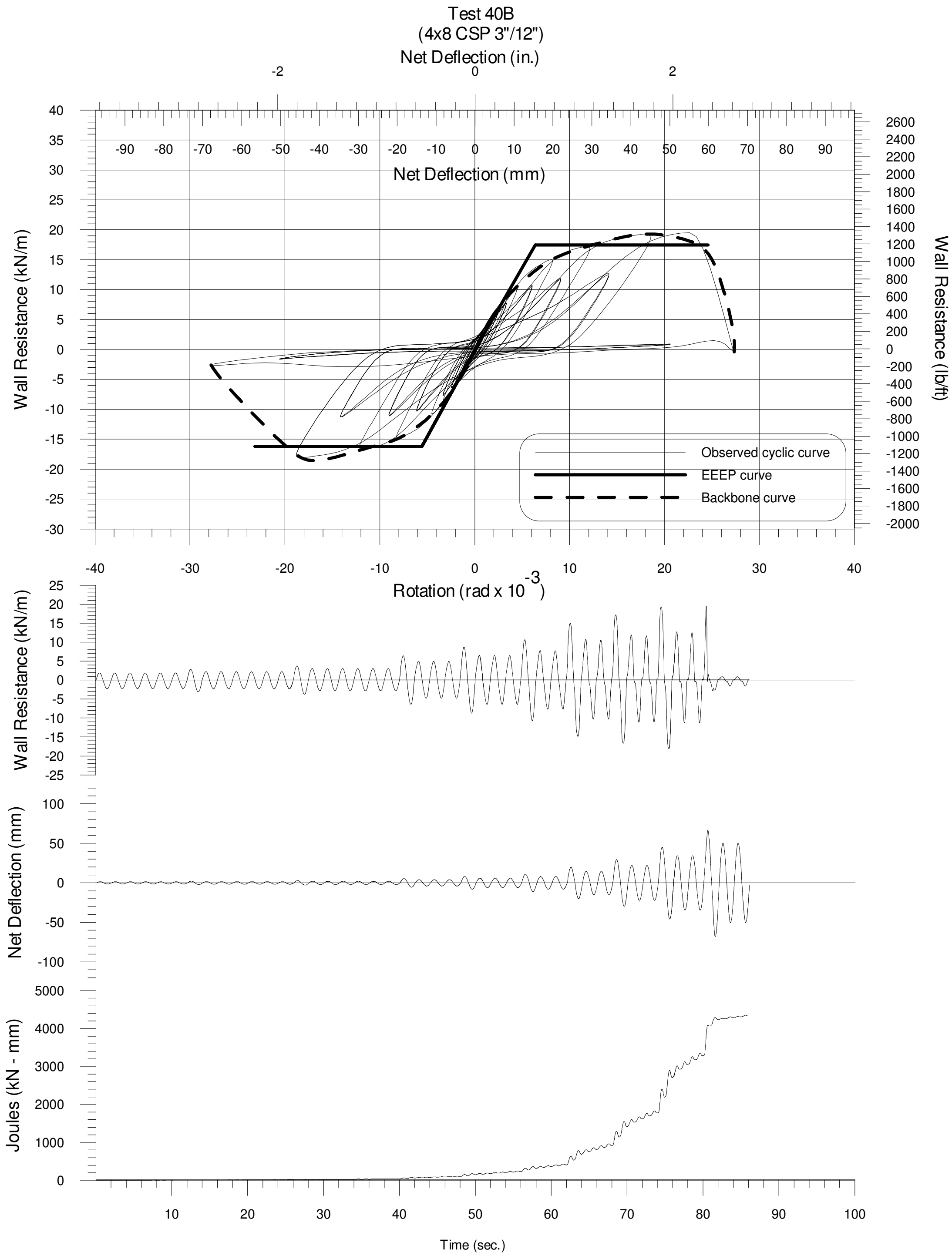
Test 38C
(4x8 CSP 4"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Observed cyclic curve
EEEP curve
Backbone curve
Rotation (rad x 10^-3)
Net Deflection (mm)
Joules (kN - mm)
Time (sec.)

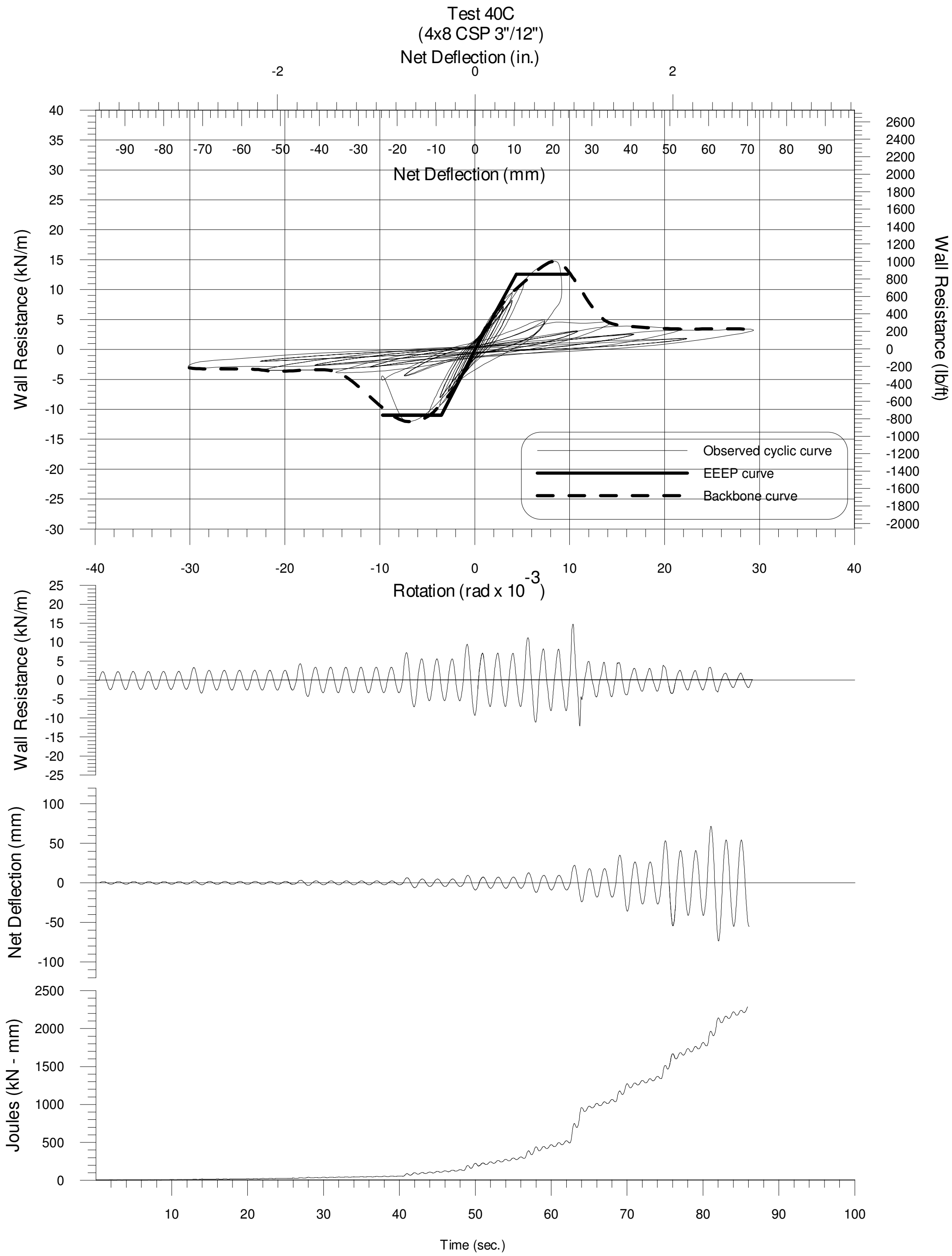

Test 38-A,B,C Backbone
(4x8 CSP 4"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^-3)
A
B
C


Test 38-A,B,C EEEP
(4x8 CSP 4"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^-3)
A
B
C

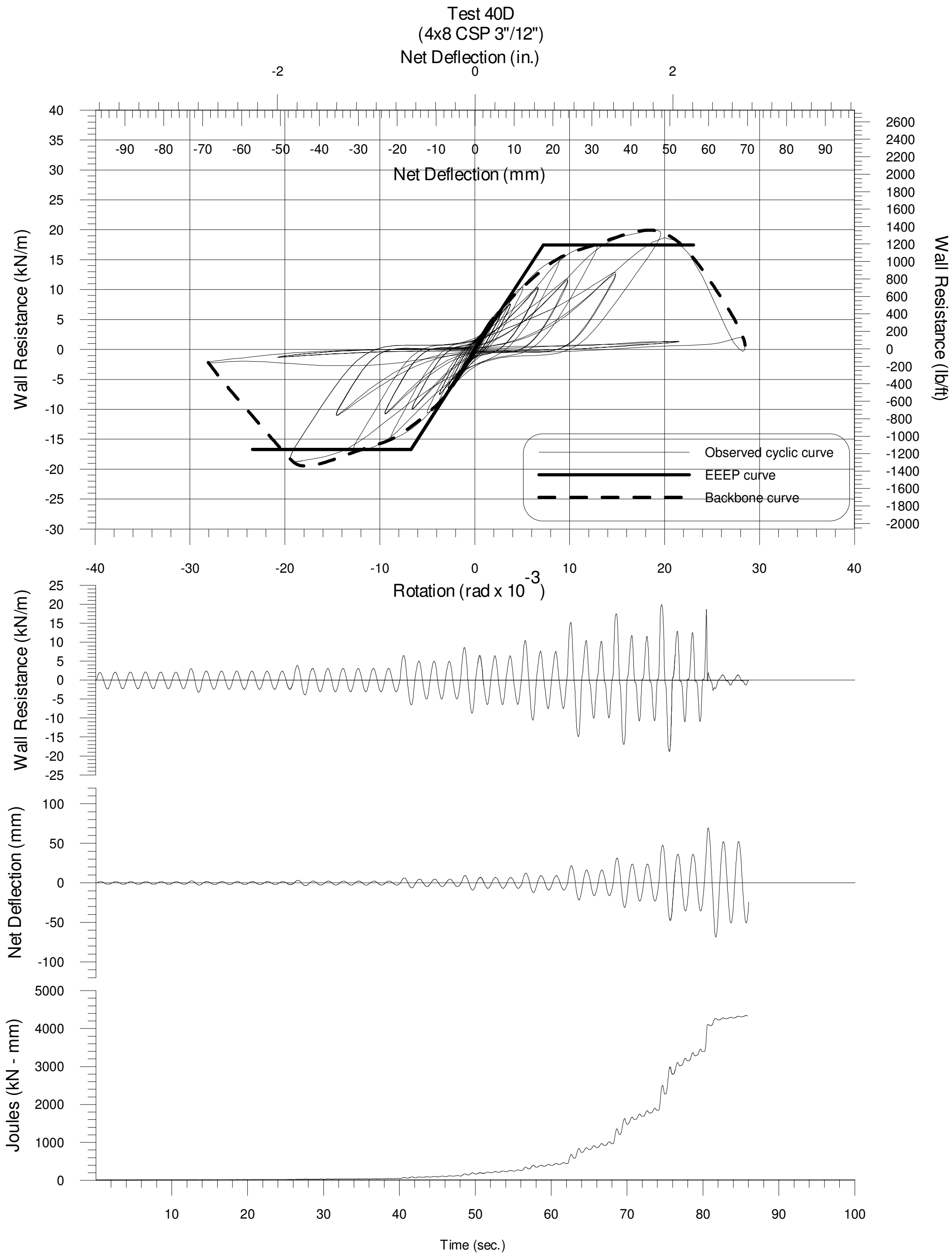


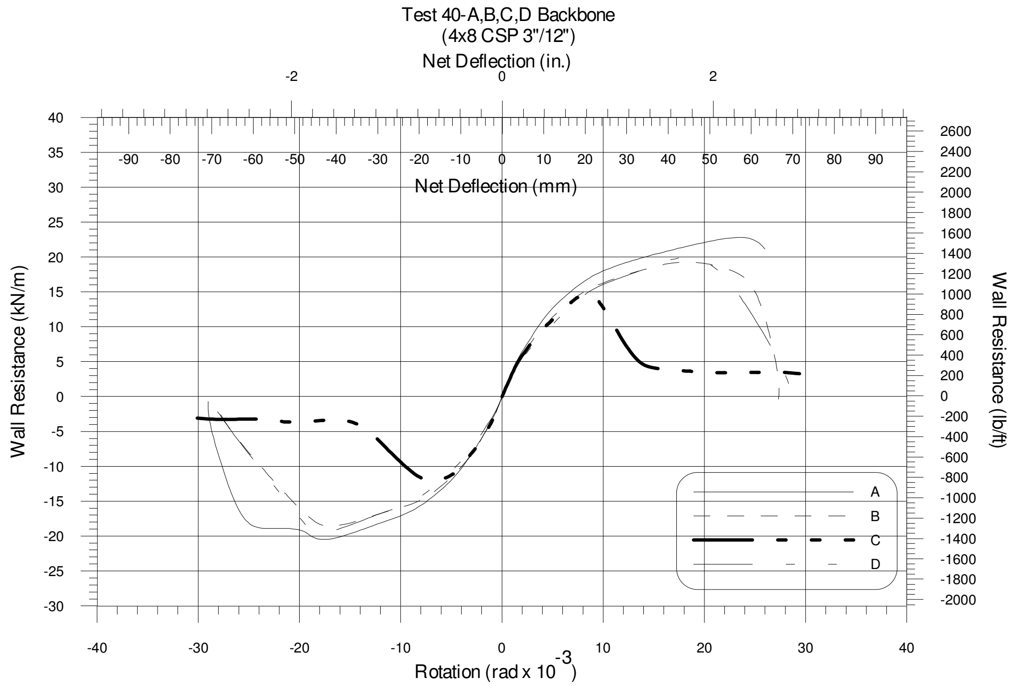
Test 40A
(4x8 CSP 3"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Observed cyclic curve
EEEP curve
Backbone curve
Rotation (rad x 10^-3)
Wall Resistance (kN/m)
Net Deflection (mm)
Joules (kN - mm)
Time (sec.)


Test 40B
(4x8 CSP 3"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^-3)
Observed cyclic curve
EEEP curve
Backbone curve
Net Deflection (mm)
Joules (kN - mm)
Time (sec.)

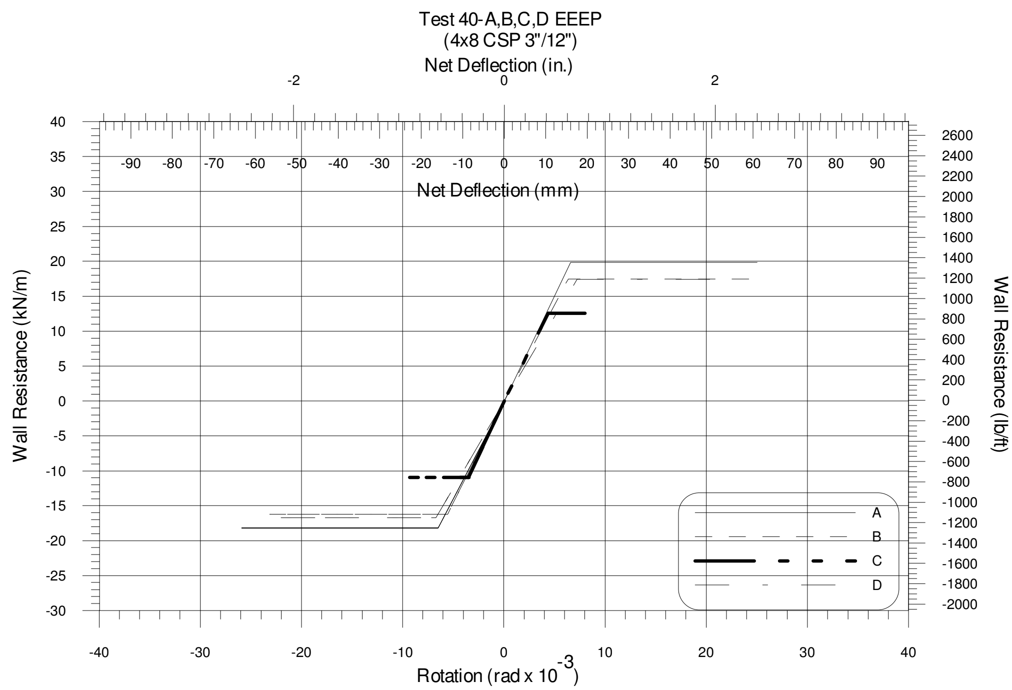


Test 40C
(4x8 CSP 3"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^-3)
Observed cyclic curve
EEEP curve
Backbone curve
Net Deflection (mm)
Joules (kN - mm)
Time (sec.)


Test 40D
(4x8 CSP 3"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Observed cyclic curve
EEEP curve
Backbone curve
Rotation (rad x 10^-3)
Wall Resistance (kN/m)
Net Deflection (mm)
Joules (kN - mm)
Time (sec.)



Test 40-A,B,C,D Backbone
(4x8 CSP 3"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^-3)
A
B
C
D



Test 40-A,B,C,D EEEP
(4x8 CSP 3"/12")
Net Deflection (in.)
Net Deflection (mm)
Wall Resistance (kN/m)
Wall Resistance (lb/ft)
Rotation (rad x 10^-3)
A
B
C
D

APPENDIX V – DESIGN PARAMETER SUMMARY TABLES

TEST 35A

	Parameters	Units
F_u	13.34	kN
$F_{0.8u}$	10.67	kN
$F_{0.4u}$	5.34	kN
F_y	11.41	kN
K_e	0.94	kN/mm
Ductility (μ)	5.43	-
$\Delta_{net.y}$	12.15	mm
$\Delta_{net.u}$	55.69	mm
$\Delta_{net.0.8u}$	65.98	mm
$\Delta_{net.0.4u}$	5.68	mm
$Area_{Backbone}$	683.57	J
$Area_{EEEP}$	683.57	J
Check	**OK**	
R_d	**3.14**	-
S_y	**9.36**	kN/m

TEST 35B

	Parameters	Units
F_u	15.21	kN
$F_{0.8u}$	12.17	kN
$F_{0.4u}$	6.08	kN
F_y	13.12	kN
K_e	1.09	kN/mm
Ductility (μ)	5.14	-
$\Delta_{net.y}$	12.07	mm
$\Delta_{net.u}$	52.80	mm
$\Delta_{net.0.8u}$	62.04	mm
$\Delta_{net.0.4u}$	5.60	mm
$Area_{Backbone}$	734.78	J
$Area_{EEEP}$	734.78	J
Check	**OK**	
R_d	**3.05**	-
S_y	**10.76**	kN/m

TEST 35C

	Parameters	Units
F_u	14.15	kN
$F_{0.8u}$	11.32	kN
$F_{0.4u}$	5.66	kN
F_y	12.30	kN
K_e	1.15	kN/mm
Ductility (μ)	5.33	-
$\Delta_{net.y}$	10.66	mm
$\Delta_{net.u}$	47.20	mm
$\Delta_{net.0.8u}$	56.79	mm
$\Delta_{net.0.4u}$	4.91	mm
$Area_{Backbone}$	632.89	J
$Area_{EEEP}$	632.89	J
Check	**OK**	
R_d	**3.11**	-
S_y	**10.09**	kN/m

TEST 35D

	Parameters	Units
F_u	15.00	kN
$F_{0.8u}$	12.00	kN
$F_{0.4u}$	6.00	kN
F_y	13.44	kN
K_e	1.18	kN/mm
Ductility (μ)	5.23	-
$\Delta_{net.y}$	11.43	mm
$\Delta_{net.u}$	43.29	mm
$\Delta_{net.0.8u}$	59.82	mm
$\Delta_{net.0.4u}$	5.10	mm
$Area_{Backbone}$	727.04	J
$Area_{EEEP}$	727.04	J
Check	**OK**	
R_d	**3.08**	-
S_y	**11.02**	kN/m

TEST 35E

	Parameters	Units
F_u	12.61	kN
$F_{0.8u}$	10.09	kN
$F_{0.4u}$	5.05	kN
F_y	11.28	kN
K_e	1.12	kN/mm
Ductility (μ)	6.86	-
$\Delta_{net.y}$	10.10	mm
$\Delta_{net.u}$	48.50	mm
$\Delta_{net.0.8u}$	69.22	mm
$\Delta_{net.0.4u}$	4.52	mm
$Area_{Backbone}$	723.57	J
$Area_{EEEP}$	723.57	J
Check	**OK**	
R_d	**3.57**	-
S_y	**9.25**	kN/m

TEST 35F

	Parameters	Units
F_u	14.46	kN
$F_{0.8u}$	11.57	kN
$F_{0.4u}$	5.78	kN
F_y	12.78	kN
K_e	1.18	kN/mm
Ductility (μ)	6.28	-
$\Delta_{net.y}$	10.82	mm
$\Delta_{net.u}$	45.75	mm
$\Delta_{net.0.8u}$	67.97	mm
$\Delta_{net.0.4u}$	4.90	mm
$Area_{Backbone}$	799.71	J
$Area_{EEEP}$	799.71	J
Check	**OK**	
R_d	**3.40**	-
S_y	**10.49**	kN/m

36A

	Negative	Positive	Units
F_u	-11.45	11.79	kN
$F_{0.8u}$	-9.16	9.43	kN
$F_{0.4u}$	-4.58	4.72	kN
F_y	-10.15	10.26	kN
K_e	0.95	1.00	kN/mm
Ductility (μ)	5.48	5.13	-
Δ_y	-10.64	10.23	mm
Δ_u	-50.10	44.66	mm
$\Delta_{0.8u}$	-58.30	52.50	mm
$\Delta_{0.4u}$	-4.80	4.70	mm
$Area_{Backbone}$	537.84	486.39	kN-mm
$Area_{EEEP}$	537.84	486.39	kN-mm
Check	**OK**	**OK**	
R_d	**3.16**	**3.04**	-
S_y	**-8.33**	**8.42**	kN/m

36B

	Negative	Positive	Units
F_u	-11.79	13.17	kN
$F_{0.8u}$	-9.43	10.54	kN
$F_{0.4u}$	-4.71	5.27	kN
F_y	-10.56	11.79	kN
K_e	1.02	0.96	kN/mm
Ductility (μ)	5.39	4.71	-
Δ_y	-10.30	12.31	mm
Δ_u	-32.59	47.49	mm
$\Delta_{0.8u}$	-55.50	58.00	mm
$\Delta_{0.4u}$	-4.60	5.50	mm
$Area_{Backbone}$	531.78	611.34	kN-mm
$Area_{EEEP}$	531.78	611.34	kN-mm
Check	**OK**	**OK**	
R_d	**3.13**	**2.90**	-
S_y	**-8.66**	**9.67**	kN/m

36C

	Negative	Positive	Units
F_u	-11.98	13.29	kN
$F_{0.8u}$	-9.59	10.63	kN
$F_{0.4u}$	-4.79	5.32	kN
F_y	-10.96	11.47	kN
K_e	1.02	1.13	kN/mm
Ductility (μ)	5.47	6.23	-
Δ_y	-10.75	10.14	mm
Δ_u	-50.57	49.40	mm
$\Delta_{0.8u}$	-58.80	63.20	mm
$\Delta_{0.4u}$	-4.70	4.70	mm
$Area_{Backbone}$	585.59	666.61	kN-mm
$Area_{EEEP}$	585.59	666.61	kN-mm
Check	**OK**	**OK**	
R_d	**3.15**	**3.39**	-
S_y	**-8.99**	**9.41**	kN/m

TEST 37A

	Parameters	Units
F_u	19.99	kN
$F_{0.8u}$	15.99	kN
$F_{0.4u}$	8.00	kN
F_y	17.65	kN
K_e	1.15	kN/mm
Ductility (μ)	4.39	-
$\Delta_{net.y}$	15.38	mm
$\Delta_{net.u}$	57.24	mm
$\Delta_{net.0.8u}$	67.47	mm
$\Delta_{net.0.4u}$	6.97	mm
$Area_{Backbone}$	1055.33	J
$Area_{EEEP}$	1055.33	J
Check	**OK**	
R_d	**2.79**	-
S_y	**14.48**	kN/m

TEST 37B

	Parameters	Units
F_u	21.81	kN
$F_{0.8u}$	17.45	kN
$F_{0.4u}$	8.72	kN
F_y	18.37	kN
K_e	1.39	kN/mm
Ductility (μ)	4.46	-
$\Delta_{net.y}$	13.18	mm
$\Delta_{net.u}$	53.26	mm
$\Delta_{net.0.8u}$	58.75	mm
$\Delta_{net.0.4u}$	6.26	mm
$Area_{Backbone}$	958.46	J
$Area_{EEEP}$	958.46	J
Check	**OK**	
R_d	**2.81**	-
S_y	**15.07**	kN/m

TEST 37C

	Parameters	Units
F_u	19.81	kN
$F_{0.8u}$	15.85	kN
$F_{0.4u}$	7.92	kN
F_y	17.85	kN
K_e	1.29	kN/mm
Ductility (μ)	5.31	-
$\Delta_{net.y}$	13.78	mm
$\Delta_{net.u}$	57.81	mm
$\Delta_{net.0.8u}$	73.23	mm
$\Delta_{net.0.4u}$	6.12	mm
$Area_{Backbone}$	1184.22	J
$Area_{EEEP}$	1184.22	J
Check	**OK**	
R_d	**3.10**	-
S_y	**14.64**	kN/m

TEST 37D

	Parameters	Units
F_u	20.56	kN
$F_{0.8u}$	16.44	kN
$F_{0.4u}$	8.22	kN
F_y	18.17	kN
K_e	1.34	kN/mm
Ductility (μ)	4.90	-
$\Delta_{net.y}$	13.53	mm
$\Delta_{net.u}$	57.35	mm
$\Delta_{net.0.8u}$	66.32	mm
$\Delta_{net.0.4u}$	6.13	mm
$Area_{Backbone}$	1081.85	J
$Area_{EEEP}$	1081.85	J
Check	**OK**	
R_d	**2.97**	-
S_y	**14.90**	kN/m

TEST 37E

	Parameters	Units
F_u	17.95	kN
$F_{0.8u}$	14.36	kN
$F_{0.4u}$	7.18	kN
F_y	15.49	kN
K_e	1.06	kN/mm
Ductility (μ)	4.85	-
$\Delta_{net.y}$	14.61	mm
$\Delta_{net.u}$	58.62	mm
$\Delta_{net.0.8u}$	70.92	mm
$\Delta_{net.0.4u}$	6.77	mm
$Area_{Backbone}$	985.29	J
$Area_{EEEP}$	985.29	J
Check	**OK**	
R_d	**2.95**	-
S_y	**12.70**	kN/m

TEST 37F

	Parameters	Units
F_u	17.50	kN
$F_{0.8u}$	14.00	kN
$F_{0.4u}$	7.00	kN
F_y	15.57	kN
K_e	1.14	kN/mm
Ductility (μ)	5.08	-
$\Delta_{net.y}$	13.68	mm
$\Delta_{net.u}$	55.36	mm
$\Delta_{net.0.8u}$	69.54	mm
$\Delta_{net.0.4u}$	6.15	mm
$Area_{Backbone}$	976.23	J
$Area_{EEEP}$	976.23	J
Check	**OK**	
R_d	**3.03**	-
S_y	**12.77**	kN/m

	Negative	Positive	Units
F_u	-18.22	18.79	kN
$F_{0.8u}$	-14.58	15.03	kN
$F_{0.4u}$	-7.29	7.51	kN
F_y	-16.37	16.84	kN
K_e	1.35	1.16	kN/mm
Ductility (μ)	6.05	5.09	-
Δ_y	-12.13	14.57	mm
Δ_u	-52.62	50.30	mm
$\Delta_{0.8u}$	-73.40	74.10	mm
$\Delta_{0.4u}$	-5.40	6.50	mm
$Area_{Backbone}$	1102.56	1125.27	kN-mm
$Area_{EEEP}$	1102.56	1125.27	kN-mm
Check	**OK**	**OK**	
R_d	**3.33**	**3.03**	-
S_y	**-13.43**	**13.81**	kN/m

38B

	Negative	Positive	Units
F_u	-17.25	18.15	kN
$F_{0.8u}$	-13.80	14.52	kN
$0.4*F_{0.4u}$	-6.90	7.26	kN
F_y	-15.58	15.63	kN
K_e	1.44	1.12	kN/mm
Ductility (μ)	5.54	4.31	-
Δ_y	-10.84	14.00	mm
Δ_u	-51.85	49.58	mm
$\Delta_{0.8u}$	-60.00	60.30	mm
$\Delta_{0.4u}$	-4.80	6.50	mm
$Area_{Backbone}$	850.36	833.17	kN-mm
$Area_{EEEP}$	850.36	833.17	kN-mm
Check	**OK**	**OK**	
R_d	**3.17**	**2.76**	-
S_y	**-12.78**	**12.82**	kN/m

38C

	Negative	Positive	Units
F_u	-18.63	19.34	kN
$F_{0.8u}$	-14.90	15.47	kN
$F_{0.4u}$	-7.45	7.74	kN
F_y	-16.87	16.77	kN
K_e	1.49	1.15	kN/mm
Ductility (μ)	5.62	4.13	-
Δ_y	-11.32	14.52	mm
Δ_u	-51.36	52.85	mm
$\Delta_{0.8u}$	-63.60	60.00	mm
$\Delta_{0.4u}$	-5.00	6.70	mm
$Area_{Backbone}$	977.37	884.29	kN-mm
$Area_{EEEP}$	977.37	884.29	kN-mm
Check	**OK**	**OK**	
R_d	**3.20**	**2.70**	-
S_y	**-13.84**	**13.75**	kN/m

TEST 39A

	Parameters	Units
F_u	27.15	kN
$F_{0.8u}$	21.72	kN
$F_{0.4u}$	10.86	kN
F_y	22.48	kN
K_e	1.47	kN/mm
Ductility (μ)	4.23	-
$\Delta_{net.y}$	15.29	mm
$\Delta_{net.u}$	58.14	mm
$\Delta_{net.0.8u}$	64.69	mm
$\Delta_{net.0.4u}$	7.39	mm
$Area_{Backbone}$	1282.06	J
$Area_{EEEP}$	1282.06	J
Check	**OK**	
R_d	**2.73**	-
S_y	**18.44**	kN/m

TEST 39B

	Parameters	Units
F_u	21.24	kN
$F_{0.8u}$	16.99	kN
$F_{0.4u}$	8.50	kN
F_y	17.65	kN
K_e	1.05	kN/mm
Ductility (μ)	3.51	-
$\Delta_{net.y}$	16.87	mm
$\Delta_{net.u}$	55.18	mm
$\Delta_{net.0.8u}$	59.15	mm
$\Delta_{net.0.4u}$	8.12	mm
$Area_{Backbone}$	894.90	J
$Area_{EEEP}$	894.90	J
Check	**OK**	
R_d	**2.45**	-
S_y	**14.47**	kN/m

TEST 39C

	Parameters	Units
F_u	21.23	kN
$F_{0.8u}$	16.98	kN
$F_{0.4u}$	8.49	kN
F_y	18.22	kN
K_e	1.07	kN/mm
Ductility (μ)	2.83	-
$\Delta_{net.y}$	17.02	mm
$\Delta_{net.u}$	47.40	mm
$\Delta_{net.0.8u}$	48.18	mm
$\Delta_{net.0.4u}$	7.93	mm
$Area_{Backbone}$	722.87	J
$Area_{EEEP}$	722.87	J
Check	**OK**	
R_d	**2.16**	-
S_y	**14.95**	kN/m

40A

	Negative	Positive	Units
F_u	-24.37	26.93	kN
$F_{0.8u}$	-19.49	21.54	kN
$F_{0.4u}$	-9.75	10.77	kN
F_y	-22.14	24.22	kN
K_e	1.39	1.52	kN/mm
Ductility (μ)	3.98	3.82	-
Δ_y	-15.90	15.97	mm
Δ_u	-46.14	60.96	mm
$\Delta_{0.8u}$	-63.30	60.96	mm
$\Delta_{0.4u}$	-7.00	7.10	mm
$Area_{Backbone}$	1225.60	1283.24	kN-mm
$Area_{EEEP}$	1225.60	1283.24	kN-mm
Check	**OK**	**OK**	
R_d	**2.64**	**2.58**	-
S_y	**-18.16**	**19.87**	kN/m
		2.5% Drift Limit Controls	

	Negative	Positive	Units
F_u	-22.07	23.79	kN
$F_{0.8u}$	-17.65	19.04	kN
$F_{0.4u}$	-8.83	9.52	kN
F_y	-19.74	21.30	kN
K_e	1.45	1.38	kN/mm
Ductility (μ)	4.14	3.87	-
Δ_y	-13.64	15.44	mm
Δ_u	-44.67	55.19	mm
$\Delta_{0.8u}$	-56.50	59.80	mm
$\Delta_{0.4u}$	-6.10	6.90	mm
$Area_{Backbone}$	980.89	1109.31	kN-mm
$Area_{EEEP}$	980.89	1109.31	kN-mm
Check	**OK**	**OK**	
R_d	**2.70**	**2.60**	-
S_y	**-16.20**	**17.47**	kN/m

40C

	Negative	Positive	Units
F_u	-14.72	17.97	kN
$F_{0.8u}$	-11.77	14.38	kN
$F_{0.4u}$	-5.89	7.19	kN
F_y	-13.35	15.31	kN
K_e	1.55	1.45	kN/mm
Ductility (μ)	2.76	2.25	-
Δ_y	-8.62	10.56	mm
Δ_u	-17.24	20.44	mm
$\Delta_{0.8u}$	-23.80	23.80	mm
$\Delta_{0.4u}$	-3.80	4.96	mm
$Area_{Backbone}$	260.25	283.49	kN-mm
$Area_{EEEP}$	260.25	283.49	kN-mm
Check	**OK**	**OK**	
R_d	**2.13**	**1.87**	-
S_y	**-10.95**	**12.56**	kN/m

	Negative	Positive	Units
F_u	-22.90	24.24	kN
$F_{0.8u}$	-18.32	19.39	kN
$F_{0.4u}$	-9.16	9.69	kN
F_y	-20.38	21.25	kN
K_e	1.24	1.21	kN/mm
Ductility (μ)	3.48	3.20	-
Δ_y	-16.46	17.54	mm
Δ_u	-46.76	46.26	mm
$\Delta_{0.8u}$	-57.20	56.10	mm
$\Delta_{0.4u}$	-7.40	8.00	mm
$Area_{Backbone}$	997.86	1005.97	kN-mm
$Area_{EEEP}$	997.86	1005.97	kN-mm
Check	**OK**	**OK**	
R_d	**2.44**	**2.32**	-
S_y	**-16.71**	**17.43**	kN/m