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Key Testing Defined Common Sense Engineering Concepts & Considerations

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Why Evaluate Braced Wall Panels?

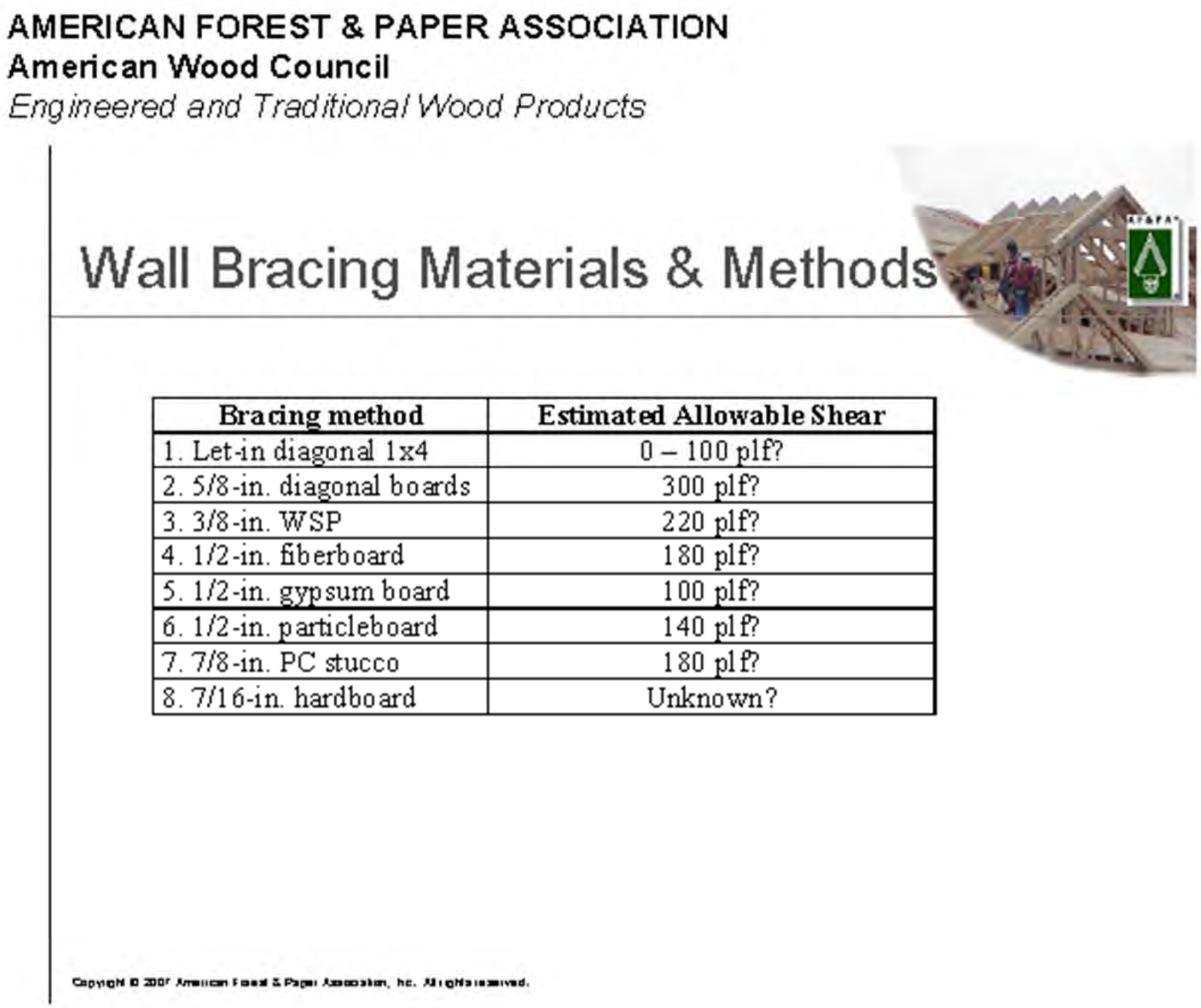
1) Testing should determine nominal unit shear capacity values.

2) Rational design is dependent on having accurate nominal unit shear capacity values and applied engineering facts.

3) Increased data and knowledge leads to better engineering judgments and more accurate designs.

4) Product advancement and innovation cannot and will not happen without a good technical foundation and a level playing field.

Why Evaluate Wall Bracing Performance?



AMERICAN FOREST & PAPER ASSOCIATION
American Wood Council
Engineered and Traditional Wood Products

Wall Bracing Materials & Methods

Bracing method	Estimated Allowable Shear
1. Let-in diagonal 1x4	0 – 100 plf?
2. 5/8-in. diagonal boards	300 plf?
3. 3/8-in. WSP	220 plf?
4. 1/2-in. fiberboard	180 plf?
5. 1/2-in. gypsum board	100 plf?
6. 1/2-in. particleboard	140 plf?
7. 7/8-in. PC stucco	180 plf?
8. 7/16-in. hardboard	Unknown?

In a formal shear wall design, we can quantify the shear resistance in bracing material; in fact, the code provides those numbers for everything but let-in bracing. But because the overall resistance to racking in conventional construction isn't completely understood, we don't know exactly what shear resistance is being provided by the bracing material itself. Here are some estimates of the shear strength of the 8 allowed bracing materials applied according to the IRC. The widely varying numbers explain why different materials must be provided in different amounts.

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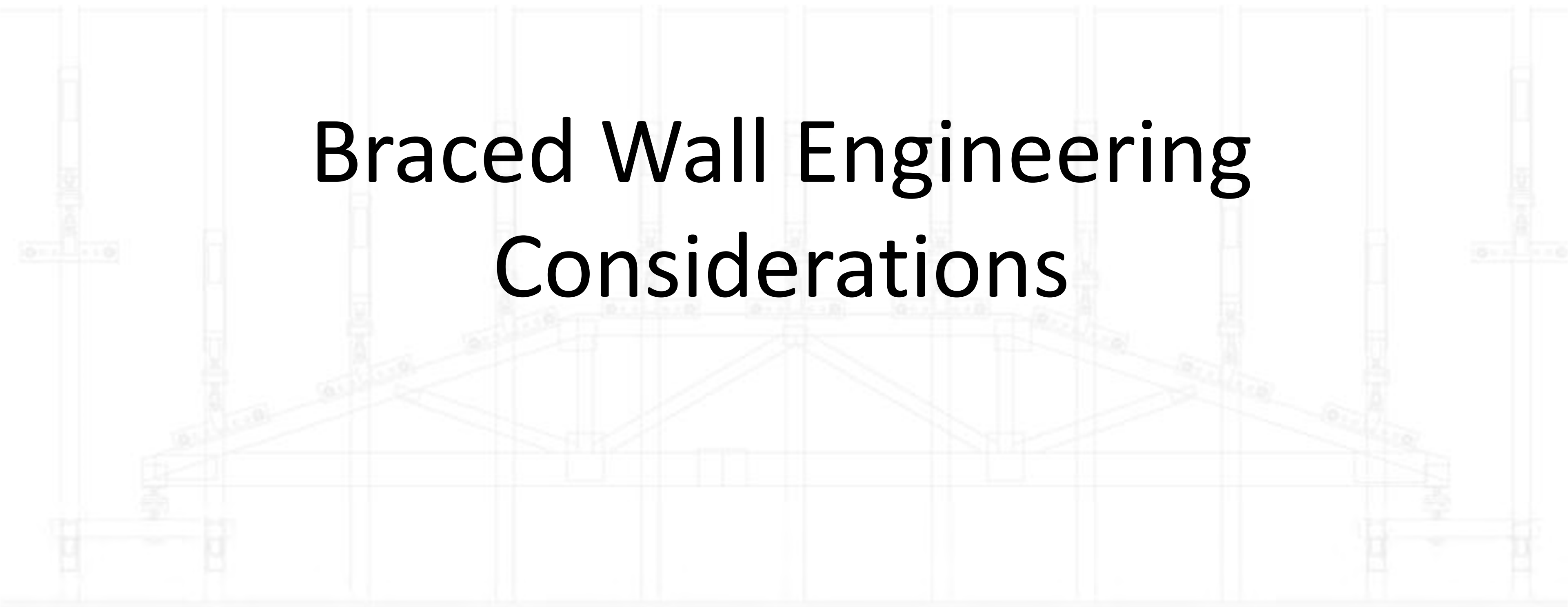

Braced Wall Engineering Considerations

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Braced Wall Panel in a Braced Wall Line System Effect

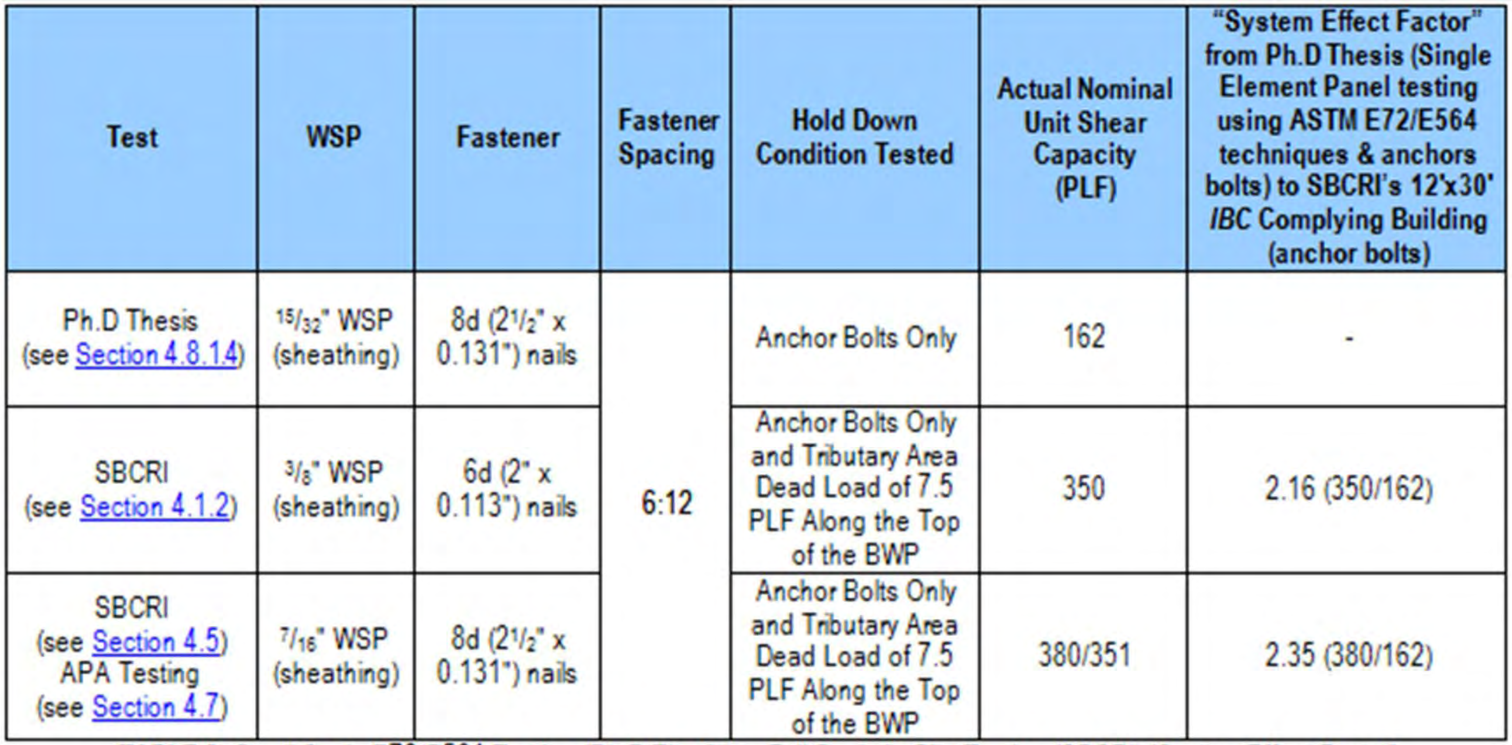
Is there one?

Common sense would say there should be.

System Effect – Is There One for Braced Wall Panels?

This testing is not an apples-to-apples comparison, yet the nominal unit shear capacity values determined by the Ph.D. student on a single 4'-wide BWP strongly suggest the in-situ testing performed by SBCRI yields a "System Effect Factor" as shown.

This is also supported by data from Seiders and Dolan-Toothman testing.



Test	WSP	Fastener	Fastener Spacing	Hold Down Condition Tested	Actual Nominal Unit Shear Capacity (PLF)	"System Effect Factor" from Ph.D Thesis (Single Element Panel testing using ASTM E72/E564 techniques & anchors bolts) to SBCRI's 12'x30' *IBC* Complying Building (anchor bolts)
Ph.D Thesis (see Section 4.8.14)	$^{15}/_{32}$" WSP (sheathing)	8d (2$^{1}/_{2}$" x 0.131") nails	6:12	Anchor Bolts Only	162	-
SBCRI (see Section 4.1.2)	$^{3}/_{8}$" WSP (sheathing)	6d (2" x 0.113") nails		Anchor Bolts Only and Tributary Area Dead Load of 7.5 PLF Along the Top of the BWP	350	2.16 (350/162)
SBCRI (see Section 4.5) APA Testing (see Section 4.7)	$^{7}/_{16}$" WSP (sheathing)	8d (2$^{1}/_{2}$" x 0.131") nails		Anchor Bolts Only and Tributary Area Dead Load of 7.5 PLF Along the Top of the BWP	380/351	2.35 (380/162)

TABLE 9: Small Scale E72/E564 Testing (Ph.D Thesis) to Full Scale In Situ Testing (SBCRI) "System Effect Factor"

The "System Effect Factor" found above proves what engineers assume; if one does a single element test in isolation there should be a positive system effect when an apples-to-apples comparison is made.

Past testing and this data show that this is a reasonable engineering assumption.

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Evaluation of the Contribution of Gypsum Wall Board (GWB)

Common sense says that WSP and GWB stiffnesses are different.

Does it make sense that lateral resistance of two sheet materials of different stiffness is additive?

Testing the Contribution of GWB

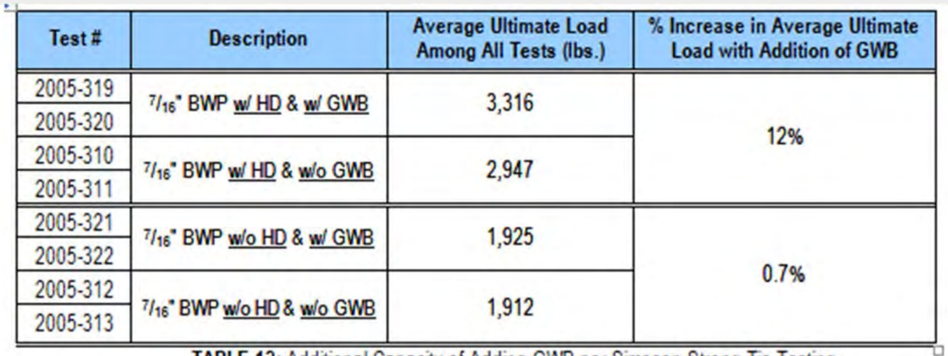
SDPWS suggests that the GWB capacity of 200 plf is directly additive to the WSP BWP capacity [i.e., 200 plf (GWB capacity) plus 515 plf ($^3/_8$" WSP) = 715 plf].

- But again, the 200 plf capacity correlates to GWB that is fully restrained.

APA reports test data that shows GWB along with a WSP in a partially restrained condition increases capacity by only 32 plf.

Publically available testing from Simpson Strong-Tie is found to the right.

- The average percent increase in additional capacity that adding $^1/_2$" GWB per the Simpson testing is similar to Dolan & Toothman's conclusion, "...GWB was effective in increasing the peak load for walls with hold-down connections... GWB was not effective in changing the peak load for walls without hold-down connections."



Test #	Description	Average Ultimate Load Among All Tests (lbs.)	% Increase in Average Ultimate Load with Addition of GWB
2005-319 2005-320	$^7/_{16}$" BWP w/ HD & w/ GWB	3,316	12%
2005-310 2005-311	$^7/_{16}$" BWP w/ HD & w/o GWB	2,947	
2005-321 2005-322	$^7/_{16}$" BWP w/o HD & w/ GWB	1,925	0.7%
2005-312 2005-313	$^7/_{16}$" BWP w/o HD & w/o GWB	1,912	

TABLE 12: Additional Capacity of Adding GWB per Simpson Strong-Tie Testing

SBCRI testing shows agreement with Dolan & Toothman's concepts where there is a capacity increase with GWB when used in situ.

A reasonable number is 100 plf, which fits in-situ test data.

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Evaluation of Nominal Unit Shear Capacity Values Generated by Monotonic vs. Cyclic Testing

Common sense says that resistance is resistance and that there should not be radical differences between the two test methods.

Does it make sense that fundamental material resistance will radically change merely through a change in how the load is applied?

The answer is “yes” as the applied load approaches an “impact-like application.” Otherwise, probably not so much.

Testing Monotonic vs. Cyclic Nominal Unit Shear Capacity

According to the Dolan & Toothman testing:

> "... The results indicate that the monotonic and cyclic response of all of the walls were similar in stiffness and load up to a displacement of approximately 50 mm (2 in). ..."
>
> "... The wall type that experienced the most reduction was GWB when tested alone. All of the walls displayed reduced strength when tested cyclically except for hardboard-sheathed walls which actually increased in strength."

Table 18 of Report No. WMEL-2002-03 (see table below) defines that a conservative average ratio of roughly 0.90 for all wall types would be reasonable (i.e., a monotonic nominal unit capacity value times a 0.9 factor would equal a cyclic nominal unit capacity value.

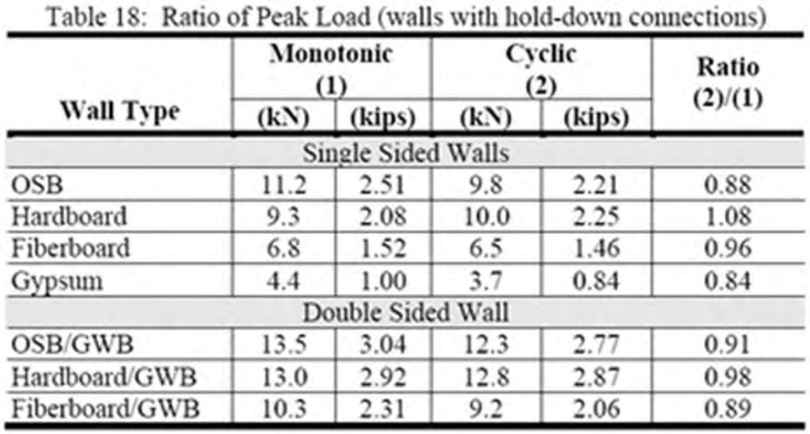


Table 18: Ratio of Peak Load (walls with hold-down connections)

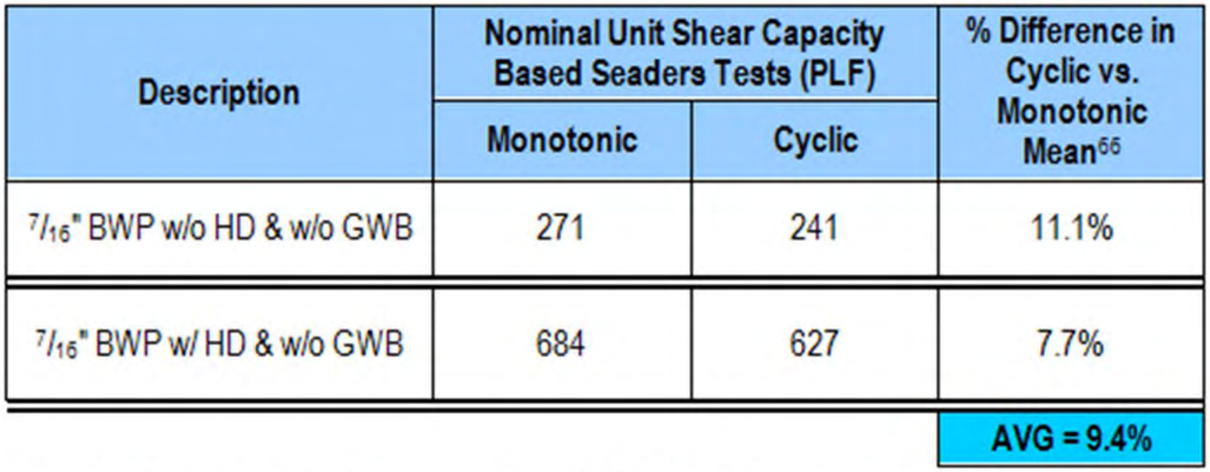
Wall Type	Monotonic (1)		Cyclic (2)		Ratio (2)/(1)
	(kN)	(kips)	(kN)	(kips)	
Single Sided Walls					
OSB	11.2	2.51	9.8	2.21	0.88
Hardboard	9.3	2.08	10.0	2.25	1.08
Fiberboard	6.8	1.52	6.5	1.46	0.96
Gypsum	4.4	1.00	3.7	0.84	0.84
Double Sided Wall					
OSB/GWB	13.5	3.04	12.3	2.77	0.91
Hardboard/GWB	13.0	2.92	12.8	2.87	0.98
Fiberboard/GWB	10.3	2.31	9.2	2.06	0.89

Table 17: Ratio of Peak Load (Walls with Hold-Down Connections) (Table 18 from Report No. WMEL-2002-03)

Testing Monotonic vs. Cyclic Nominal Unit Shear Capacity

According to the Seaders report:

“....It appears from the data that there is a strong trend toward a lower variability in the results from the cyclic testing compared to the monotonic testing. This is primarily due to two factors, namely, the incremental loading and the fully reversed nature of the cyclic testing protocol. ...”



Description	Nominal Unit Shear Capacity Based Seaders Tests (PLF)		% Difference in Cyclic vs. Monotonic Mean[66]
	Monotonic	Cyclic	
$^{7}/_{16}$" BWP w/o HD & w/o GWB	271	241	11.1%
$^{7}/_{16}$" BWP w/ HD & w/o GWB	684	627	7.7%
			AVG = 9.4%

Table 16: Percent Difference Between Monotonic & Cyclic Seaders Testing for $^{7}/_{16}$" WSP BWP in a Fully and Partially Restrained Wall Framed with DF at 24" o.c.

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Evaluation of Nominal Unit Shear Capacity Values Generated by Monotonic vs. Cyclic Testing

Common sense says that resistance is resistance and that there should not be radical differences between the two test methods.

Test data proves common sense is correct.

A reasonable monotonic test factor of 0.9 should be able to be used to convert monotonic nominal unit strength capacity to cyclic nominal unit strength capacity. SBCRI testing confirms this is true for in-situ testing as well.

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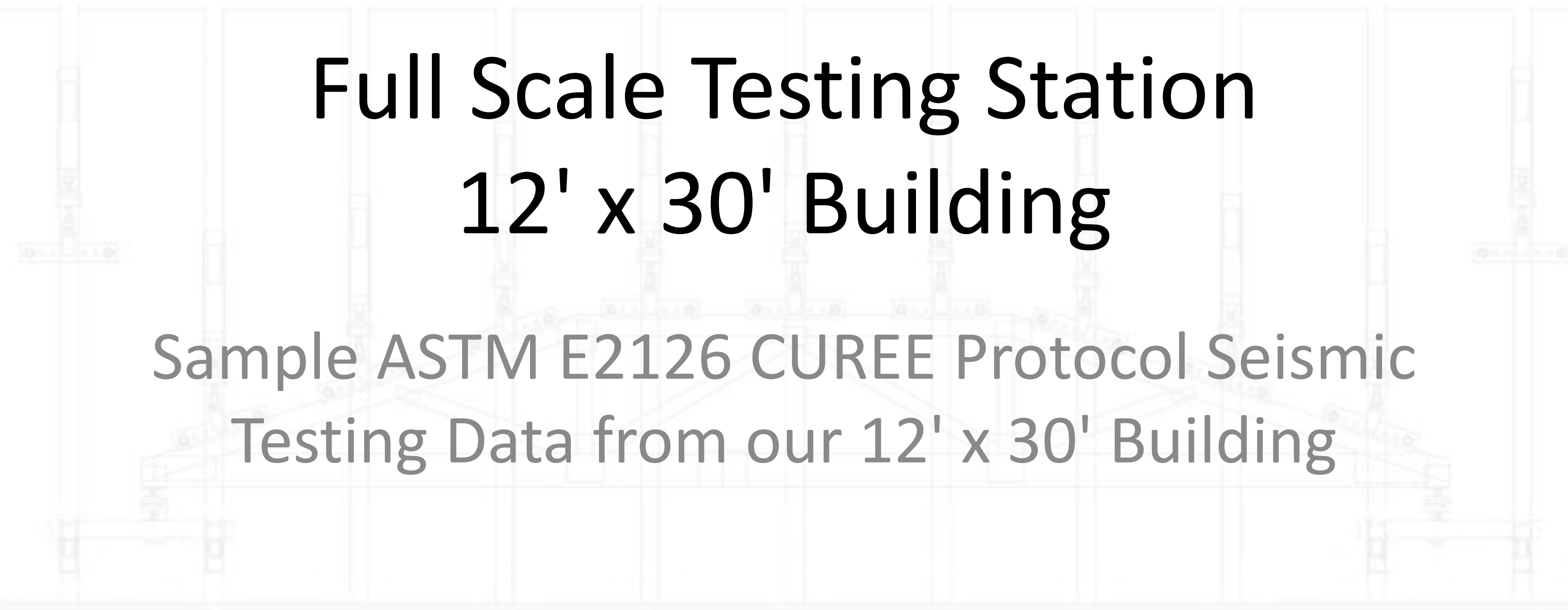


Full Scale Testing Station
12' x 30' Building

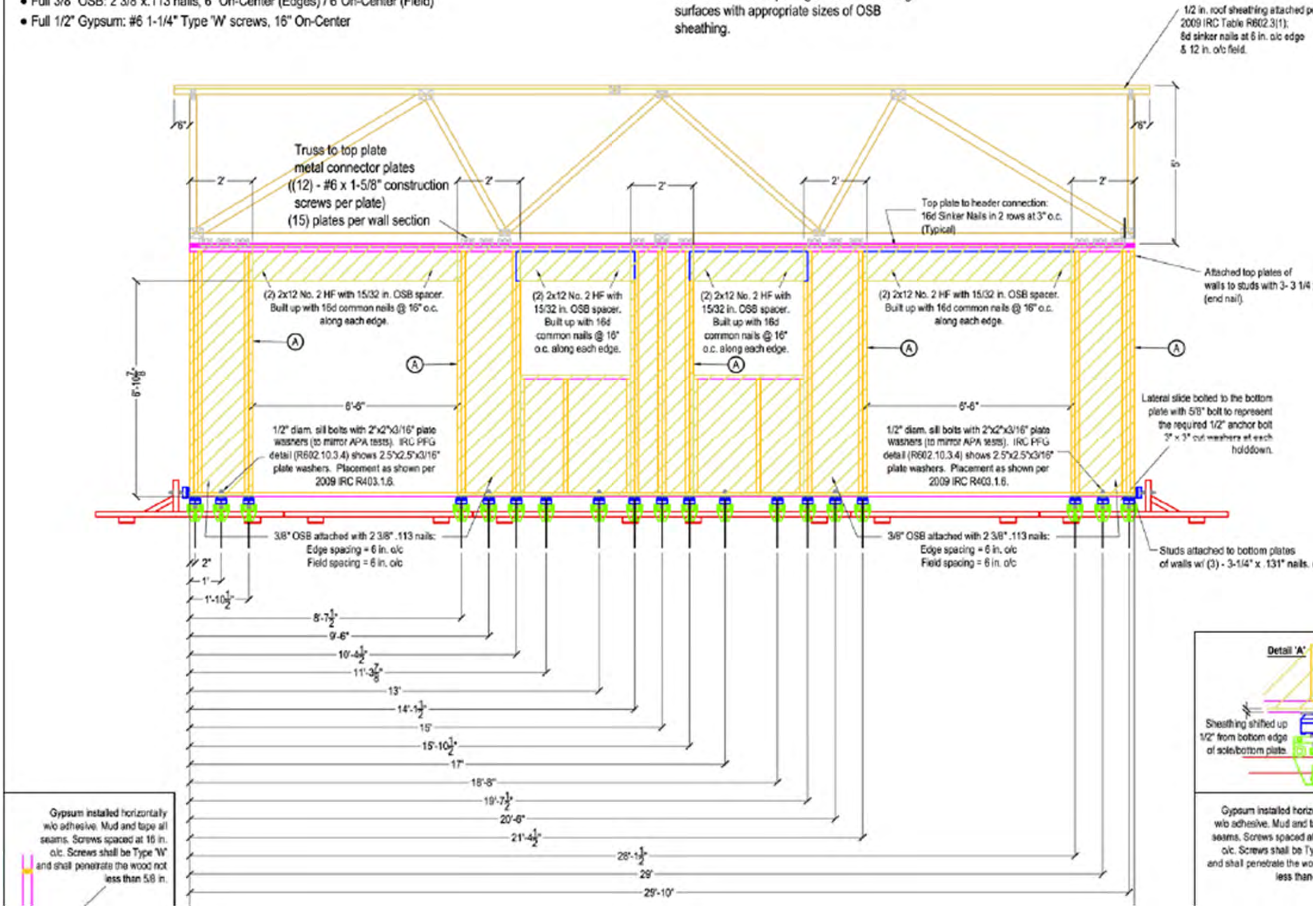
Sample ASTM E2126 CUREE Protocol Seismic Testing Data from our 12' x 30' Building

09-0104-39a

- 24" On-Center Stud Spacing
- Full 3/8" OSB: 2 3/8"x.113 nails, 6" On-Center (Edges) / 6"On-Center (Field)
- Full 1/2" Gypsum: #6 1-1/4" Type 'W' screws, 16" On-Center

NOTE:

- 2' x 8' strips of OSB to be used at all piers of door and window openings. Cover remaining surfaces with appropriate sizes of OSB sheathing.



Gypsum installed horizontally w/o adhesive. Mud and tape all seams. Screws spaced at 16 in. o/c. Screws shall be Type 'W' and shall penetrate the wood not less than 5/8 in.

Gypsum installed horiz w/o adhesive. Mud and t seams. Screws spaced a o/c. Screws shall be Ty and shall penetrate the wo less than


LP
BUILDING PRODUCTS
SAGOLA, MI
APA
RATED SHEATHING
WALL-24 OC
SIZED FOR SPACING
EXPOSURE 1
407
PRP-108 HUD-UM-40C
CATEGORY
CONSTRUCTION SHEATHING
W24
9.5mm
CSA O325-07
EXTERIOR TYPE
ADHESIVE
STRENGTH AXIS
THIS DIRECTION

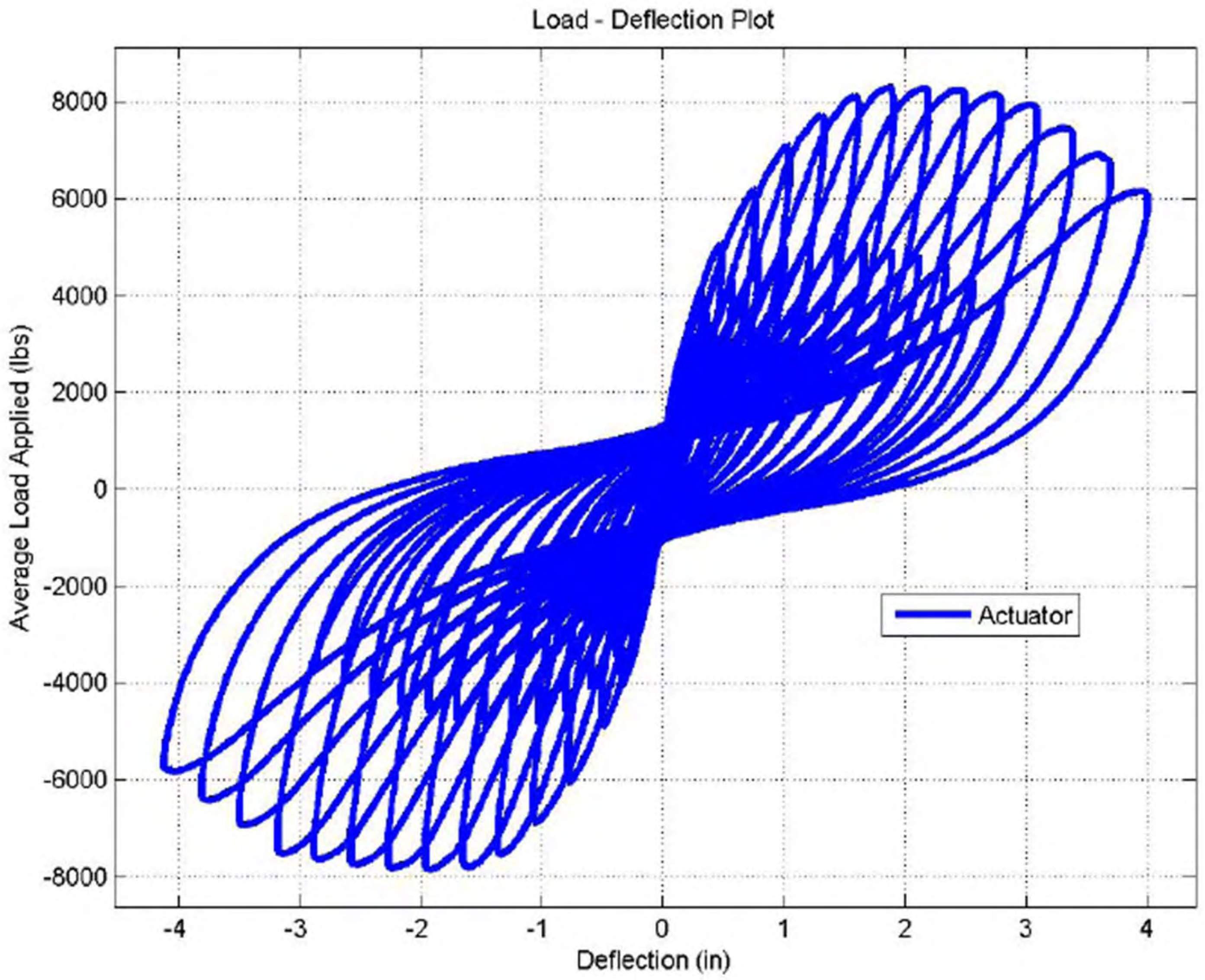


Figure 7: Load-Deflection Plot – Full Data Set – Actuator Displacement

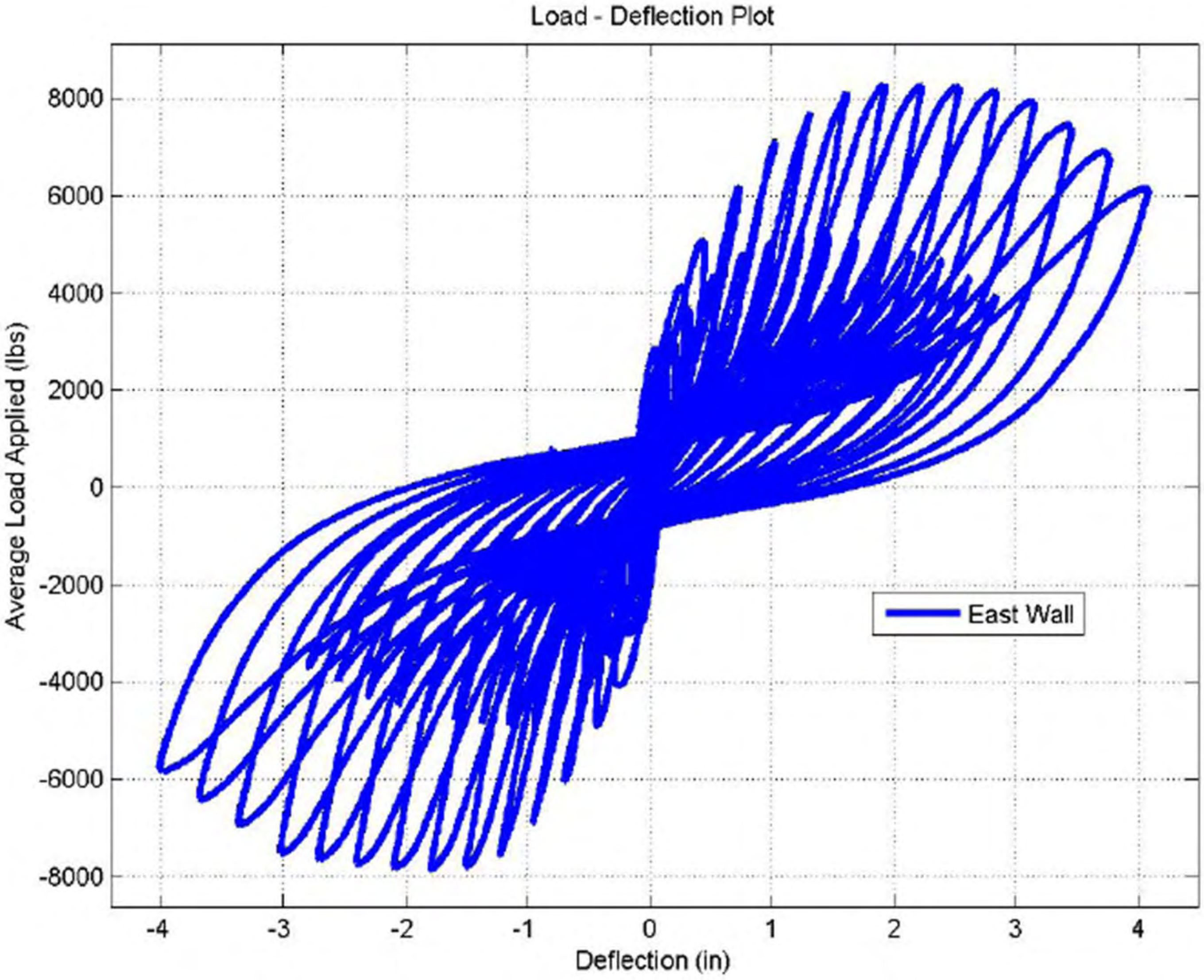


Figure 8: Load-Deflection Plot – Full Data Set – Global Wall Displacement – East Wall

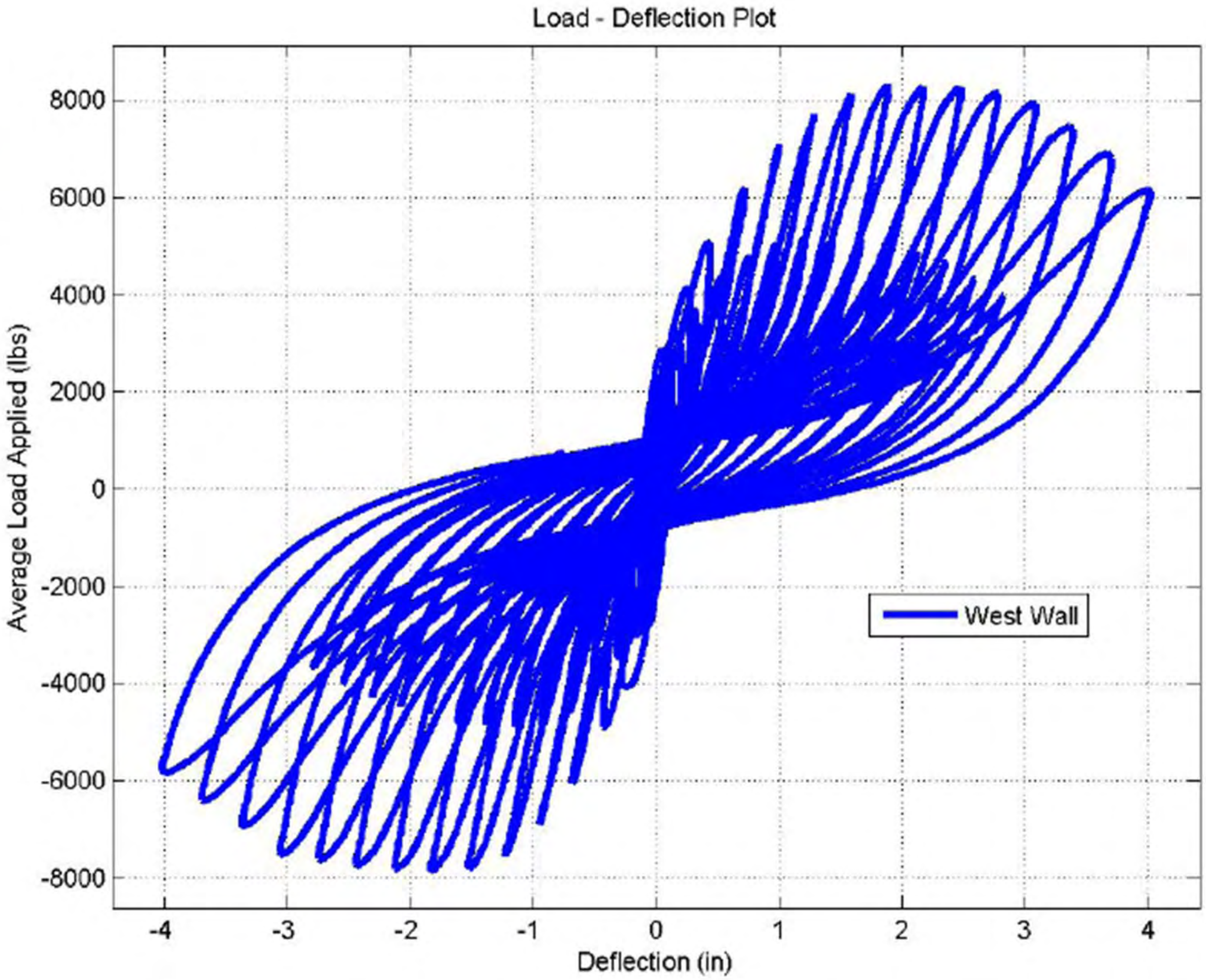


Figure 9: Load-Deflection Plot – Full Data Set – Global Wall Displacement – West Wall

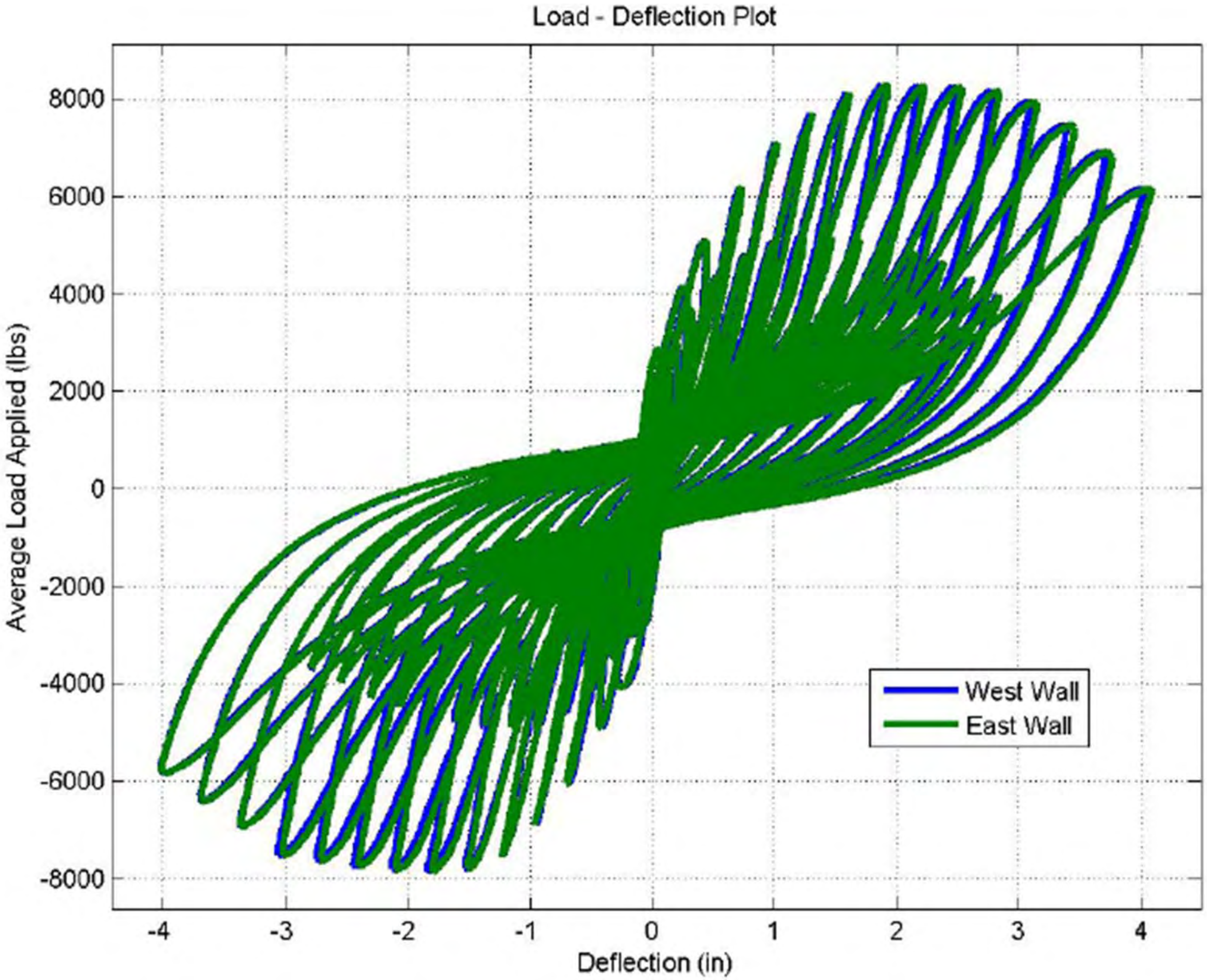


Figure 10: Load-Deflection Plot – Full Data Set – Global Wall Displacement – Both Walls

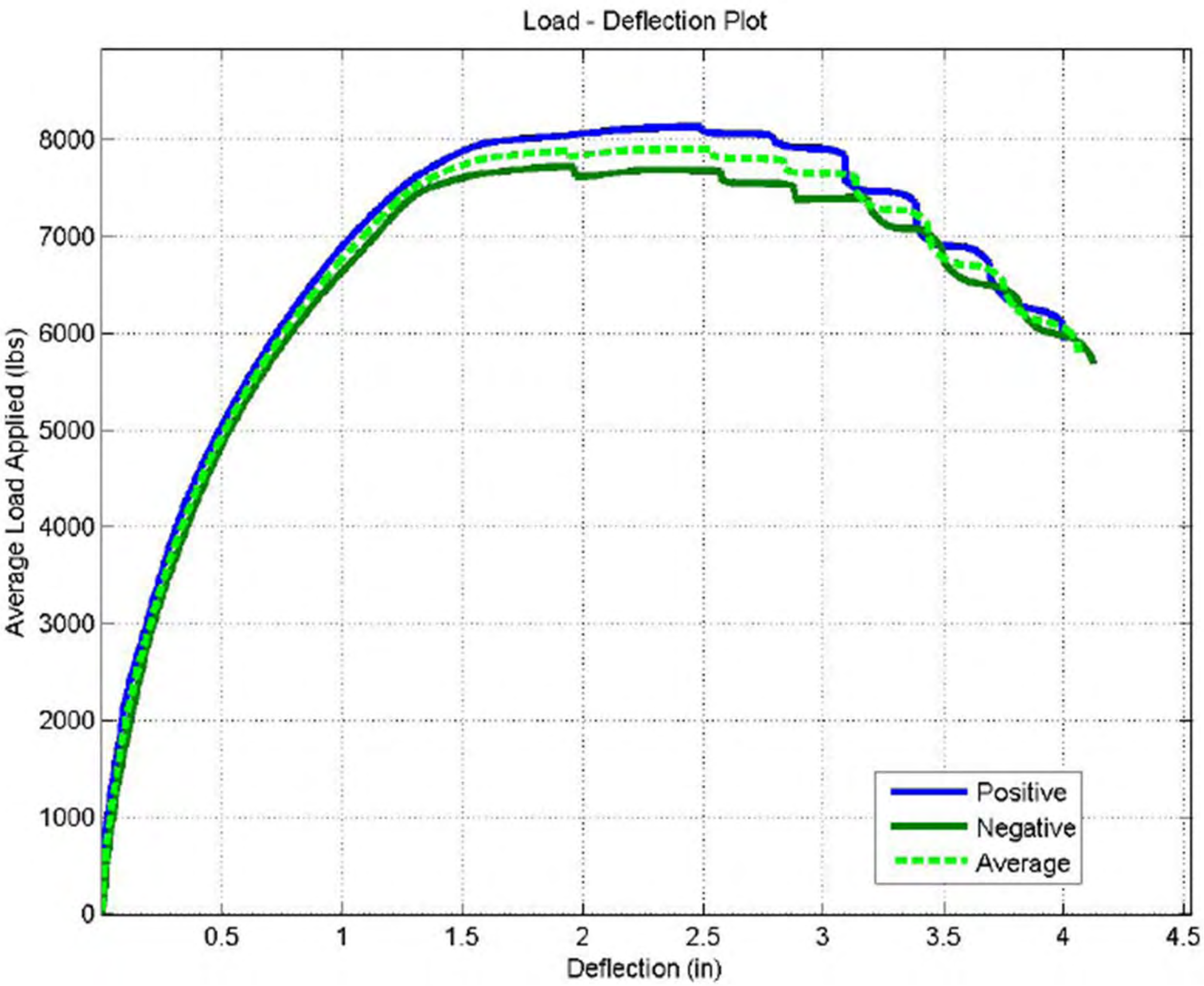


Figure 11: Backbone Curves – Actuator Displacement

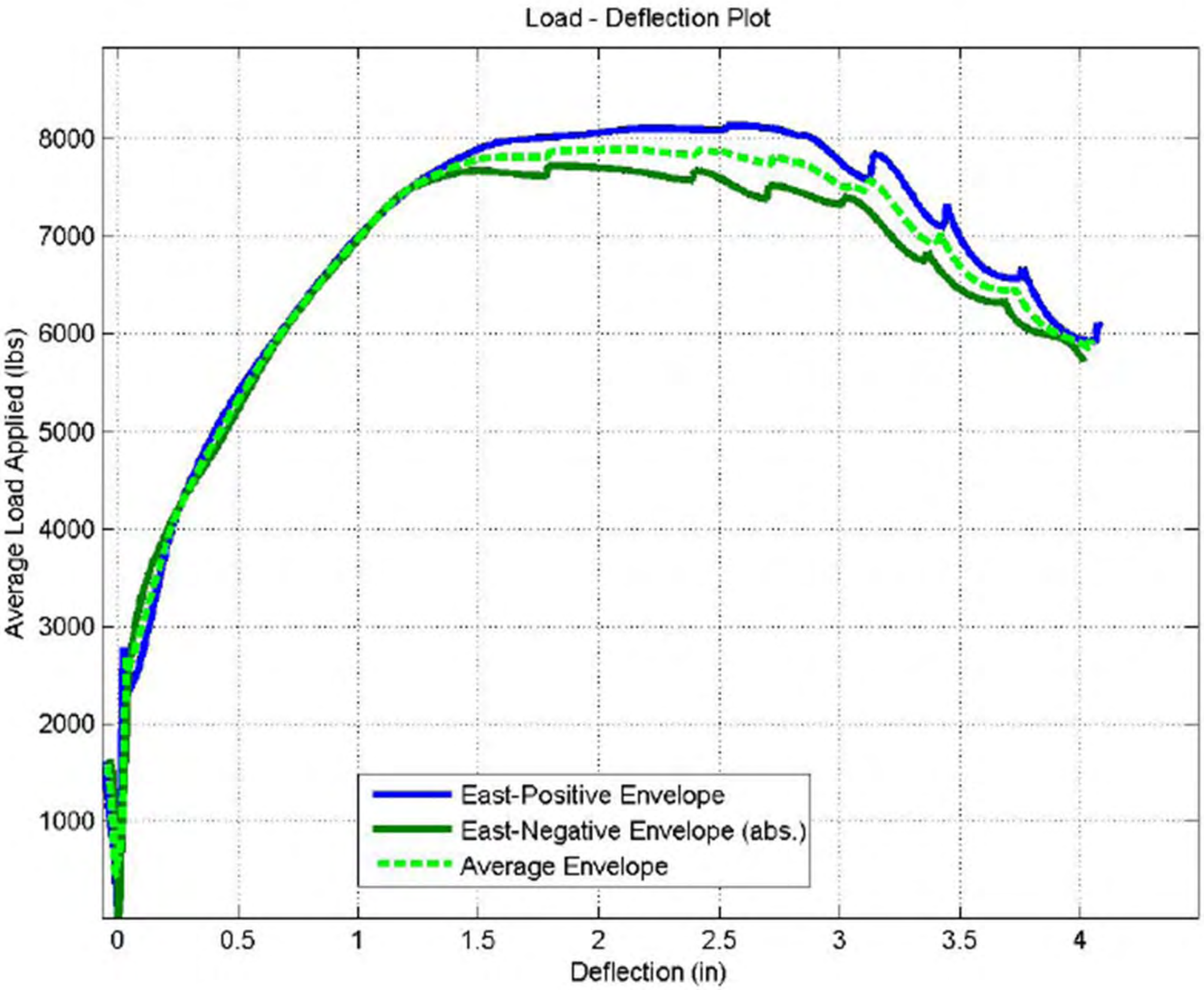


Figure 12: East Wall Backbone Curves – Global Wall Displacement

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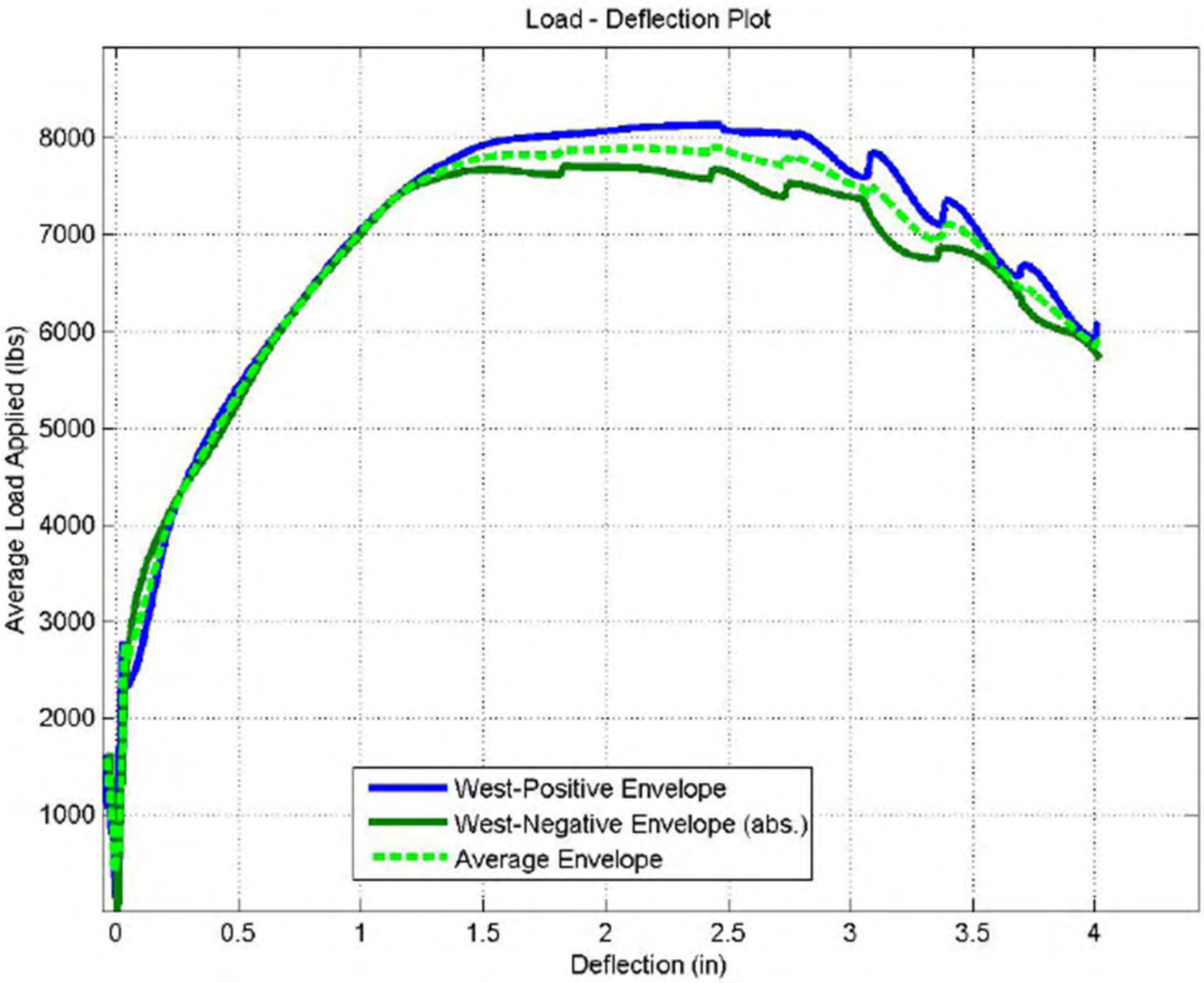

Figure 13: West Wall Backbone Curves – Global Wall Displacement

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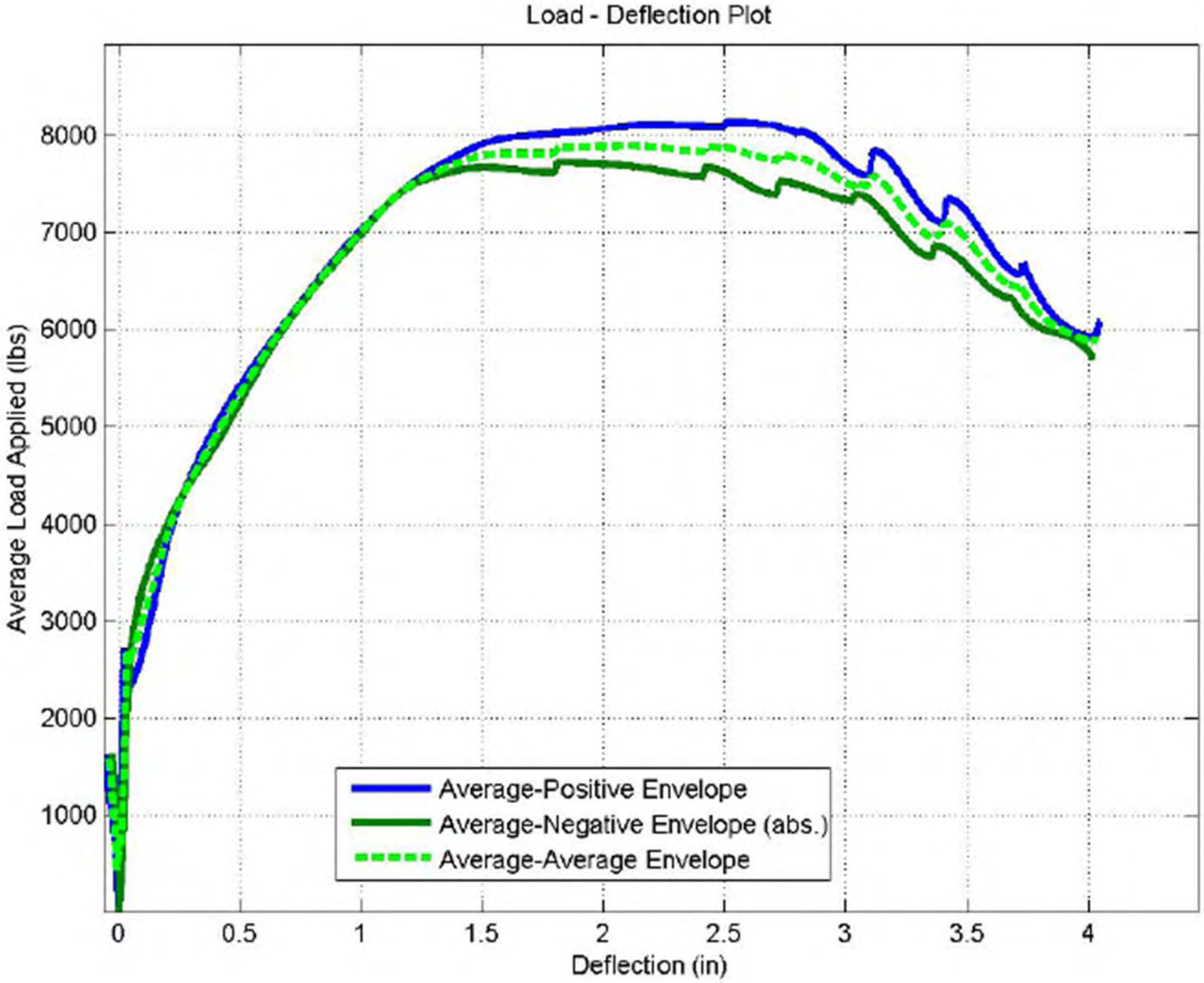
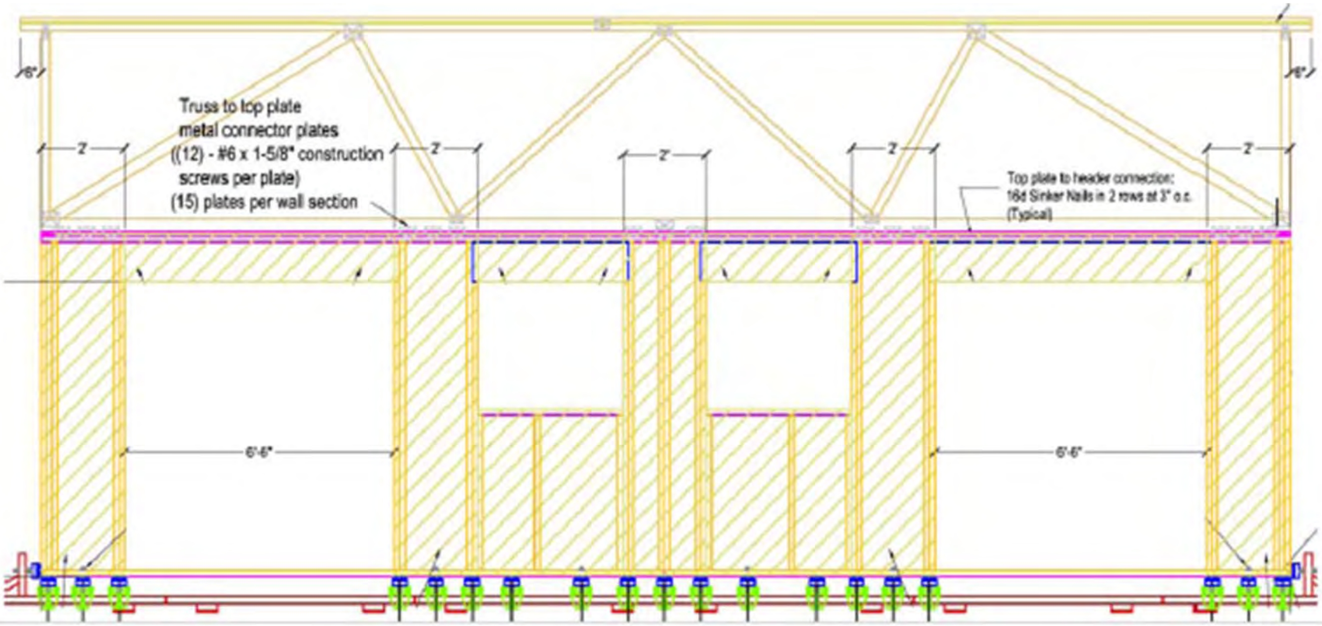


Figure 14: Average Wall Backbone Curves – Global Wall Displacement



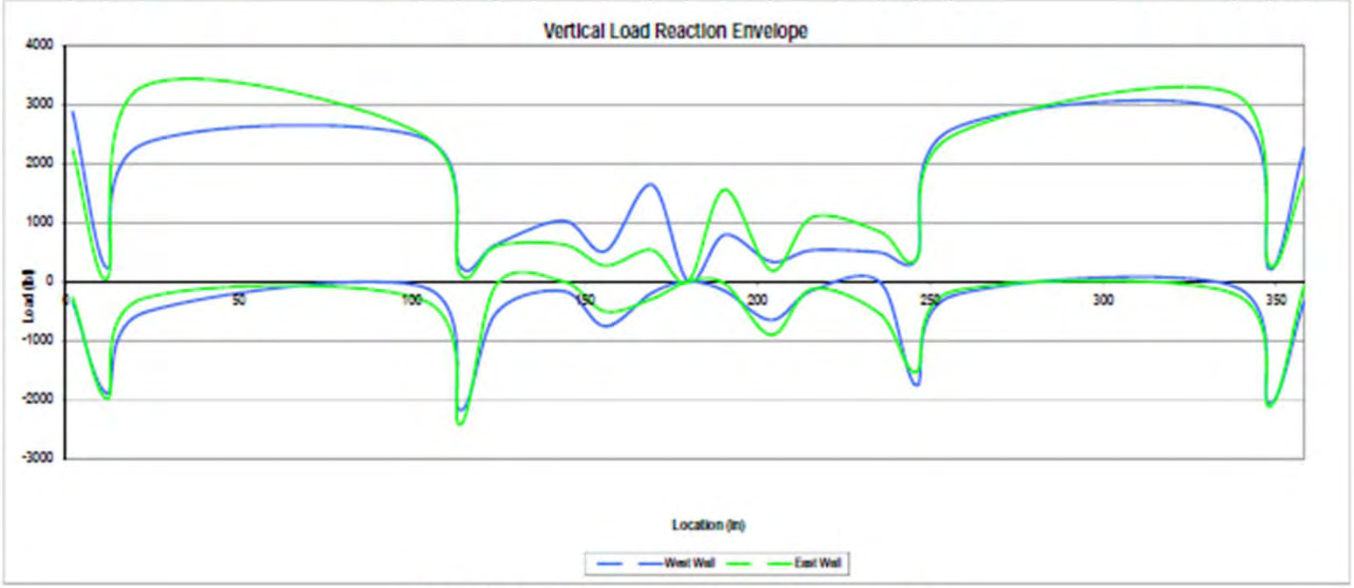


Figure 15: Vertical Distribution of Loads During Cyclic Test

Testing & Technical Substance Behind Our Evaluation of Lateral Braced Wall Design

- Qualtim/SBCRI testing uses the standardized testing procedure techniques of ASTM E2126, E564 and E72, as appropriate, in our full building testing.
- A comprehensive set of non-proprietary data and BWP/BWL analysis provided courtesy of Qualtim is available at:
  - sbcri.info/bcters.php
  - sbcri.info/ibcirc.php

Qualtim/SBCRI Next Steps

- Evaluate Seismic Design Coefficients
  - AC 130/AC 320 Appendix A Method, Hamburger Analytical Method, ATC Method, etc.
  - Make comparisons of results based on 12' x 30' building testing
  - Compare to ASCE 7
  - Compare to SBCRI E564 residual capacity testing
  - Recommend an approach that provides an accurate measure of residual safety
- Evaluate Perforated Shear Wall Methods
- Further Refine Composite Stiffness – WSP & GWB
- Provide Benchmarked Performance Tables for Market Use – Comparative Equivalency – Level Playing Field Work

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IBC/IRC Braced Wall Panel in a Braced Wall Line Math

There are implied design factors that increase capacity of WSP codified into the *IBC* and *IRC* as "code compliance law."

Given this, don't these products have a code-mandated design value competitive advantage with respect to anchor bolt applications, when compared to non-code listed BWPs?

Is this fair?

Doesn't this constrain innovation, new product development and advancement of knowledge based creative engineering?