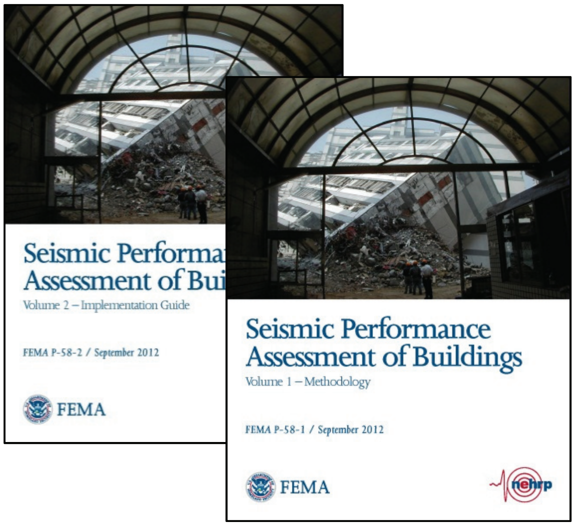

Background Document

FEMA P-58/BD-3.8.2

Fragility Curves for Cold-Formed Steel Light-Frame Structural Systems

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Background Documentation

FEMA P-58 Background Documents are a series of reports documenting the technical background and source information for key aspects of the FEMA P-58 methodology and its implementation. These reports were developed over the course of the 10-year ATC-58/ATC-58-1 Projects funded under FEMA Contracts EMW-2001-RP-0056 and HSFEHQ-06-D-1105.

Background Documents were developed by consultants, serving at various levels within the project hierarchy, reporting the results of: (1) decisions on technical development protocols; (2) focused studies on the development of key aspects of the methodology; (3) documentation of recommended procedures; and (4) collection of available data for the development of structural and nonstructural fragilities. They were initially intended to serve as a record of the technical state-of-knowledge at the time they were produced, and as resources for the development of the eventual project reports. As such, they represent a snapshot in time, and may, or may not, match the technical content, recommended procedures, or data incorporated into the final methodology and its implementation.

This Background Document is intended for the purpose of providing supplemental knowledge to users of the FEMA P-58 methodology. Information contained herein has not been independently verified for accuracy as a stand-alone document, and may have been superseded in its final implementation within the methodology. Users of information in this document assume all liability arising from such use.

Notice

Cover illustration – Primary resource documents for the FEMA P-58 *Seismic Performance Assessment of Buildings, Methodology and Implementation* series of products: FEMA P-58-1, *Volume 1 – Methodology*, and FEMA P-58-2, *Volume 2 – Implementation Guide*.

Fragility Curves for Cold-Formed Steel Light-Frame Structural Systems

Developed for the
ATC-58 Structural Performance Products Team

By

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Table of Contents

1. Introduction and Scope

The objective of this document was to develop fragility curves for cold-formed steel, light-framed shear walls. While many light-frame structures consist of wood frame shear walls, for which fragility curves have already been developed (Ekiert and Filiatrault 2008), the use of cold-formed steel framing with structural panels has become increasingly popular in low-rise residential construction and has been used for quite some time in commercial construction. Therefore, when analyzing damage to a structure with steel-frame walls, it is necessary to utilize cold-formed steel shear wall fragility functions. All walls analyzed in this report are considered part of a platform frame structural system. Balloon framed structural systems are not considered. The cold-formed steel (CFS) wall structural systems considered in this document are as follows:

- CFS System #1: CFS light-framed walls with wood structural panel sheathing (plywood or OSB), seismic hold downs and various fastener spacing.
- CFS System #2: CFS light-framed walls with exterior flat strap X-bracing and seismic hold downs.
- CFS System #3: CFS light-framed walls with 22 mil or 31 mil exterior steel sheathing, seismic hold downs and various fastener spacing.

Fragility curves for walls with Wood Structural Panel (WSP) sheathing were developed to include all walls with wood structural panel sheathing regardless of fastener spacing. The user of these fragility curves can therefore perform damage assessment on CFS structures with walls of known fastener spacing or can perform a more general analysis to save time or in any instance where individual wall fastener spacing is unknown.

None of the test data analyzed for the purpose of this document included walls with gypsum wallboard (GWB) due to the unavailability of experimental data. However the results of monotonic and cyclic tests of full-size CFS light-framed shear walls sheathed with OSB (Salenikovich and Dolan 1999) revealed that CFS shear walls had a similar capacity to wood light-framed shear walls. Additionally, it was shown that failure modes of CFS light-framed shear walls were similar to those present in tests conducted on wood light-framed shear walls (Salenikovich, et al., 1999), with the primary failure mode being head pull through of sheathing screws. Although CFS light-framed shear walls experience slightly more flexure in the framing than wood light-framed shear walls due to local elastic buckling (dimpling) of the wall stud or track around the fastener, deformation patterns observed for CFS light-framed shear walls and wood light-framed shear walls are very similar. It is therefore the judgment of the authors that when analyzing CFS light-framed shear walls with GWB, the fragility parameters derived Damage States 1 and 2 (DS_1 and DS_2) in “Fragility Curves for Wood Light-Frame Structural Systems” (Ekiert and Filiatrault, 2008) should be used.

The fragility functions reported in this document were developed in accordance with fragility reporting requirements for the ATC-58 project (Porter 2007). To develop the fragility parameters θ (mean) and β (dispersion), the authors used methods A and E. Method A is used when test data is available and all tested components experienced the damage state of interest. Method A was used in conjunction with Method E (expert opinion) when analyzing monotonic and cyclic test data to determine Damage State 1 (DS_1) for walls with structural panel sheathing (see Figure 1 for details). The test data analyzed in this document came from experiments conducted by Chen (2004), Serette (1997), Nguyen, Hall and Serette (1996), Boudreault (2005), Branston, Boudreault and Chen (2004), Blais (2006), Hikita (2006), Rokas

(2006) and Branston (2004). Wall specimens tested by the aforementioned authors were subjected to one of the following four loading protocols:

1) Monotonic Loading-wall specimens were loaded to a displacement of 0.5in of lateral deflection after which the load was released. The specimens were then loaded to 1.5in of lateral deflection after which the load was released. The specimens were then loaded to failure.
2) Monotonic Loading-wall specimens were loaded until failure with no release of load.
3) Cyclic Loading-wall specimens were subjected to the Sequential Phase Displacement (SPD) protocol with a cyclic rate of displacement of 1.0Hz.
4) Cyclic Loading-CUREE-Caltech loading protocol.

A set of fragility curves was developed for each CFS shear wall system included in this report. These fragility curves consist of an Engineering Demand Parameter (EDP) and a Damage State (DS_i) associated with the demand parameter. For each wall system, two or three damage states were included based on the type of structural configuration and whether the authors could confidently assert that a certain damage state occurred in a specimen based on test data. If the authors could not confidently assert that a test specimen exhibited a certain damage state, test data for that specimen was omitted from the respective fragility curve. However, test data for the specimen could still be used for lower bound damage states and their respective fragility curves. For example, data for a wall specimen that was not loaded until failure could still be used to generate a fragility curve associated with the damage state of wall panel replacement. Due to the fact that no wall specimens included aesthetic cladding or multiple types of cladding (e.g. gypsum, stucco, etc.) each damage state was identified based on the amount of repair necessary to restore the structural integrity of the wall (e.g. re-fasten structural panel, replace buckled studs, etc.).

Each collection of fragility curves was generated using Story Drift Ratio (SDR) as the Engineering Demand parameter (EDP). SDR is taken to be the amount of horizontal drift the wall experienced expressed in % of story height (i.e. SDR = (horizontal drift/wall height) x100). All data analyzed for this report was checked for outliers using Pierce's criterion as outlined in Section 3.2 of "Developing Fragility Functions for Building Components for ATC-58," (Porter 2007). The probability that a given damage state is exceeded for a specific SDR was calculated using the Hazen plotting position. Once developed, each fragility curve was subjected to a goodness of fit test at the 5% significance level using the Lilliefors Test (Lilliefors 1967).

Included in the appendices of this document is the pertinent experimental data used to develop the fragility curves present within this document. Tables and figures in the appendices include raw test data as well as data obtained from best fit envelope curves developed from cyclic test data. Additionally, summaries of field reports for individual wall specimen damage states are included in Appendix B.

2. Fragilities of CFS Walls with WSP Sheathing and Various Fastener Spacing

This section of the report includes fragility functions for all CFS System #1 wall types. These curves were developed by combining all shear wall test data for walls with WSP sheathing, regardless of the spacing of the sheathing fasteners. These fragility curves will be especially useful, when large-scale damage assessments are performed in which there is not significant time to individually assess damage to numerous buildings based on the numerous fastener schedules of structural walls. These fragility functions will also be of great use when damage assessment is performed on a building comprised of CFS walls with unknown faster spacing.

Construction of the fragility curves for CFS light-frame shear walls with wood structural panel sheathing and various fastener spacing was based cyclic and monotonic test data from experiments conducted by Chen (2004), Serette (1997), Nguyen, Hall and Serette (1996), Boudreault (2005), Branston, Boudreault and Chen (2004), Blais (2006), Hikita (2006), Rokas (2006) and Branston (2004). Specifications for the wall specimens tested are as follows:

- Walls 8ft in height by either 2ft, 4ft or 8ft in length
- 1-1/2"x3-1/2" A446 33ksi steel top and bottom tracks with 38 mil thickness
- 1-1/2"x3-1/2" A446 33ksi steel studs spaced at 24" o.c.
- No. 8-1" sharp point flat head screws for panel to framing connection for '96 and '97 wall specimens
- No. 8-1.5" self piercing bugle head screws for panel to framing connection for all other wall specimens
- Wood structural panel sheathing attached with long dimension parallel to studs
- Spacing of sheathing to framing fasteners at 2"-6" on panel edges 12" spacing in the field
- Seismic hold-downs at wall ends

2.1 Definition of Damage States

For all walls with wood structural panel sheathing, three damage states were defined based on the level of repair needed to restore the wall to a non-damaged state. The first type of repair (DS_1) consists of refastening the structural wall panel. The authors defined DS_1 to be the SDR (%) at which either monotonic curves or best-fit envelope curves from experimental data show significant or abrupt decrease in stiffness (as determined by viewing two tangent lines to the test load-deflection curve or envelope curve). The change in stiffness considered as significant was a 40% - 60% decrease in stiffness. The intersection of the two tangent lines defined the displacement for DS_1. This decrease in stiffness is caused by either pull through of the sheathing to framing connectors from the wood structural panel sheathing or local crushing of the wall panel at the connector to sheathing interface. In the authors' opinion (that is based upon observations of wall testing) this level of damage is repairable with less than 20% of the sheathing fasteners showing distress. These fasteners are usually located in the corners of the sheathing panels. The repair would be made at a time where the finish material envelope, such as siding material, were removed, and the repair would entail placing new screws near the damaged screws, but in undamaged sheathing material. This is a repair that often will not be done because unless close inspection of the sheathing is done, the wall will not necessarily show distress. The finish materials would have to be removed to observe the damage to the sheathing around the fasteners. Refer to Figure 1 for an example of a best-fit envelope curve at which DS_1 is defined. The authors used both negative and positive displacements to establish average DS_1 values for each test specimen.

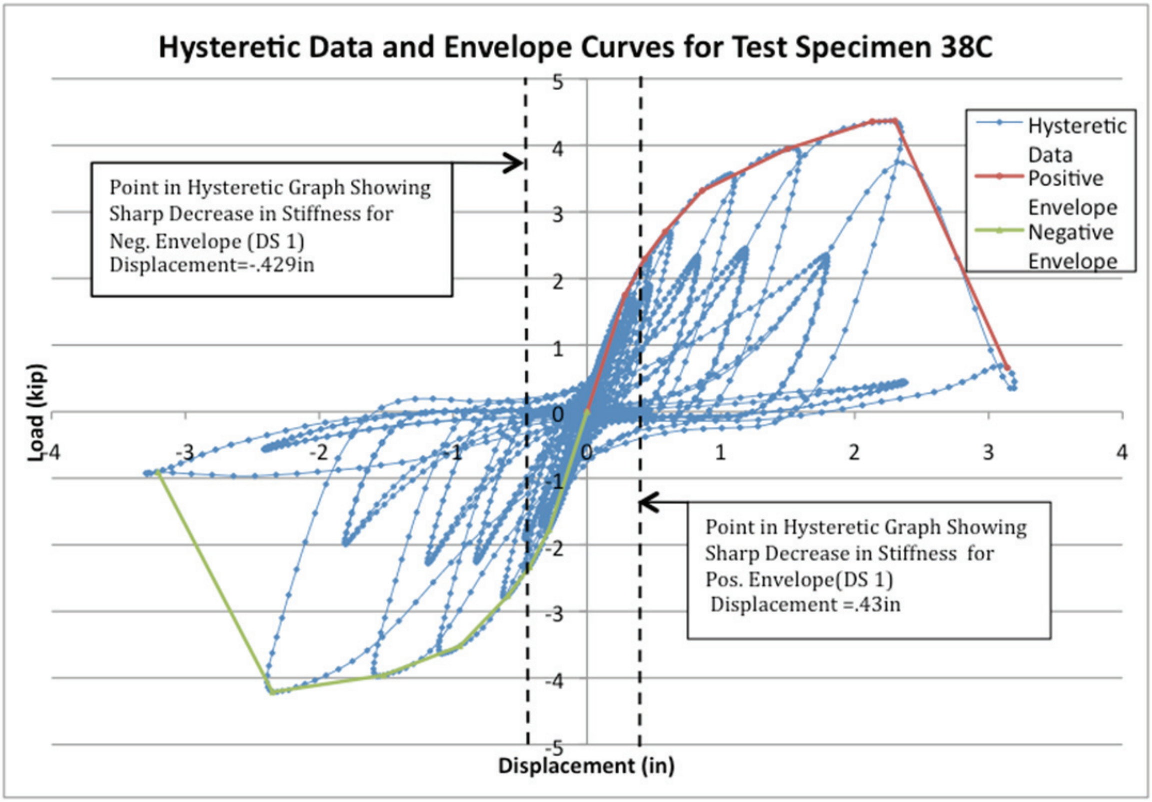


Figure 1-Example of DS_1 Displacement Values from Hysteretic Data. Test Data from Rokas and Rogers (2006)

A method similar to that defining DS_1 was used to define the second damage state (DS_2). The SDR at DS_2 was taken to be the SDR at which the wall specimens experienced peak load. Following peak load and corresponding SDR (%), the walls exhibited a sharp decrease in stiffness (usually a negative stiffness) prior to failure. At the point of peak load, wall specimens exhibited one or more of the following failure modes:

1) Permanent rotation of sheathing
2) Most screw heads have pull-through of sheathing, or
3) Most screws have experienced tear out at sheathing panel edges

Therefore, DS_2 repairs would entail removal of the building contents within 6 feet of the wall, removal of the finish materials, and complete replacement of all structural sheathing panels. In addition to this, the authors recommend inspecting all framing components (tracks and studs) for buckling. In the case of any track or flange yielding or buckling, the damaged framing components would need to be replaced in addition to the sheathing. Experience shows that the top and bottom tracks of the framing are the two elements that most likely will show damage at this load level. They will probably have to be replaced or patched 50 percent of the time. A splice can be used to stiffen the buckled section of the track flange between the studs if the track has not been bent. Few studs show distress at this level. If they do, they will usually be the end studs due to the unbalanced forces in them. However, if they are designed for the overstrength, these will usually not be significantly damaged other than locally where the screws cause dimpling. If the new sheathing is attached in new locations, the existing studs should function as expected. Shown in Figure 2 is an example of DS_2 determination based on review of cyclic test data.

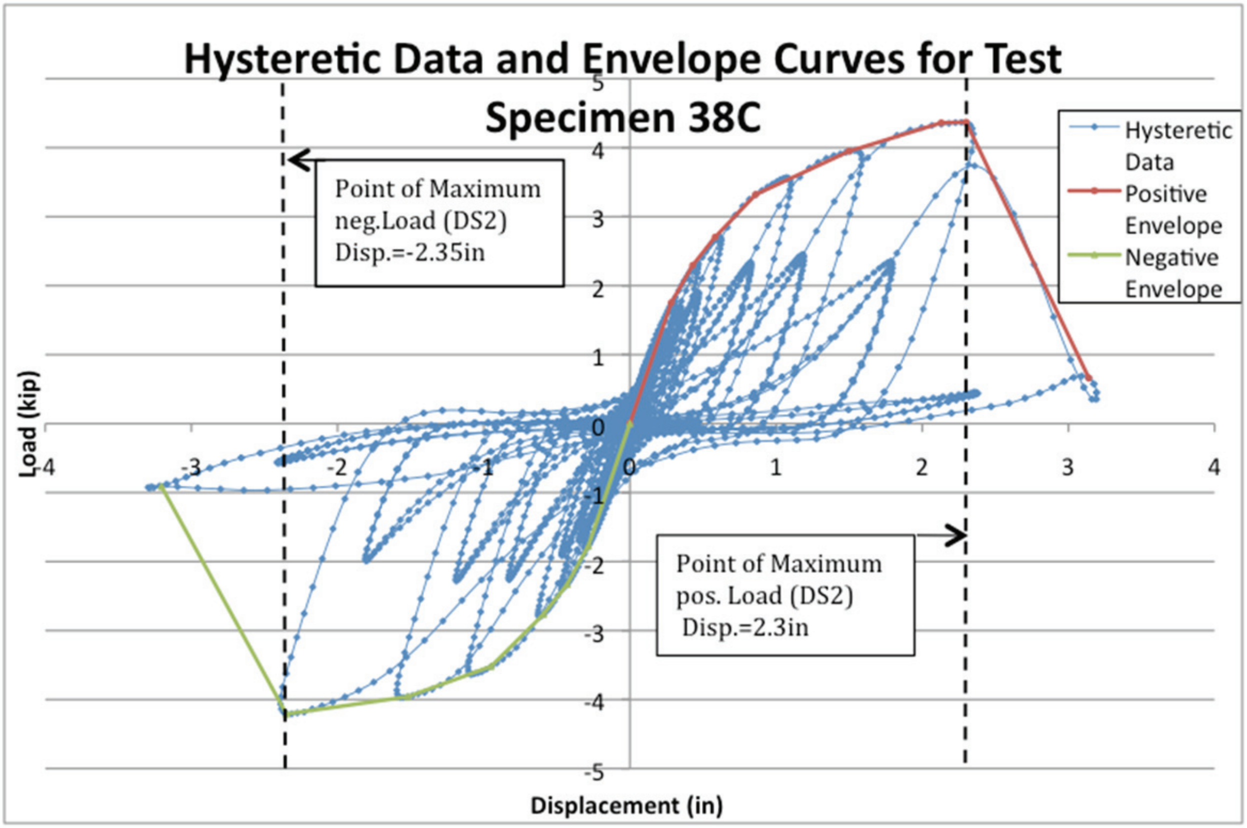


Figure 2- Example of DS_2 Displacement Values from Hysteretic Data. Test Data from Rokas and Rogers (2006)

In the case of DS_3, it is required that the wall be torn down and rebuilt. DS_3 was determined by the authors to correspond to the SDR at which the wall specimen experienced 80% of post peak loading. The definition of failure being defined as when the wall reaches a displacement with a load equal to 80% of the peak load for the wall has been used for several years in ASTM 2126 and other assembly test standards as well as research projects such as the CUREE-Caltech Woodframe project. When a wall specimen reached the SDR corresponding to the pre-determined failure load of 80% post peak load, the specimen exhibited physical deformations associated with DS_2 in addition to one or more of the following failure modes:

1) Wood bearing failure at panel to fastener interface
2) Local elastic buckling (dimpling) of studs at fastener penetrations
3) Global buckling of studs or tracks
4) Shear failure of fasteners
5) Withdrawal of fasteners from studs

The analysis procedure for DS_3 was similar to the procedures followed to obtain SDR (%)'s for DS_1 and DS_2. Both monotonic and cyclic test data was analyzed to determine 80% post peak load displacement values. Multiple specimens were encountered which, when subjected to cyclic loading, did not fail due to limitations of the test equipment. These specimens were omitted from the data set used to develop the DS_3 fragility curve. Additionally, some specimens failed at loads corresponding to displacements much lower than the mean 80% post-peak displacement value. The most common factor effecting premature failure is improper construction methods or pre-existing damage to components such as local buckling in the end studs due to impact damage. Therefore, these specimens were omitted from the data set using Pierce's Criterion. A reasonable quality assurance inspection of materials used in wall construction would typically eliminate these types of problems.

DS_3 SDR values for walls tested under cyclic loading protocol were obtained using the same method as shown for DS_2 and DS_3. Shown in Figure 3 is an example of one DS_3 SDR value obtained from monotonic test data. The three damage states considered for all walls with structural panels are listed in Table 1 and illustrated in Figures 4, 5 and 6.

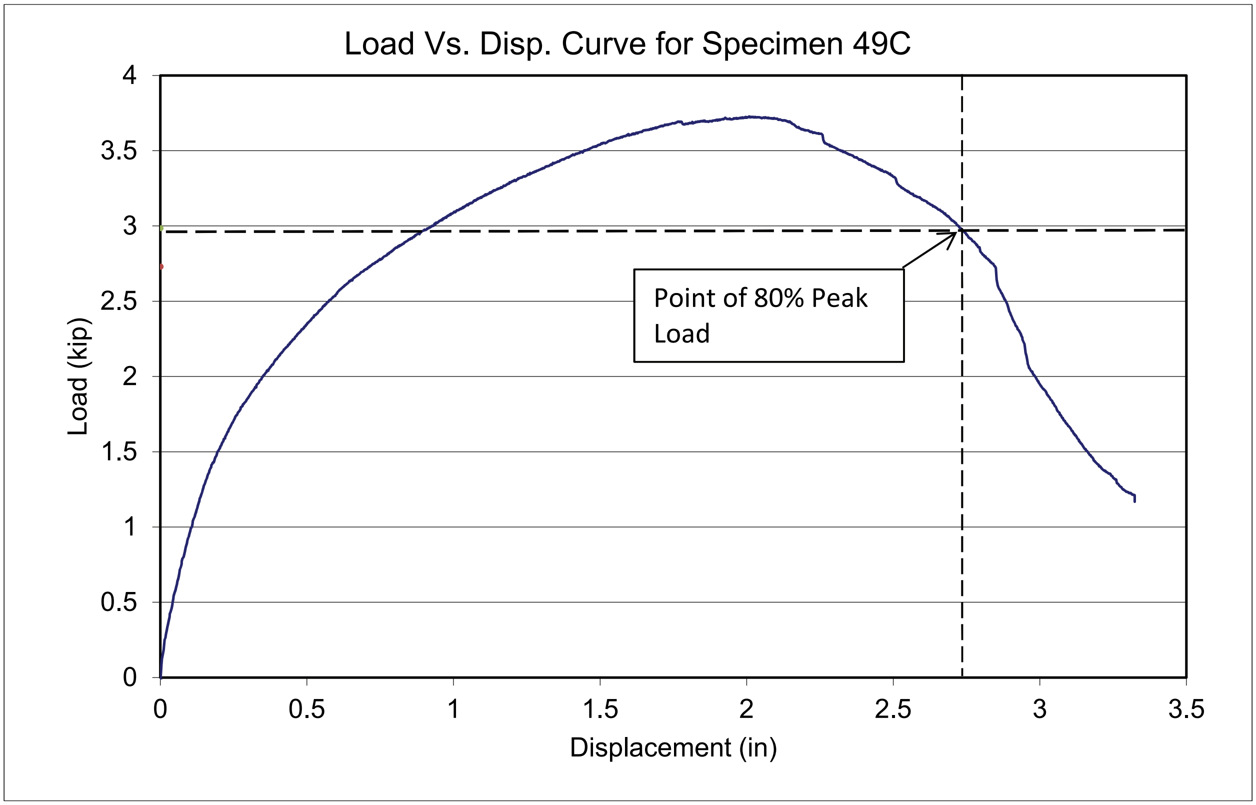
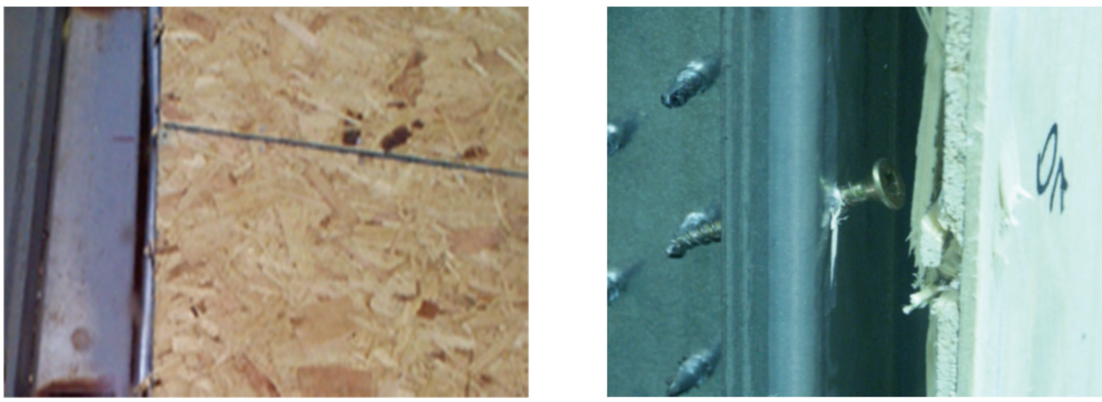


Figure 3-Example of DS_3 obtained from Monotonic Test Data. Test data from Hikita (2006).

Table 1 - Description of Damage States and Required Repairs for all Walls with WSP Sheathing.

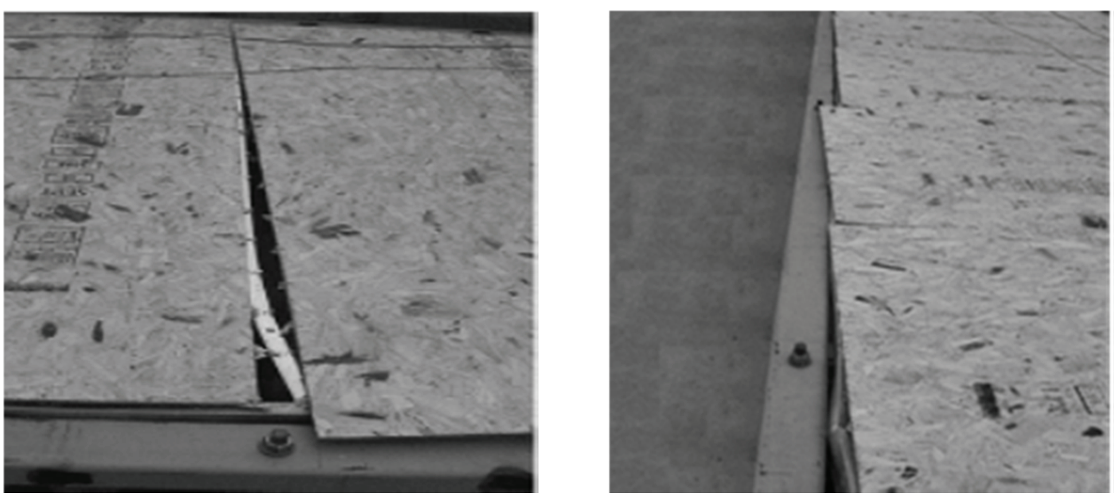
Damage States (DS_i)	Description of Damage State

DS_1	Fastener Pull through- Removal of contents within 6 feet of wall, Refasten structural panels at locations showing damage (up to 20% of sheathing screws)
DS_2	Failure of structural panels- Removal of contents within 6 feet of wall; Removal of sheathing panels; Inspect studs and tracks for damage other than local dimpling from previous screws; Replacement/repair of damaged framing, Replacement of sheathing
DS_3	Failure of wall-Replace wall



(a) (b)

Figures 4a and 4b- Screw Head Pull-Through of Sheathing (DS_1)



(a) (b)

Figures 5a and 5b-Permanent Rotation of Sheathing with Fastener Pull-Through (DS_2)


(a) (b)

Figures 6a and 6b-DS_3 buckling of wall track (a) and buckling of wall studs (b)

2.2 Development of Fragility Curves

The fragility curves constructed for all walls with structural panels are shown in Figure 7. The values for fragility parameters θ and β (mean and dispersion respectively) are given in Table 2.

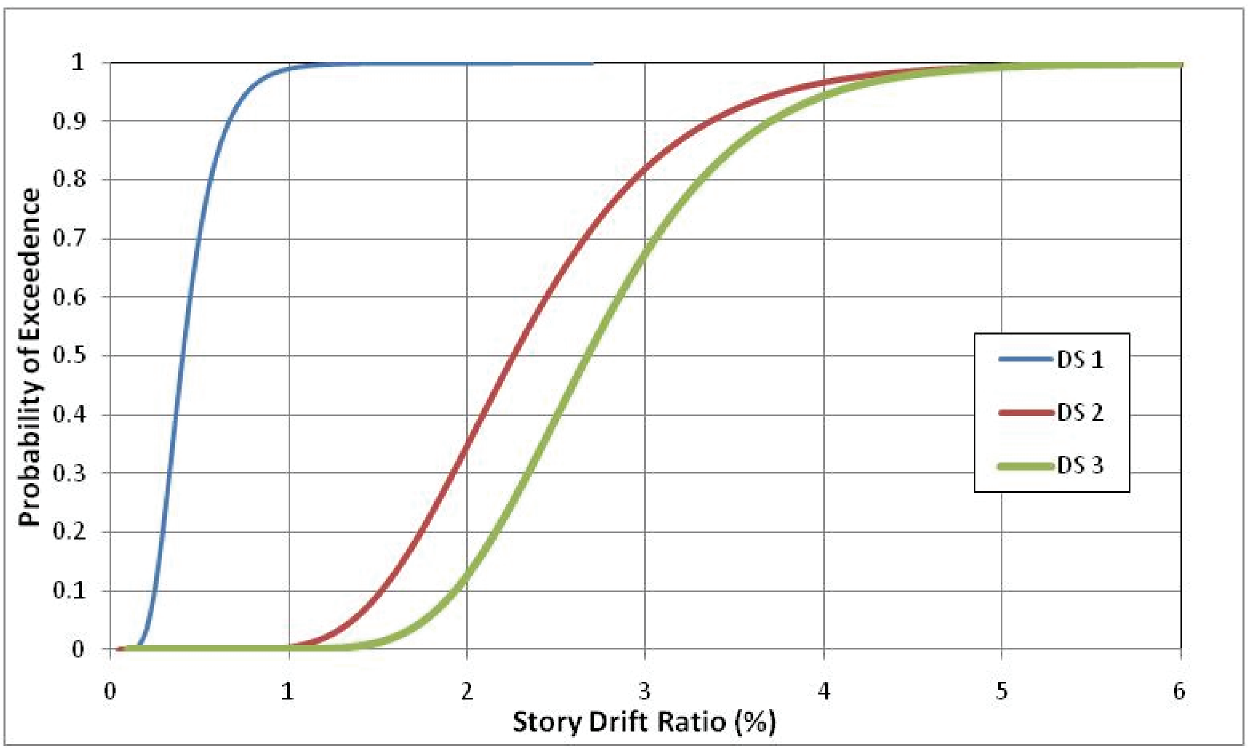


Figure 7 – Fragility Curves for all Walls with WSP Sheathing.

Table 2 – Median and Dispersion Values for all Walls with WSP Sheathing.

Damage States	Demand Parameter (DP)	Median (θ)	Dispersion (β)
DS_1		0.40	0.40
DS_2	Story Drift Ratio SDR (%)	2.26	0.30
DS_3		2.67	0.25

3. Fragilities of Shear Walls with Flat Strap X-Bracing

This section addresses the development of fragility curves for shear walls with flat-strap diagonal bracing (X-bracing). Very little testing has performed on shear walls with X-bracing. Although test data was limited for the development of fragility curves for walls with X-bracing, due to the infrequency of this construction method being utilized in high wind or seismic zones, the authors believe the generation of these fragility curves to be important considering that X-bracing as a means of lateral reinforcement is deemed acceptable by AISI Section E8 (AISI 2001). Specifications for the wall specimens tested are as follows:

- Walls 8ft in height by 4ft in length
- 1-1/2"x3-1/2" A446 33ksi steel top and bottom tracks with 33 mil thickness
- 1-1/2"x3-1/2" A446 33ksi steel studs spaced at 24" o.c.
- 4-1/2" 22 mil or 31 mil flat strap X-bracing one side
- No 8-1/2in self drilling modified truss head screw (20 screws used to attach strap to gusset plate)
- Seismic tie-downs at wall ends

3.1 Definition of Damage States

The damage states defined in this section are different than those defined in previous sections. Data was obtained for cyclic tests performed on walls with X-bracing (Serrette, 1997). Although no data from monotonic testing of X-brace walls was analyzed for development of these fragility curves, for assemblies with 4-1/2" X-bracing failure of the specimens was identical to that observed during monotonic loading tests (Serrette, 1997). Based on the results from tests performed by Serrette, engineers must be cautious when designing with X-bracing in high wind and seismic zones since when under high loads, straps attached on only one side of the shear wall result in eccentricity which can put both the chord stud and track in strong axis bending. The combination of these behaviors 'pulls' the track out of plane, resulting in failure of the wall before the strap capacity is reached (Serrette, 1997). Therefore it is suggested that when designing walls with X-bracing on one side, designers should design the chord studs and tracks for 150% of the X-brace yield strength (Serrette, 1997). The industry has recognized this issue and has begun work with Collin Roger at McGill University to develop improved design methodologies for steel X-bracing. With these findings in mind, the authors have defined two damage states for walls with flat strap X-bracing. Since few observations were recorded throughout the loading phase, confident assertions regarding SDR values at which DS_1 and DS_2 occurred can only be made for values at peak load and wall failure respectively. Analysis of data to determine DS_1 and DS_2 was performed using the same methods highlighted in Section 2 of this document (see Figures 1 and 2). DS_1 is defined at the point of peak load. At this damage state, local buckling of the chord stud occurs. Repair of the buckled chord stud will result in removal contents within 6 feet of the wall, removal of any cladding components (siding, GWB, etc.), and replacement of the buckled stud(s). One should expect to replace both end studs in walls that reach this damage state.

DS_2 occurs at 80% of post peak loading. At this point, the wall has failed, either due to eccentricities resulting in strong axis bending of studs and tracks or due to yielding of the X-bracing. If DS_2 is reached, complete reconstruction of the wall is required. Figures 12 and 13 depict damage states DS_1 and DS_2 respectively.

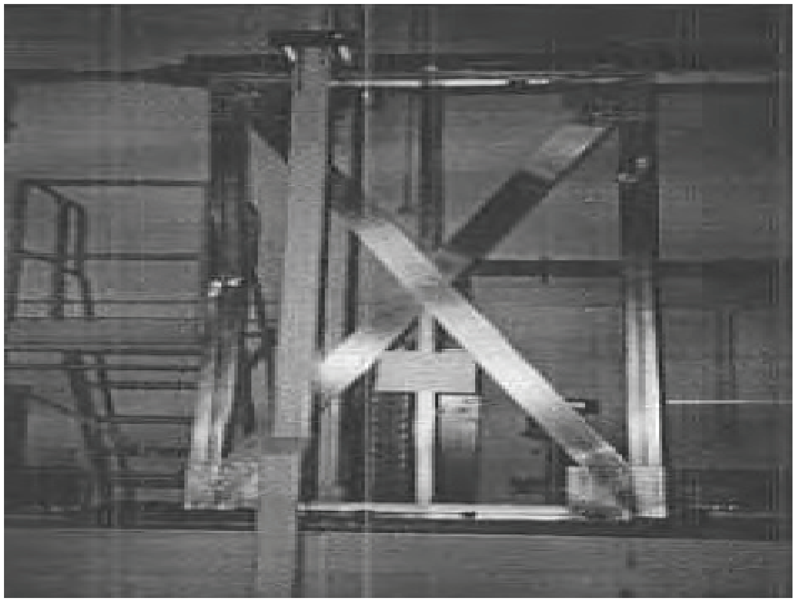


Figure 12 – Buckling of chord stud (DS_1)

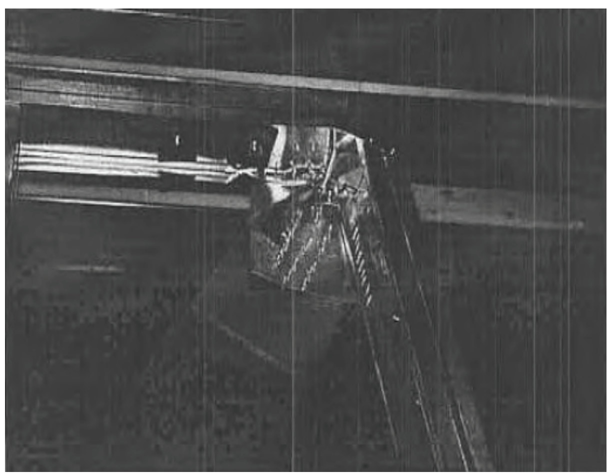


Figure 13- Bending yielding of track, X-bracing and Gusset (DS_2)

3.2 Development of Fragility Curves

Construction of the fragility curves for shear walls with flat strap X-bracing was based on cyclic test data (Serrette, 1997). Only data pertaining to walls with 4-1/2" wide X-bracing was available to construct these fragility curves. Therefore, the authors advise that these fragility curves be used only when assessing damage to walls with 4-1/2" X-bracing since different failure modes were reported to exist with different strap specifications. As stated earlier in this section, the industry is addressing this problem with current testing. Figure 14 displays DS_1 and DS_2 for walls with 4-1/2" flat strap X-bracing. Median and dispersion values for these fragility curves are shown in Table 11.

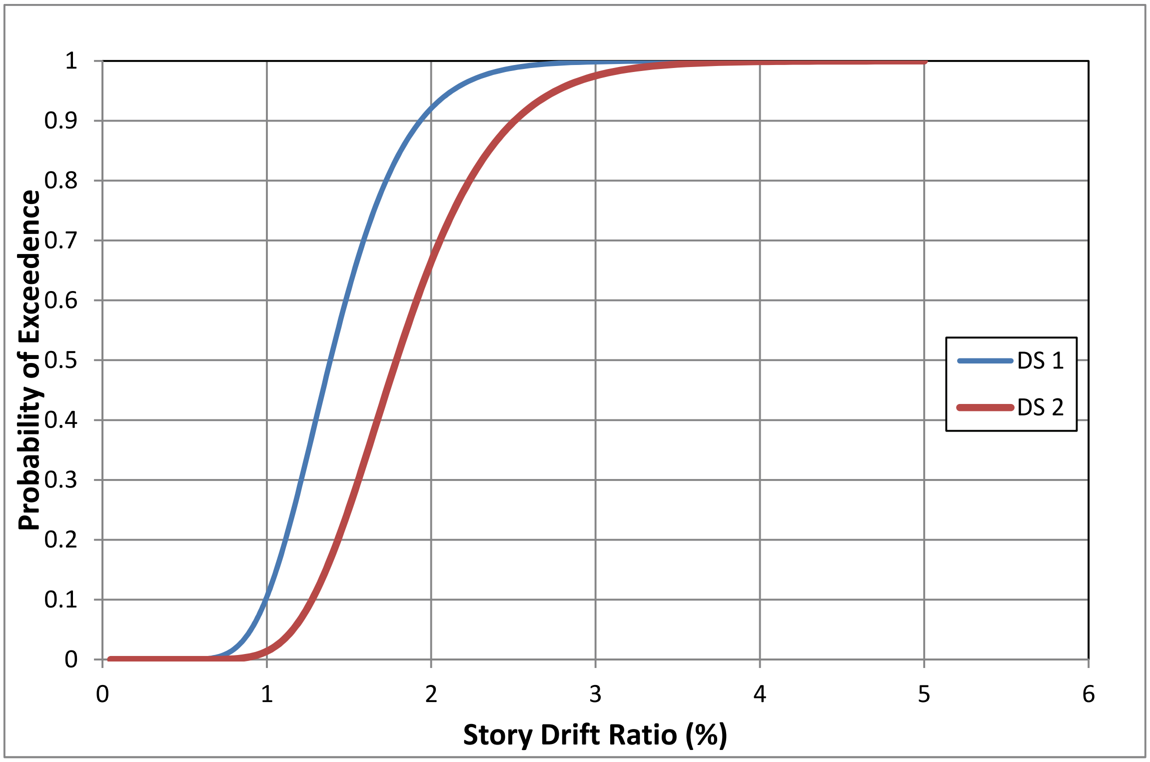


Figure 14 – Fragilities of Walls with 4-1/2" Flat Strap X-Bracing.

Table 11 – Median and Dispersion Values for Walls with 4-1/2" Flat Strap X-Bracing

Damage States (DS_i)	Demand Parameter (DP)	Median (θ)	Dispersion (β)
DS_1	Story Drift Ratio SDR (%)	1.39	.25
DS_2		1.79	.25

4. Fragilities of Shear Walls with 22 mil or 31 mil Steel Sheathing

Construction of fragility curves for CFS walls with 22 or 31 mil steel sheathing was based on cyclic test data (Serrette, 1997). As reported by Serrette (1997) all walls with steel sheathing as the main lateral force resisting system performed quite well when subjected to cyclic loading. Serrette reported that using thicker gauge steel sheathing provides higher design capacities, yet the failure mode moves from rupture at the edge of the steel sheathing to sheathing screw pullout from wall studs (Serrette, 1997). Aspect ratios (height/width) of walls used to develop the fragility curves in this section ranged from 2:1 to a high aspect ratio of 4:1 (2ftx8ft wall) which is the maximum allowable aspect ratio shear walls (AISI 2001).

Specifications for the wall specimens tested are as follows:

- Walls 8ft in height by 2ft or 4ft length
- 1-1/2"x3-1/2" A446 33ksi steel top and bottom tracks with 33 mil thickness
- 1-1/2"x3-1/2" A446 33ksi steel studs spaced at 24" o.c.
- 22 mil or 31 mil steel sheathing
- No. 8-18x1/2in self-drilling modified truss head screws used to attach sheathing to studs
- Fastener pattern used to attach steel sheathing to studs ranged from 6"/12" to 2"/12"
- Seismic tie-downs at wall ends

4.1 Definition of Damage States

For walls with 22 or 31 mil steel sheathing, two damage states were defined. The first was determined based on the individual SDR drift of walls at peak load capacity. At this SDR, walls exhibited either pull out of the fastener from framing members or block shear rupture of the steel sheathing at panel edges. As was previously discussed, pull out of fasteners from framing members is more likely to be the governing failure mode with walls sheathed with thicker steel sheathing (31 mil). Additionally, it was reported by Serrette (1997) that walls high aspect ratios (4:1) are capable of resisting high loads at fairly low displacements. However, after the seismic event, the wall will have zero initial stiffness and will therefore not resist further loading until brought back to the displacement at which the initial peak load occurred. This being said, the authors recommend complete replacement of steel sheathing at DS_1 in addition to the inspection of all framing members for rupture, global and local buckling. DS_2 occurs when the wall has sustained SDR corresponding to the point of 80% post peak loading. At this SDR the wall has failed and would need to be torn down and replaced as buckling of studs and tracks will most likely have occurred. Figures 15 and 16 depict damage states DS_1 and DS_2 respectively.

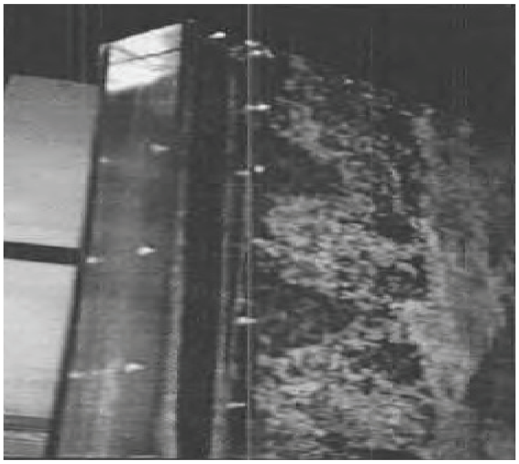


Figure 15 – Pull out of Fasteners from Studs (DS_1)

Figure 16 – Failed wall Specimen (DS_2)

4.2 Development of Fragility Curves

The fragility curves shown in Figure 17 are for shear walls with 22 or 31 mil steel sheathing. The close proximity of curve DS_1 to DS_2 accurately reflects the abrupt decrease in stiffness that was present in wall specimens after DS_1 initiated. This is due to the fact that once fasteners began to pull out of the wall studs or block shear rupture at panel edges began, an "unzipping" effect occurred where either of the two aforementioned failures moved from one fastener to the next causing relatively abrupt failure of the wall. Median and dispersion values for walls with steel sheathing are presented in Table 12.

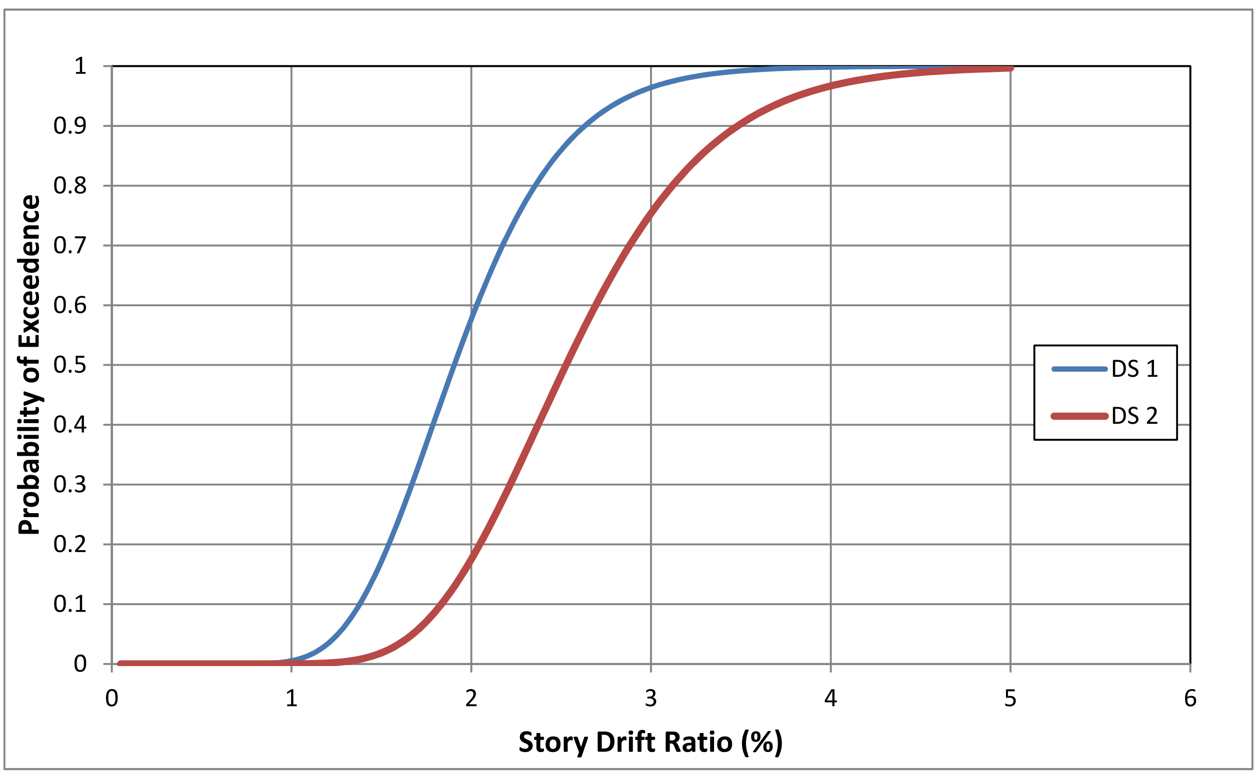


Figure 17 – Fragilities for Shear Walls with 22 mil or 31 mil Steel Sheathing

Table 12 – Median and Dispersion Values for Walls with 22 mil Or 31 mil Steel Sheathing

Damage States (DS_i)	Demand Parameter (DP)	Median (θ)	Dispersion (β)
DS_1	Story Drift Ratio SDR (%)	1.90	.25
DS_2		2.53	.25

5. Summary of Fragility Curves for CFS Light-Frame Systems

Included in Table 13 is a summary of the demand parameters, medians and dispersions for the various CFS structural systems analyzed in this document. Also included in Table 13 is the ATC method used to calculate the fragility parameters θ and β.

Table 13 – Summary of Demand Parameter and Fragility Parameters

System Type	Demand Parameter	Median (θ)			Dispersion (β)			Method Used*
		DS_1	DS_2	DS_3	DS_1	DS_2	DS_3	
CFS sys#1-all walls	SDR (%)	0.40	2.26	2.67	0.40	0.30	0.25	A, E
CFS sys#2-steel sheathing	SDR (%)	1.39	1.79	N/A	0.25	0.25	N/A	A, E
CFS sys#3-X-bracing	SDR (%)	1.90	2.53	N/A	0.25	0.25	N/A	A, E

*A-Parameters Derived from Actual Test Data (method A), E-Expert Judgment (method E)

6. Consequences of Damage States

This section of the document provides a table of consequences stemming from the various damage states reported throughout the document. The consequences of various damage states are categorized as follows:

C1-Damage state involves significant repair cost

C2-Damage state may cause injury or death

C3-Damage state threatens post-earthquake operability

C4-Damage state causes red-tagging of building

The authors acknowledge that certain consequences of damage states may differ depending on the configuration of the structure being assessed. For example a CFS wall which experienced DS_3 (failure of wall requiring complete replacement of wall) may or may not collapse depending on the magnitude of gravity loads above it and the system effects of the building. Likewise, a CFS wall which experience DS_1 (fastener pull through requiring refastening of sheathing) may or may not involve significant repair cost depending on the aesthetic cladding atop the structural sheathing and the length of the wall being assessed. In fact, this repair might be overlooked altogether due to the fact that the finish materials might mask the damage and the observer might not think that the wall is damaged at all. Therefore, to error on the side of caution, all potential consequences of various damage states are reported in Table 15.

Table 15 – Consequences involving Various Damage States

Structural System	Damage State (DS_i)	Consequences of Various Damage States			
		C1	C2	C3	C4
CFS Sys. #1	DS_1	Possibly	NO	NO	Not Likely
	DS_2	No	NO	YES	YES
	DS_3	YES	YES	YES	YES
CFS Sys. #2	DS_1	Possibly	NO	NO	Possibly
	DS_2	YES	NO	YES	YES
	DS_3	YES	YES	YES	YES
CFS Sys. #3	DS_1	YES	NO	YES	YES
	DS_2	YES	YES	YES	YES

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Appendix A – Lognormal Fragility Functions

This Appendix contains the individual fragility curves with the raw data plotted and the goodness of fit results for each data set analyzed. The fragility parameters are also reported as calculated. The values in the report are rounded as per the standard for the ACT-58 project.

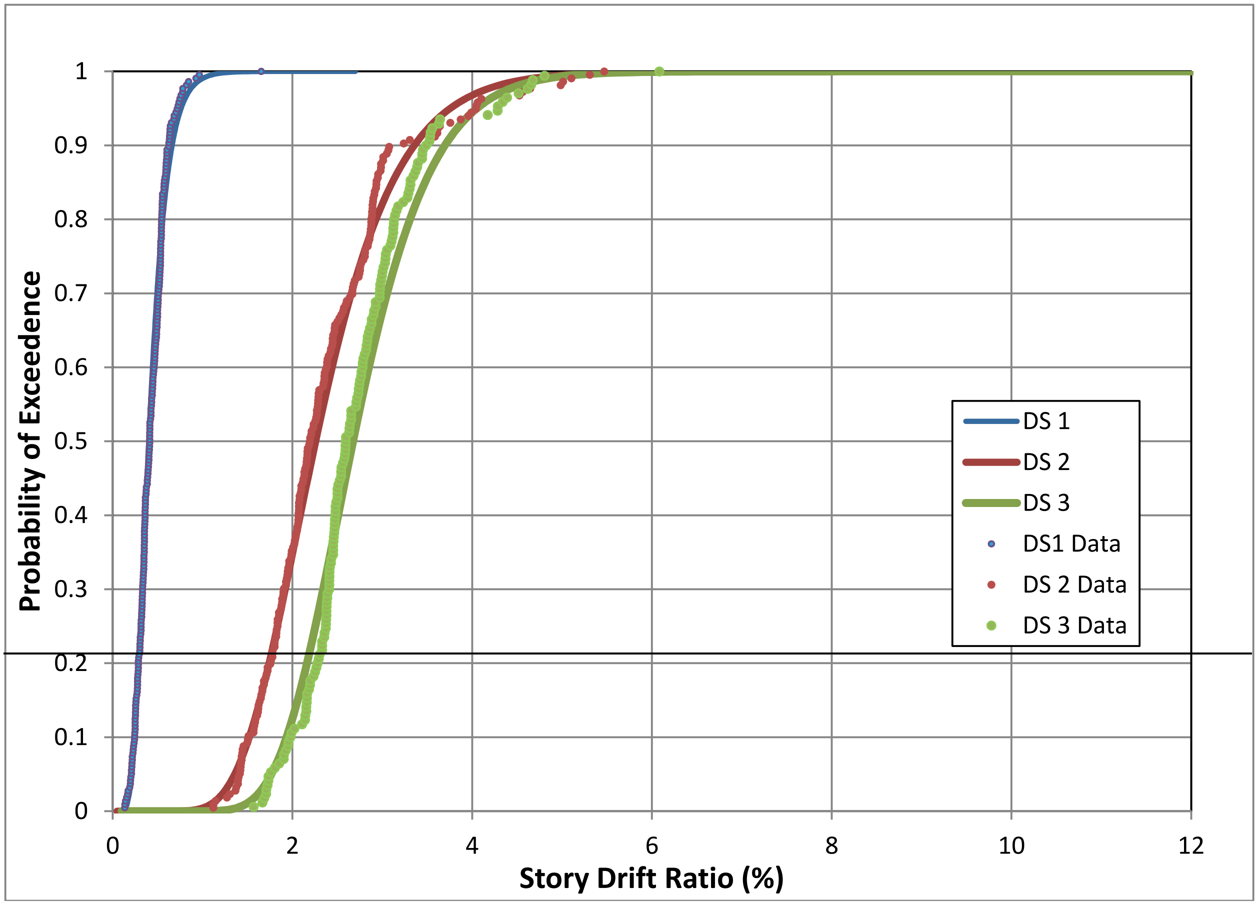


Figure A1 – Fragility Curves for all Walls with Structural Sheathing

Table A1 - Medians and Dispersions for Walls with Structural Sheathing

DS_i	Median θ	Dispersion β	# of samples	Lilliefors Test @ 5% significance
DS1	0.4	0.39	217	Passes
DS2	2.26	0.31	216	Passes
DS3	2.67	0.25	187	Passes

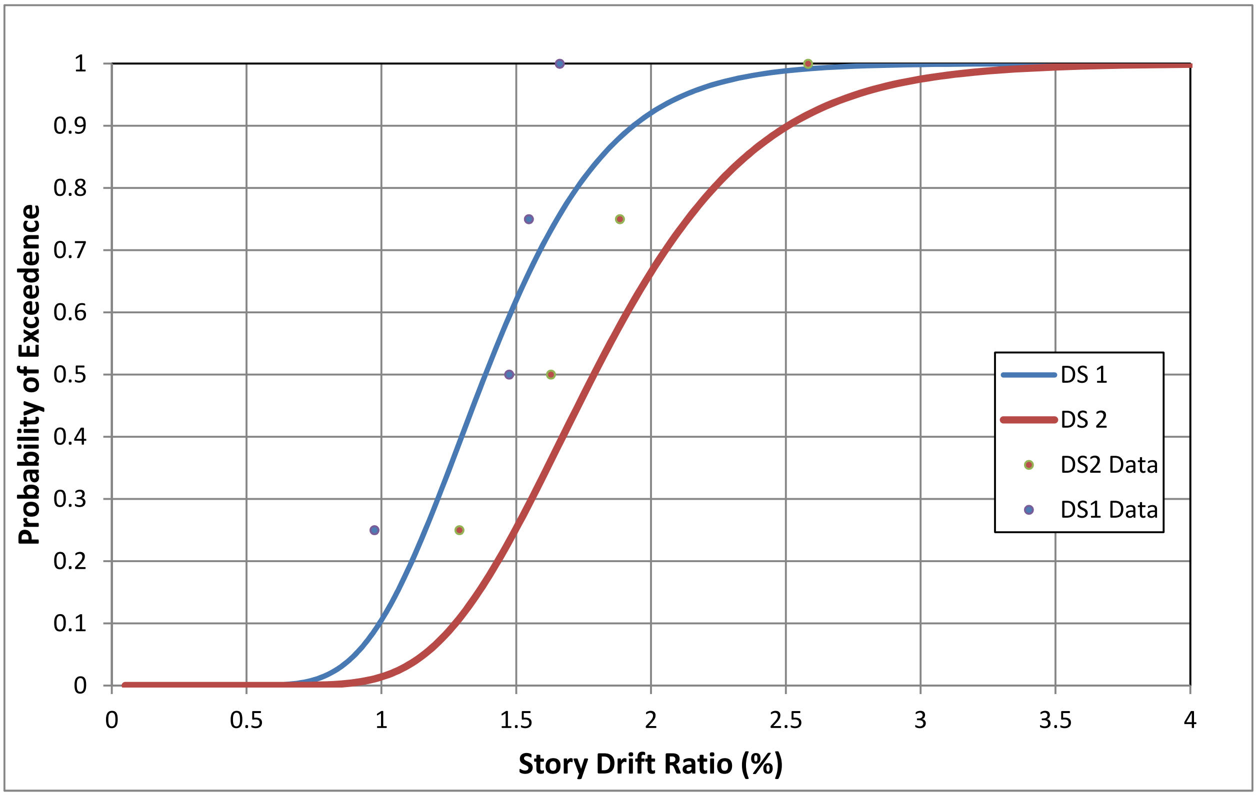


Figure A2 – Fragility Curves for Walls with Flat Strap X-Bracing

Table A2 - Medians and Dispersions for Walls with Flat Strap X-Bracing

DS_i	Median θ	Dispersion β	# of samples	Lilliefors Test @ 5% significance
DS1	1.39	0.26	4	Passes
DS2	1.79	0.26	4	Passes

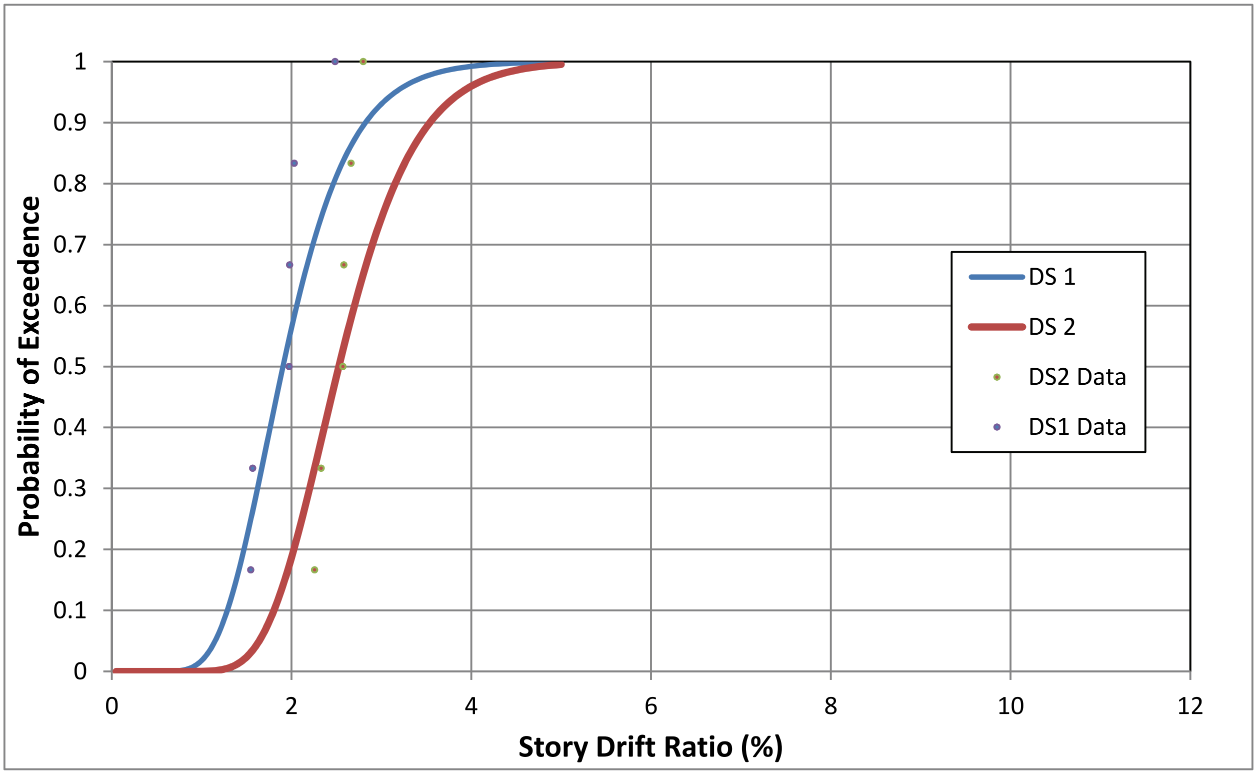


Figure A3 – Fragility Curves for Walls with 22 mil or 31 mil Steel Sheathing

Table A3 - Medians and Dispersions for Walls with 22 mil or 31 mil Steel Sheathing

DS_i	Median θ	Dispersion β	# of samples	Lilliefors Test @ 5% significance
DS1	1.9	0.25	6	Passes
DS2	2.53	0.25	6	Fails

Appendix B- Test Data and Field Observations

This Appendix contains the data used to generate the fragility curves and is provided as a convenience to the reader.

Table B1- Monotonic Test Data from Boudreault (2005)

Test	Panel Type	Fastener Schedule (mm)	Displ. at 0.4 S_u ($\Delta_{net,0.4u}$) mm	Yield Load (S_y) kN/m	Displ. at S_y ($\Delta_{net,y}$) mm
1A	CSP	102 / 305	9.14	13.43	19.25
1B	CSP	102 / 305	9.39	14.77	20.27
1C	CSP	102 / 305	8.13	14.41	17.47
AVERAGE	**CSP**	**102 / 305**	**8.89**	**14.20**	**19.00**
1D	CSP Richply	102 / 305	9.39	22.46	19.24
1E	CSP Richply	102 / 305	9.32	18.59	19.68
1F	CSP Richply	102 / 305	8.33	18.78	17.92
AVERAGE	**CSP Richply**	**102 / 305**	**9.01**	**19.94**	**18.95**
5A	DFP	102 / 305	7.83	17.51	16.24
5B	DFP	102 / 305	9.26	21.58	19.46
5C	DFP	102 / 305	10.55	19.73	21.76
5D	DFP	102 / 305	9.91	21.08	21.34
AVERAGE	**DFP**	**102 / 305**	**9.39**	**19.98**	**19.70**

Table B2-Cyclic Test Data for Positive Cycles from Boudreault (2005)

Test	Panel Type	Fastener Schedule (mm)	Yield Load (S_{y+}) kN/m	Displ. at S_{y+} ($\Delta_{net,y+}$) mm
3A	CSP	102 / 305	15.09	9.34
3B	CSP	102 / 305	15.84	9.72
3C	CSP	102 / 305	15.08	13.62
AVERAGE	**CSP**	**102 / 305**	**15.34**	**10.89**
4A	CSP	102 / 305	14.63	16.55
4B	CSP	102 / 305	15.61	13.29
4C	CSP	102 / 305	16.19	14.75
AVERAGE	**CSP**	**102 / 305**	**15.48**	**14.86**
6A	DFP	102 / 305	18.79	16.88
6B	DFP	102 / 305	19.37	16.67
6C	DFP	102 / 305	19.23	15.11
AVERAGE	**DFP**	**102 / 305**	**19.13**	**16.22**

Table B3- Cyclic Test Data for Negative Cycles from Boudreault (2005)

Test	Panel Type	Fastener Schedule (mm)	Yield Load (S_{y-}) kN/m	Displ. at S_{y-} ($\Delta_{net,y-}$) mm
3A	CSP	102 / 305	-15.89	-11.54
3B	CSP	102 / 305	-15.81	-10.79
3C	CSP	102 / 305	-15.16	-10.11
AVERAGE	**CSP**	**102 / 305**	**-15.62**	**-10.81**
4A	CSP	102 / 305	-13.12	-15.82
4B	CSP	102 / 305	-13.64	-18.67
4C	CSP	102 / 305	-14.19	-14.18
AVERAGE	**CSP**	**102 / 305**	**-13.65**	**-16.22**
6A	DFP	102 / 305	-17.56	-15.66
6B	DFP	102 / 305	-16.60	-14.82
6C	DFP	102 / 305	-17.55	-15.90
AVERAGE	**DFP**	**102 / 305**	**-17.24**	**-15.46**

Table B4 – Monotonic Test Data From Hikita (2006)

Test	Panel Type	Fastener Schedule	Maximum Wall Resistance (S_u) kN/m	Displ. @ 0.4S_u ($\Delta_{net, 0.4u}$) mm	Displ. @ S_u ($\Delta_{net,u}$) mm	Displ. @ 0.8 S_u ($\Delta_{net, 0.8u}$)
47A	DFP	75/305	31.11	10.83	70.98	80.77
47B	DFP	75/305	28.98	10.63	72.80	82.83
47C[1]	DFP	75/305	32.40	11.25	70.12	74.43
Average			30.83	10.90	71.30	79.34
49A	OSB	152/305	10.92	3.31	38.41	60.12
49B[1]	OSB	152/305	11.75	4.13	40.61	52.67
49C	OSB	152/305	13.32	4.28	45.96	64.17
49D	OSB	152/305	12.13	3.71	40.32	52.16
Average			12.03	3.86	41.33	57.28
51A	OSB	75/305	22.17	4.88	42.01	54.47
51B[1]	OSB	75/305	23.11	4.69	36.66	41.12
51C	OSB	75/305	22.35	4.02	36.86	48.5
Average			22.54	4.53	38.51	48.03
53A	CSP	152/305	13.39	6.67	57.06	77.44
53B	CSP	152/305	12.41	9.25	55.71	81.58
53C[1]	CSP	152/305	13.15	5.71	55.84	76.12
Average			12.98	7.21	56.20	78.38
55A	CSP	152/305	25.68	11.01	70.19	88.80
55B[1]	CSP	75/305	28.36	11.31	69.91	75.91
55C	CSP	75/305	24.70	11.56	68.44	83.94
55D	CSP	75/305	27.08	12.26	71.94	84.14
Average			26.46	11.54	70.12	83.20

Table B5 – Test Results For Reversed Cyclic Tests (Positive Cycles) from Hikita (2006)

Test	Panel Type	Fastener Schedule	Maximum Wall Resistance ($S_{u'+}$) (positive cycle) kN/m	Displacement as Su'+ ($\Delta_{net, u+}$) mm	Δnet, 0.8u+ (mm)
48A	DFP	75/305	29.26	65.39	69.67
48B	DFP	75/305	29.14	66.44	69.05
48C[1]	DFP	75/305	28.35	50.05	74.47
AVERAGE			28.92	60.63	71.06
50A	OSB	152/305	10.77	33.24	51.68
50B	OSB	152/305	10.49	30.84	48.83
50C[1]	OSB	152/305	11.11	46.66	48.51
AVERAGE			10.79	36.91	49.67
52A	OSB	75/305	22.18	26.79	39.94
52B	OSB	75/305	22.12	37.11	39.34
52C[1]	OSB	75/305	25.64	41.25	42.21
AVERAGE			23.31	35.05	40.50
54A	CSP	152/305	11.95	56.06	65.12
54B	CSP	152/305	12.16	58.66	66.4
54C[1]	CSP	152/305	12.96	41.29	65.2
AVERAGE			12.36	52.00	65.57
56A[1]	CSP	75/305	26.90	57.13	58.05
56B	CSP	75/305	25.56	60.29	63.78
56C	CSP	75/305	25.85	57.6	59.52
AVERAGE			26.10	58.34	60.45

Table B6 - Test Results For Reversed Cyclic Tests (Negative Cycles) from Hikita (2006)

Test	Panel Type	Fastener Schedule	Maximum Wall Resistance ($S_{u'-}$) (negative cycle) kN/m	Displacement as Su'- ($\Delta_{net,\,u-}$) mm
48A	DFP	75/305	-27.99	-49.09
48B	DFP	75/305	-27.20	-47.25
48C[1]	DFP	75/305	-27.85	-41.68
AVERAGE			-27.68	-46.01
50A	OSB	152/305	-10.70	-33.01
50B	OSB	152/305	-10.06	-34.26
50C[1]	OSB	152/305	-10.79	-31.22
AVERAGE			-10.52	-32.83
52A	OSB	75/305	-20.83	-30.82
52B	OSB	75/305	-22.23	-27.1
52C[1]	OSB	75/305	-22.99	-29.58
AVERAGE			-22.01	-29.17
54A	CSP	152/305	-10.93	-43.43
54B	CSP	152/305	-11.56	-40.49
54C[1]	CSP	152/305	-11.59	-39.97
AVERAGE			-11.36	-41.30
56A[1]	CSP	75/305	-21.47	-45.98
56B	CSP	75/305	-22.60	-39.975
56C	CSP	75/305	-20.22	-39.13
AVERAGE			-21.43	-41.70

Table B7 – Test Data from Nguyen, Hall and Serrette (1996)

Test Specimen	Maximum Load Capacity (lb/ft)	Displacement at max Load (in)
A6	1038	2.41
A7	1087	2.43
A2	931	1.50
A3	891	1.47
A5	1033	2.19
A6	989	1.94
E1	990	2.38
E2	1061	2.77
D1	846	1.50
D2	875	1.50
D3	1473	2.36

D4	1350	2.30
D5	1763	2.30
D6	1709	1.86
D7	1933	1.84
D8	1891	2.10
F1	1190	2.25
F2	1243	2.23
F3	1516	2.37
F4	1604	2.52
F5	1918	1.84
F6	1850	1.73
A1	545	0.77
A3	621	0.96
A2	915	0.95

Table B8– Test Observations from Serrette and Research Assistants (1997)

Test Specimen	Behavior of Wall Assembly
A1	Screws pull through plywood sheathing at the bottom corners
A2	Screw pull through sheathing along bottom edge
A3	Buckling of bottom track after screws pulled through sheathing. Buckling in chord studs approx. 2ft above track.
A4	Screws pull through plywood sheathing at bottom corners. Buckling in bottom track at shear anchor.

A5	Screws break vertical edges of OSB. Screws pull through OSB along bottom edge.
A6	Screws break vertical edges of OSB. Screws pull through OSB along bottom edge.
A7	Screws pull through OSB sheathing along bottom edge and both sides. Local buckling in the lip of all studs.
A8	Screws pulled through plywood along top and vertical edges.
B1	Screw shear along bottom track. Screws pulled out of sheathing along vertical edges.
B2	Screws pulled through panel along vertical edges and along bottom track.
B3	Screw shear along entire vertical edge (load side). Screws pull through panel at top and bottom track.
B4	Screw pull through panel along vertical edge and bottom track. Some screws sheared.
C1	Buckling in both chord studs (at web knockouts)
C2	Buckling in both chord studs (at web knockouts)
C3	Top and bottom track pulled out of plane of the wall. Buckling in chord stud at loaded end.
C4	Top and bottom track pulled out of plane of the wall. Buckling in chord stud occurred after bending in top and bottom track.
D1	Screws pulled out of studs. Screws rupture edge of sheathing. Many screws loose after test is stopped.
D2	Screws pulled out of stud along top track and at vertical edges adjacent to top track. Screws pulled out interior stud close to top track.

Table B9 – Average Max Loads and Displacements for Similar Test Specimens from Serrette (1997)

Test Specimen	Average Maximum Load (lb/ft)	Displacement at Max Load (in)
A1	1775	2.2
A2		
A3	2190	2.7
A4		
A5	1523	1.6
A6		
A7	2058	2.0
A8		
B1	892	1.8
B2		
B3	904	1.2
B4		
C1	821	1.2
C2		
C3	839	0.8
C4		
D1	392	1.0
D2		

Table B10- Test Observations from Branston (2004)

Specimen ID	Test Protocol	Pullout withdrawl (Po)	Fatigue Fracture Shear (FF)	Pull Through Sheathing (PT)	Partial Pull-through (PPT)	Tearout of Sheathing (TO)	Wood bearing Failure (WB)
7A	MONO	X	X	X		X	
7B	MONO		X	X	X	X	X
7C	MONO	X	X	X	X	X	X
8A	CYCLIC		X	X	X	X	X

8B	CYCLIC	X	X	X			X
8C	CYCLIC	X	X	X	X		X
9A	MONO		X	X		X	
9B	MONO		X	X	X	X	
9C	MONO			X	X	X	
10A	CYCLIC		X	X		X	X
10B	CYCLIC	X	X	X		X	
10C	CYCLIC		X	X		X	X
11A	MONO				X	X	
11B	MONO		X	X	X		X
11C	MONO		X	X	X	X	X
12A	CYCLIC		X	X	X	X	
12B	CYCLIC		X	X	X	X	X
12C	CYCLIC		X	X	X	X	X
13A	MONO		X	X	X	X	X
13B	MONO			X	X		X
13C	MONO			X	X	X	X
14A	CYCLIC		X	X	X	X	X
14B	CYCLIC		X	X	X	X	X
14C	CYCLIC	X	X	X	X	X	X
14D	CYCLIC			X	X	X	X
21A	MONO			X	X	X	
21B	MONO		X	X	X	X	
21C	MONO		X	X	X		
22A	CYCLIC		X	X	X	X	X
22B	CYCLIC		X	X	X	X	X
22C	CYCLIC		X	X	X	X	X
23A	MONO			X	X	X	
23B	MONO			X	X	X	
23C	MONO		X	X	X		
24A	CYCLIC			X	X	X	X
24B	CYCLIC		X	X	X	X	X
24C	CYCLIC	X	X	X	X	X	X
25A	MONO			X	X	X	
25B	MONO			X	X	X	
25C	MONO			X	X	X	
26A	CYCLIC	X		X	X	X	X
26B	CYCLIC		X	X	X	X	X
26C	CYCLIC	X	X	X	X		X

Table B11 - Test Observations from Boudreault (2004)

Specimen ID	Panel Type	Test Protocol	Pullout withdrawl (Po)	Fatigue Fracture Shear (FF)	Pull Through Sheathing (PT)	Partial Pull-through (PPT)	Tearout of Sheathing (TO)	Wood bearing Failure (WB)
1A		MONO			X	X	X	X
1B		MONO			X		X	
1C		MONO		X	X		X	X
1D		MONO			X	X	X	
1E		MONO			X		X	X
1F		MONO			X	X		X
3A		CYCLIC		X	X	X		X
3B		CYCLIC	X	X	X	X		X
3C		CYCLIC	X	X	X		X	
4A		CUREE		X	X	X		X
4B		CUREE		X	X		X	X
4C		CUREE		X	X	X	X	X
5A		MONO			X		X	X
5B		MONO			X	X	X	X
5C		MONO			X	X	X	X
5D		MONO			X		X	X
6A		CYCLIC		X	X	X	X	X
6B		CYCLIC		X	X	X	X	X
6C		CYCLIC		X	X	X	X	

Table B12- Test Observations from Chen (2004)

Specimen ID	Panel Type	Test Protocol	Pullout withdrawl (Po)	Fatigue Fracture Shear (FF)	Pull Through Sheathing (PT)	Partial Pull-through (PPT)	Tearout of Sheathing (TO)	Wood bearing Failure (WB)
15A		MONO					X	
15B		MONO			X	X	X	
15C		MONO			X	X	X	
16A		CYCLIC			X	X	X	
16B		CYCLIC				X	X	
16C		CYCLIC					X	X
17A		MONO			X	X	X	
17B		MONO			X		X	
17C		MONO			X	X	X	
18A		CYCLIC			X	X	X	
18B		CYCLIC				X	X	
18C		CYCLIC			X	X	X	X

19A		MONO			X	X	X	X
19B		MONO			X	X	X	X
19C		MONO			X	X	X	
20A		CYCLIC			X	X	X	X
20B		CYCLIC			X		X	
20C		CYCLIC			X	X	X	
27A		MONO			X	X	X	
27B		MONO			X	X	X	X
27C		MONO			X	X	X	X
28A		CYCLIC			X	X	X	
28B		CYCLIC				X	X	
28C		CYCLIC				X	X	
29A		MONO		X	X	X	X	X
29B		MONO		X	X	X	X	X
29C		MONO		X	X	X	X	X
30A		CYCLIC			X	X	X	X
30B		CYCLIC			X	X	X	X
30C		CYCLIC			X	X	X	X
31A		MONO			X	X	X	X
31B		MONO			X	X	X	X
31C		MONO			X	X	X	X
31D		MONO			X	X	X	X
31E		MONO			X	X	X	X
31F		MONO			X	X	X	X
32A		CYCLIC			X	X	X	X
32B		CYCLIC			X	X	X	X
32C		CYCLIC			X	X	X	X
33A		MONO				X	X	X
33B		MONO				X	X	X
33C		MONO				X	X	X
34A		CYCLIC			X	X	X	X
34B		CYCLIC			X	X	X	X
34C		CYCLIC			X	X	X	X
34D		CYCLIC			X	X	X	X

Table B13-Test Observations from Rokas (2006)

Specimen ID	Panel Type	Test Protocol	Pullout withdrawl (Po)	Fatigue Fracture Shear (FF)	Pull Through Sheathing (PT)	Partial Pull-through (PPT)	Tearout of Sheathing (TO)	Wood bearing Failure (WB)
36A	CSP	CUREE			X			X
36B	CSP	CUREE			X			X
36C	CSP	CUREE			X			X
38A	CSP	CUREE			X	X		X
38B	CSP	CUREE			X	X		X
38C	CSP	CUREE			X	X		X
40A	CSP	CUREE			X	X		X
40B	CSP	CUREE			X	X		X
40C	CSP	CUREE			X	X		X

Table 14 - Test Observations from Blais (2006)

Specimen ID	Test Protocol	Pullout withdrawl (Po)	Fatigue Fracture Shear (FF)	Pull Through Sheathing (PT)	Partial Pull-through (PPT)	Tearout of Sheathing (TO)	Wood bearing Failure (WB)
41A	MONO			X	X		X
41B	MONO		X	X	X		X
41C	MONO			X	X		X
43A	MONO		x	x	x		x
43B	MONO			X	X		X
43C	MONO			X	X		X
45A	MONO			X	X		X
45B	MONO			X	X		X
45C	MONO			X	X		X
42A	CYCLIC			X	X		X
42B	CYCLIC		X	X	X		X
42C	CYCLIC		X	X	X		X
44A	CYCLIC			X	X		X
44B	CYCLIC			X	X		X
44C	CYCLIC			X	X		X
46A	CYCLIC		X	X	X		X
46B	CYCLIC		X	X	X		X
46C	CYCLIC		X	X	X		X

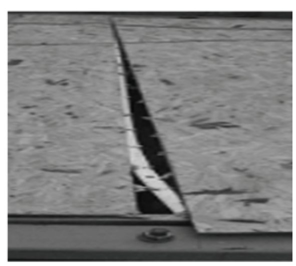
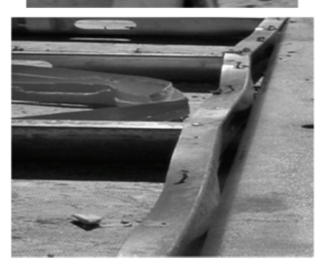
Table B15 - Test Observations from Hikita (2006)

Specimen ID	Test Protocol	Pullout withdrawl (Po)	Fatigue Fracture Shear (FF)	Pull Through Sheathing (PT)	Partial Pull-through (PPT)	Tearout of Sheathing (TO)	Wood bearing Failure (WB)
47A	MONO			X	X	X	X
47B	MONO			X	X		X
47C	MONO			X	X	X	X
48A	CYCLIC	X		X	X		X
48B	CYCLIC			X	X		X
48C	CYCLIC	X		X	X		X
49A	MONO			X	X	X	
49B	MONO			X	X	X	
49C	MONO			X	X	X	
49D	MONO			X	X	X	X
50A	CYCLIC			X	X	X	
50B	CYCLIC			X	X	X	X
50C	CYCLIC			X	X	X	X
51A	MONO			X	X		X
51B	MONO			X	X		X
51C	MONO			X	X	X	X
52A	CYCLIC			X			X
52B	CYCLIC			X	X		
52C	CYCLIC			X	X	X	X
53A	MONO	X		X		X	
53B	MONO			X	X	X	X
53C	MONO			X	X	X	X
54A	CYCLIC		X	X	X	X	X
54B	CYCLIC			X	X	X	X
54C	CYCLIC			X	X	X	X
55A	MONO			X	X	X	X
55B	MONO			X	X	X	X
55C	MONO			X	X	X	X
55D	MONO			X	X	X	X
56A	CYCLIC			X	X		X
56B	CYCLIC			X	X		X
56C	CYCLIC			X	X		X

Appendix C- Fragility Specification Forms

This Appendix contains the fragility information in the format requested for the project.

[Cold-Formed Steel Walls w/ Wood Structural Panel Sheathing]—[Number]	
Developer and Date:	Alex Grummel and Dan Dolan, May, 2010
NISTIR Classification:	
Description (Basic Composition):	38 mil cold-formed steel framing with wood structural panel sheathing (7/16-in. OSB and 3/8-in. plywood) attached with No. 8 screws (at various specimens 2”-6” on perimeter and 12” in the field). All walls had overturning restraint at the ends of the wall specimen as required by the AISI design standard.
Construction Quality: (1)	High quality laboratory conditions representing the requirements of the AISI design standard
Seismic Installation Conditions:	Overturning restraint required and sheathing screws driven flush with surface of the sheathing.
Normative Quantity (unit):	Linear feet, square feet of wall
Demand Parameter:	Story Drift Ratio
Number of Damage States:	3

Type of Damage States:	X ordered	mutually exclusive	simultaneous
Damage States	**DS1**	**DS2**	**DS3**
Description:	• Sheathing fastener pull through or tear out (up to 20% of fasteners)	• Failure of structural panels	• Failure of Wall
Illustrations:		 	 
Probability: (2)			

(0) If possible, describe in terms of relevant code or standard.
(1) For ordered damage states, leave “Probability” blank and provide fragility parameters for each damage state. For mutually exclusive or simultaneous damage states, provide fragility parameters in DS1 column only, and state probabilities of each damage state in “Probability.” For simultaneous damage states, ensure that the probabilities add to at least 1.0.

[Cold-Formed Steel Walls w/ Wood Structural Panel Sheathing] – [Number]			
Fragility Parameters	**DS1**	**DS2**	**DS3**
Median Demand, θ: (3)	0.40	2.26	2.67
Data dispersion, β_d: (4)	0.40	0.30	0.25
Uncertainty, β_u: (5)	0.10	0.10	0.10
Total Dispersion, β: (6)	0.40	0.30	0.25
Correlation:			

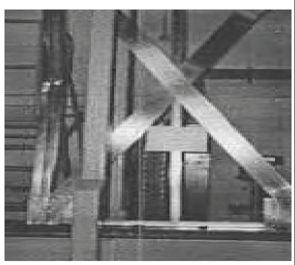
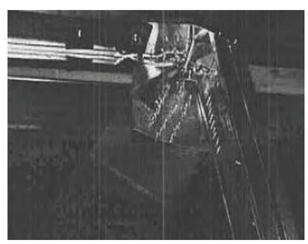
Quality Ratings		DS1		DS2		DS3
Data Quality:		none		none		none
		marginal		marginal		marginal
	X	average		average		average
		superior	X	superior	X	superior
Data Relevance:		none		none		none
	X	marginal		marginal		marginal
		average		average		average
		superior	X	superior	X	superior
Documentation Quality:		marginal		marginal		marginal
	X	average		average		average
		superior	X	superior	X	superior
Rationality:		marginal		marginal		marginal
		average		average		average
		superior		superior		superior
		N/A		N/A		N/A

Extrapolation (7)							
Seismic Installation Condition	**Included in data? (Y/N)**	**θ**	**β**	**θ**	**β**	**θ**	**β**
Good	**N**						
Fair	**N**						
Poor	**N**						
Average or unknown							
Explain basis for extrapolation. What factors affect θ and β?							

(3) Round *θ* to 2 significant figures and *β* to nearest 0.05.
(4) β_d – random variability observed in test data, if available
(5) β_u – uncertainty that tests represent actual conditions of installation and loading
(6) β – SRSS combination of β_d and β_u when test data are available, or total estimated uncertainty when data are not available
(7) Identify the seismic installation conditions represented by the data set, and extrapolate fragility parameters θ and β for other seismic installation conditions.

[Cold-Formed Steel Walls w/ Wood Structural Panel Sheathing] – [Number]

Consequence Functions	DS1			DS2			DS3		
Repair Description:	Relocated room contents within 6 feet of damaged wall. Remove architectural finishes from wall, inspect sheathing fasteners, and add new fasteners near damaged ones, but locate in undamaged sheathing.			Relocated room contents within 6 feet of damaged wall. Remove architectural finishes from wall, remove sheathing, inspect framing and replace damaged framing members, replace sheathing and finish materials.			Relocated room contents within 6 feet of damaged wall. Replace entire wall.		
Repair Costs:	P_{10}	P_{50}	P_{90}	P_{10}	P_{50}	P_{90}	P_{10}	P_{50}	P_{90}
Max. consequence up to lower quantity:									
Min. consequence over upper quantity:									
Assumed distribution:		normal			normal			normal	
		lognormal			lognormal			lognormal	
Repair Time:	P_{10}	P_{50}	P_{90}	P_{10}	P_{50}	P_{90}	P_{10}	P_{50}	P_{90}
Max. consequence up to lower quantity:									
Min. consequence over upper quantity:									
Assumed distribution:		normal			normal			normal	
		lognormal			lognormal			lognormal	
LifeSafety Hazard:		yes		X	yes		X	yes	
	X	no			no			no	
Casualty-affected Planar Area (sf) per Normative Unit:									
Casualty Rate in Affected Planar Area:									
Post-event Tagging Flag:	Green or Yellow			Yellow and possibly Red			Red		
Total Damage Quantity (red tag trigger):									
Comments:									

[Cold-Formed Steel Walls w/ Flat Strap X-Bracing-]—[Number]			
Developer and Date:	Alex Grummel and Dan Dolan, May, 2010		
NISTIR Classification:			
Description (Basic Composition):	33 mil cold-formed steel framing with 4 ½ inch wide 33 mil flat strap X-bracing on one side. Straps attached to gussets with No. 8 screws.		
Construction Quality: [(1)]	High quality laboratory conditions representing the requirements of the AISI design standard		
Seismic Installation Conditions:	Overturning restraint required and sheathing screws driven flush with surface of the strapping.		
Normative Quantity (unit):	Linear feet, square feet of wall		
Demand Parameter:	Story Drift Ratio		
Number of Damage States:	2		
Type of Damage States:	X ordered	mutually exclusive	simultaneous
Damage States	**DS1**	**DS2**	**DS3**
Description:	• Local buckling of chord studs	• Failure of many framing members and collapse	•
Illustrations:			
Probability: [(2)]			

1. If possible, describe in terms of relevant code or standard.
2. For ordered damage states, leave "Probability" blank and provide fragility parameters for each damage state. For mutually exclusive or simultaneous damage states, provide fragility parameters in DS1 column only, and state probabilities of each damage state in "Probability." For simultaneous damage states, ensure that the probabilities add to at least 1.0.

[Cold-Formed Steel Walls w/ Flat Strap X-Bracing] – [Number]			
Fragility Parameters	**DS1**	**DS2**	**DS3**
Median Demand, θ: (3)	1.39	1.79	
Data dispersion, β_d: (4)	0.25	0.25	
Uncertainty, β_u: (5)	0.10	0.10	
Total Dispersion, β: (6)	0.25	0.25	
Correlation:			

Quality Ratings						
Data Quality:		none		none		none
		marginal		marginal		marginal
	X	average	X	average		average
		superior		superior		superior
Data Relevance:		none		none		none
	X	marginal		marginal		marginal
		average		average		average
		superior	X	superior		superior
Documentation Quality:		marginal		marginal		marginal
	X	average		average		average
		superior	X	superior		superior
Rationality:		marginal		marginal		marginal
		average		average		average
		superior		superior		superior
		N/A		N/A		N/A

Extrapolation (7)							
Seismic Installation Condition	**Included in data? (Y/N)**	**θ**	**β**	**θ**	**β**	**θ**	**β**
Good	**N**						
Fair	**N**						
Poor	**N**						
Average or unknown							
Explain basis for extrapolation. What factors affect θ and β?							

3. Round *θ* to 2 significant figures and *β* to nearest 0.05.
4. β_d – random variability observed in test data, if available
5. β_u – uncertainty that tests represent actual conditions of installation and loading
6. β – SRSS combination of β_d and β_u when test data are available, or total estimated uncertainty when data are not available
7. Identify the seismic installation conditions represented by the data set, and extrapolate fragility parameters θ and β for other seismic installation conditions.

[Cold-Formed Steel Walls w/ Flat Strap X-Bracing] – [Number]									
Consequence Functions	**DS1**			**DS2**			**DS3**		
Repair Description:	Relocated room contents within 6 feet of damaged wall. Remove architectural finishes from wall, inspect framing and replace damaged framing and finishes.			Relocated room contents within 6 feet of damaged wall. Remove architectural finishes from wall, replace damaged framing members (probably all of them), and finish materials.					
Repair Costs:	**P_{10}**	**P_{50}**	**P_{90}**	**P_{10}**	**P_{50}**	**P_{90}**	**P_{10}**	**P_{50}**	**P_{90}**
Max. consequence up to lower quantity:									
Min. consequence over upper quantity:									
Assumed distribution:	normal			normal			normal		
	lognormal			lognormal			lognormal		
Repair Time:	**P_{10}**	**P_{50}**	**P_{90}**	**P_{10}**	**P_{50}**	**P_{90}**	**P_{10}**	**P_{50}**	**P_{90}**
Max. consequence up to lower quantity:									
Min. consequence over upper quantity:									
Assumed distribution:	normal			normal			normal		
	lognormal			lognormal			lognormal		
LifeSafety Hazard:	X yes			X yes			yes		
	no			no			no		
Casualty-affected Planar Area (sf) per Normative Unit:									
Casualty Rate in Affected Planar Area:									
Post-event Tagging Flag:	Green or Yellow			Red					
Total Damage Quantity (red tag trigger):									
Comments:									

[Cold-Formed Steel Walls w/ 22 or 31 mil steel sheathing-]—[Number]			
Developer and Date:	Alex Grummel and Dan Dolan, May, 2010		
NISTIR Classification:			
Description (Basic Composition):	33 mil cold-formed steel framing with 22 or 31 mil steeel sheathing attached with No. 8 self-drilling screws spaced wither at 6” or 2” o.c. on the perimeter and 12” o.c. in the field		
Construction Quality: [(1)]	High quality laboratory conditions representing the requirements of the AISI design standard		
Seismic Installation Conditions:	Overturning restraint required and sheathing screws driven flush with surface of the sheathing.		
Normative Quantity (unit):	Linear feet, square feet of wall		
Demand Parameter:	Story Drift Ratio		
Number of Damage States:	2		
Type of Damage States:	X ordered	mutually exclusive	simultaneous
Damage States	**DS1**	**DS2**	**DS3**
Description:	• Pull-out of sheathing fasteners from studs	• Pull-out of sheathing fasteners from studs and buckling of steel sheathing. Buckling of framing members will probably occur	•
Illustrations:			
Probability: [(2)]			

1. If possible, describe in terms of relevant code or standard.
2. For ordered damage states, leave “Probability” blank and provide fragility parameters for each damage state. For mutually exclusive or simultaneous damage states, provide fragility parameters in DS1 column only, and state probabilities of each damage state in “Probability.” For simultaneous damage states, ensure that the probabilities add to at least 1.0.

[Cold-Formed Steel Walls w/ 22 or 31 mil steel sheathing] – [Number]							
Fragility Parameters			**DS1**		**DS2**		**DS3**
Median Demand, θ: (3)			1.90		2.53		
Data dispersion, β_d: (4)			0.25		0.25		
Uncertainty, β_u: (5)			0.10		0.10		
Total Dispersion, β: (6)			0.25		0.25		
Correlation:							
Quality Ratings							
Data Quality:			none		none		none
			marginal		marginal		marginal
		X	average	X	average		average
			superior		superior		superior
Data Relevance:			none		none		none
		X	marginal		marginal		marginal
			average		average		average
			superior	X	superior		superior
Documentation Quality:			marginal		marginal		marginal
		X	average		average		average
			superior	X	superior		superior
Rationality:			marginal		marginal		marginal
			average		average		average
			superior		superior		superior
			N/A		N/A		N/A
Extrapolation (7)							
Seismic Installation Condition	**Included in data? (Y/N)**	**θ**	**β**	**θ**	**β**	**θ**	**β**
Good	**N**						
Fair	**N**						
Poor	**N**						
Average or unknown							
Explain basis for extrapolation. What factors affect θ and β?							

1. Round θ to 2 significant figures and β to nearest 0.05.
2. β_d – random variability observed in test data, if available
3. β_u – uncertainty that tests represent actual conditions of installation and loading
4. β – SRSS combination of β_d and β_u when test data are available, or total estimated uncertainty when data are not available
5. Identify the seismic installation conditions represented by the data set, and extrapolate fragility parameters θ and β for other seismic installation conditions.

[Cold-Formed Steel Walls w/ 22 or 31 mil steel sheathing] – [Number]									
Consequence Functions	**DS1**			**DS2**			**DS3**		
Repair Description:	Relocated room contents within 6 feet of damaged wall. Remove architectural finishes from wall, inspect sheathing fasteners and replace damaged fasteners and finishes.			Relocated room contents within 6 feet of damaged wall. Remove architectural finishes and steel sheathing from wall, replace damaged framing members (probably all of them), and steel sheathing and finish materials.					
Repair Costs:	**P_{10}**	**P_{50}**	**P_{90}**	**P_{10}**	**P_{50}**	**P_{90}**	**P_{10}**	**P_{50}**	**P_{90}**
Max. consequence up to lower quantity:									
Min. consequence over upper quantity:									
Assumed distribution:	normal			normal			normal		
	lognormal			lognormal			lognormal		
Repair Time:	**P_{10}**	**P_{50}**	**P_{90}**	**P_{10}**	**P_{50}**	**P_{90}**	**P_{10}**	**P_{50}**	**P_{90}**
Max. consequence up to lower quantity:									
Min. consequence over upper quantity:									
Assumed distribution:	normal			normal			normal		
	lognormal			lognormal			lognormal		
LifeSafety Hazard:	X yes			X yes			yes		
	no			no			no		
Casualty-affected Planar Area (sf) per Normative Unit:									
Casualty Rate in Affected Planar Area:									
Post-event Tagging Flag:	Green or Yellow			Red					
Total Damage Quantity (red tag trigger):									
Comments:									