Final Report for Project Entitled:

Investigation of Fastening of Wood Structural Panels for Opening Protection (Phase 2)
PO Number AB3DBA

Performance Period: 10/10/2014 – 6/30/2015

Submitted on

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Presented to the

Florida Building Commission
State of Florida Department of Business and Professional Regulation

by

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1. Disclaimers

- This report presents the findings of research performed by the University of Florida. Any opinions, findings, and conclusions or recommendations expressed in this paper are those of the authors and do not necessarily reflect the views of the sponsors, partners and contributors. The Structural Technical Advisory Committee of the Florida Building Commission will provide a final disposition on the implications for the Florida Building Code.

2. Applicable Sections of the Code

- 1609.1.2, Exception 1, Florida Building Code 2010: Building
- Table 1609.1.2, Florida Building Code 2010: Building
- R301.2.1.2, Exception, Florida Building Code 2010: Residential
- Table R301.2.1.2, Florida Building Code 2010: Residential

3. Major Findings and Recommendations for the Code from Phase 1 (FY 2013-14)

The letter from Joe Belcher in **Appendix A** on behalf of the International Hurricane Protection Association (IHPA) describes the issues that led to the initiation of the original (Phase 1) project conducted during FY 2013-14. This final report may be obtained from FBC staff or the lead investigator.

Phase 1 research findings were used to suggest modifications to the 5th Ed. of the Florida Building Code-Building (see **Appendix B**), which are summarized below:

1. Determination of wind loads for labeling and product approval of impact resistant coverings should be streamlined and made consistent with ASCE 7-10 Components and Cladding (C&C) load calculations. The current approach yields an ultimate load that is 90% of the ASCE 7-10 C&C counterpart. Further, the Code should explicitly define the relationship between ASD and LRFD (ultimate) pressures and the terminology incorporated in the testing application standards, which vary. Appendix B contains the authors' suggestion modifications to the 5th Ed. of the Florida Building Code-Building. We suggest that the Code allows a single prescriptive design (proposed herein) and simplified guidance for designers seeking alternative fastening solutions
2. The wind-borne debris protection fastening schedule (Table 1609.1.2) for wood structural panels is not conservative, e.g. an 8 ft unsupported span of 7/16 OSB with 1 inch of spacing between the fastener and the panel edge will fail in strong winds
3. Structural wood panels are a good choice for a low-cost storm shutters outside of the HVHZ if the fastening schedule is adequate. A one-approach-fits-all, low-cost design was developed and tested for Group R-3 or R-4 occupancy buildings with a mean roof height of 45 feet or less in locations where Vult is 180 mph or less. The system did not exhibit failure during static and cyclic pressure tests derived from ASTM E330 and ASTM E1996. We believe this design reasonably complements the options for metal shutter products, which are generally rated for higher pressures with the tradeoff of increased cost

The following items were found to merit additional study and are the focal points of the Phase 2 study:

4. Predicting the catenary forces is not straightforward given the current knowledge base. The flexibility of 7/16 OSB causes large deflections (~L/15) that cause in-plane forces that combine with the withdrawal force induced by the out-of-plane wind loading. The lateral (shear) forces are dependent on a combination of factors, including flexural bending of the fasteners or other yield modes (crushing, rotating, hinging) and the free translation of the panel caused by oversizing of the holes that receive the fasteners
5. Designers need conservative yet realistic closed-form solutions to calculate catenary loads in a rational engineering analysis, however the standard equations most likely to be used by a designer are expected to significantly overpredict the lateral forces. Additional experimental research is required to validate closed-form solutions and to establish baseline parameters (e.g. load/slip) for typical panel materials, thicknesses and physical properties (e.g., moisture content). These data can be readily incorporated into existing standards published by APA and AWC that are referenced by the Code
6. Other combinations of hardware and wall types should be studied to determine if the one-approach-fits-all approach proposed in the study is acceptable or requires modifications to achieve suitability. Time and budget precluded the investigators from evaluating other combinations that are prevalent in Florida, however the experimental configuration required to perform this testing is now in place
7. Developing recommendations for larger openings is warranted, especially given the widespread use of sliding glass doors in one- and two-story residential buildings. Additional research is required to develop a prescriptive design solution for large openings that require more than one panel. The APA T460 *Hurricane Shutter Design Considerations for Florida* provides a logical starting point for designing multi-panel configurations

4. Major Findings and Recommendations for the Code from Phase 2 (FY 2014-15)

1. The Code should explicitly require that shutter systems be designed for both withdrawal <u>and</u> lateral forces for 7/32 OSB and fabric panel systems. At proof load, experimental results from testing of 1.2 m (4 ft) unsupported spans show that ratio of catenary forces to withdrawal forces is as much as 1.75 at proof load. In contrast, the metal panel system tested in this study (0.050 in steel) did not exhibit significant catenary loads up to a 6 ft unsupported span
2. Structural wood panels are a good choice for a low-cost storm shutters outside of the HVHZ if the fastening schedule is adequate. The one-approach-fits-all, low-cost design developed and tested in Phase 1 was adapted for brick over wood frame and concrete / hollow CMU substrates for single panel installations. The fastening schedule and placement on the latter was adjusted to compensate for reduced capacities for tension and shear of fasteners in hollow CMUs and potential for installation errors
3. Dual panel systems intended for large openings (specifically sliding glass doors) were also designed for wood frame, brick over wood and hollow CMU substrates. Conventional slab on grade construction (with or without a terrace at the threshold of the sliding glass door) was determined not to be ideal for creating a boundary condition at the bottom at the door. First, it is unlikely that a homeowner would install a permanent structural wood member

or hardware to attach the shutter adjacent to the track of the door. Second, adding one-size-fits-all prescriptive language for installing a track assembly is not practical. For large openings (specifically sliding glass doors), we recommend using two vertically stacked panel assemblies that are adequately stiffened to limit out-of-plane deflection—the cause of catenary forces in the panel and the counteracting lateral (shear) force on the fasteners. 15/32 plywood and SYP 2x4 perimeter and interior framing proved adequate for wind loads up to 6 kPa

4. Appendix B contains the recommended modifications to the code

5. Scope of Work

- Develop a rational engineering analysis method to calculate catenary (lateral) forces for flexible panel systems
- Determine prescriptive fastening requirements for structural wood panels attached to masonry wall systems and validate the design through experimental testing
- Design structural wood panel systems for large openings and validate the design through experimental testing. Evaluate APA T460 as a starting point for this design
- Interpret results, determine whether the problem requires action, and produce a report that explains the results and implications for the Code

6. Deliverables

- Interim report by February 15, 2015 – Interim progress report detailing the current status and progress toward completing the work described above. In addition, the Interim report will be presented to the Commission's Structural Technical Advisory Committee at a time agreed to by the Contractor and Department's Project Manager
- Final report by June 1, 2015 providing technical information on the problem background, results and implications to the Code. In addition, the final report will be presented to the Commission's Structural Technical Advisory Committee at a time agreed to by the Contractor. The department's Project Manager recommendation(s) may require revision to a future edition of the FBC will be analyzed using the criteria outlined in the currently adopted code modification form
- A breakdown of the number of hours or partial hours, in increments of fifteen (15) minutes, of work performed and a brief description of the work performed. The Contractor agrees to provide any additional documentation requested by the Department to satisfy audit requirements

7. Project

The focus areas of this study included attachment methods for masonry wall systems (e.g., concrete-block-stucco and brick veneer over wood frame) and large openings that require more than one panel. Development of a rational analysis technique to predict catenary loads is integral to this work. Activities to date are summarized below:

- The investigator reconvened an oversight committee formed by members of APA, the American Wood Council (AWC) and the International Hurricane Protection Association

(IHPA) to discuss issues related to use of structural wood panels for opening protection. One teleconference was held on January 12, 2015. The group agreed to proceed with the proposed plan without any major modifications. The maximum size of the 'large' opening was determined to be nominally 8 ft X 8 ft, or equivalently a two panel system. This size corresponds to a sliding glass door on a low-rise residential building. The group also agreed that additional tests should be performed on conventional metal shutter systems to provide a baseline comparison

- Undergraduate students were hired at the start of the spring semester. Major activities (conducted under the supervision of laboratory staff) have included:
    - Initial staging of testing area, including the Instron universal testing machine and moisture analyzer to conduct the strip width tests to characterize the catenary loads
    - Design of light wood frame and masonry (CMU and CMU-brick veneer) test frames for one- and two-panel systems. A subset of these drawings may be found in **Appendix C**
    - Reviewing basis documents from FY 2013-14 experimental series
- The investigator presented the research program to the IHPA General Meeting in Pensacola on February 12, 2015 and elicited additional feedback on the project
- During April-June, tests of strip panels were performed using a six-axis load cell to measure in-plane and out-of-plane reaction forces. Full-scale tests of five systems (single panel for CMU / hollow CMU and brick over wood; dual panel for wood, CMU / hollow CMU and brick over wood). The research design and findings are discussed in subsequent sections.

7.1. Strip Panel Testing

Experimental research was conducted to quantify catenary loads developed in strip width panels subjected to out-of-plane pressure loading. Variables included strip length (48, 72 and 96 in end-to-end) and material type (OSB, metal and fabric). The Pressure Loading Actuator (PLA) system described in Kopp et al. (2010) was the principal testing apparatus. Figure 1 shows the experimental configuration, which consisted of a vertically-oriented deep wood frame box with an interchangeable support at the bottom for the lower fastener and an AMTI six-axis load cell that could be affixed in 305 mm (1 ft) intervals along back wall of the chamber. A SYP 2x6 was bolted to the load cell to create the substrate for installing the fastener. The wood only made contact with the load cell, which ensure continuity of the load path and no load sharing with adjacent members. Polyethylene sheeting was carefully applied around the perimeter to create a seal. A Wenglor OPT2011 laser displacement sensor was installed on a freestanding post and directed to the middle of the panel.

A step-and-hold negative pressure pattern was applied in nine 60 s levels. The suction was applied to the interior side of the panel (i.e. the side facing the window), thus the positive pressure case was tested. This approach was deemed conservative for quantifying catenary forces because the panel made contact with the support (wall), which introduced frictional forces not expected to occur during negative (outward) loading.

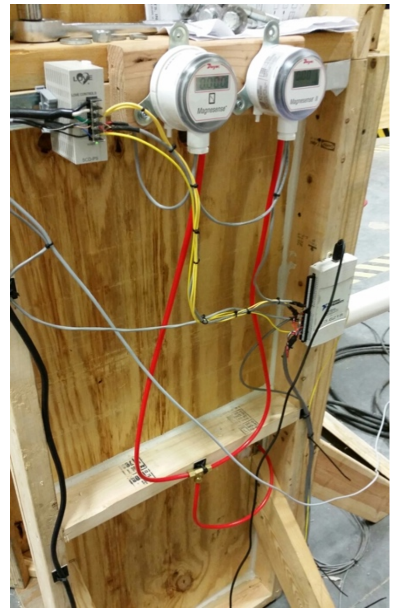
During the first level, a mild suction (0.05 kPa or ~1 psf) pressure was applied to evacuate the polyethylene sheeting that sealed the panel to the the pressure chamber. Loads were sequentially increased up to a predefined upper pressure threshold was reached. This upper bound was selected to ensure that the panel did not deflect more than 125 mm. The PLA valve was manually adjusted to determine an appropriate limit in increments of 1 kPa. For example, the suction range of metal shutter system was [0, 7 kPa], thus the nine-step sequence was -0.050, -0.875, -1.750, -2.625, -3.500, -4.375, -5.250, -6.125, -7.000 kPa.

None of the specimens exhibited damage during testing, such as visible crushing of the OSB inside the hole of the panel or permanent set in the panels. The OSB and metal shutter panels were tested to 6 kPA (leakage prevented the 7 kPA case for the metal panel), which is above the proof load. The fabric system deflected too much to test beyond 4 kPa.

Figures 2-4 show test results for selected cases. The command pressure (the input signal to the pressure loading actuator) and the measured response are shown in the upper pane. Midspan deflection is shown in the second pane. Note that initial variations (within the first 30 s) were due to loose polyethylene sheeting that obstructed the laser beam. Once the air evacuated, the sensor read true. The occasional variations in the displacement during the test are attributed to research personnel making adjustments to the sheeting during tests. The tight space required them to step into the path of the laser. The third panel shows the out-of-plane forces (measured and predicted from the applied pressure multiplied with the tributary area of the fastener) and the corresponding in-plane (lateral or catenary) forces. The bottom shows the ratio of in-plane to out-of-plane forces.

The findings clearly demonstrate that flexible panel systems are susceptible to catenary forces. In contrast, the stiff metal panel systems (which deflected less than 25 mm under 6+ kPa) experienced negligible in-plane forces. The results suggest that for fabric systems spanning a typical window (<= 4ft), the catenary force is on the order of 1.5 times the withdrawal forces at peak load. OSB covering the span should be designed to resist 1.5 – 2.0 times the withdrawal load.

The observed performance in the wood substrate case agrees with the prediction for withdrawal loads in NDS (2005), assuming a specific gravity = 0.55 for Southern Pine, a load duration factor = 1.6, wet service factor = 0.7 and an embedment of 51 mm (2 in). Withdrawal failure was not expected. The lateral limit state merits further discussion, however. NDS (2005) predicts 134 lbs for the lateral limit state, which is below the measured forces acting on the panel (that exhibited no sign of damage). The worst case corresponds to Z mode IIIs, which is associated with plastic hinge formation in the fastener and crushing in side member. Neither failure mode was observed. The American Wood Council was consulted on this observation (personal correspondence with P. Line on 6/15/2015) and was advised that NDS is more ideally suited for smaller diameter nails and larger diameter bolts/screws. The ¼ in diameter threaded fastener value is likely conservative. This opinion is further supported by the manufacturer's technical data, which lists an ultimate shear value of 523 kg (1152 lbs) for an edge distance of 19 mm (0.75 in) [25 mm (1 in) was used in this study]. Assuming a FS of 4, the fastener should hold 288 lb which is less than 300-400 lb range observed when ~5.5 kPa is applied. At the time of the report submission, we are still investigating this issue. Additional information will be provided during the presentation to the TAC regarding its resolution.



(b) Pressure measurement system

(a) Test chamber (empty) and PLA in background. Laser displacement sensor in foreground

(c) 1.2 m (4 ft) metal shutter system

Figure 1. Experimental configuration for strip panel testing

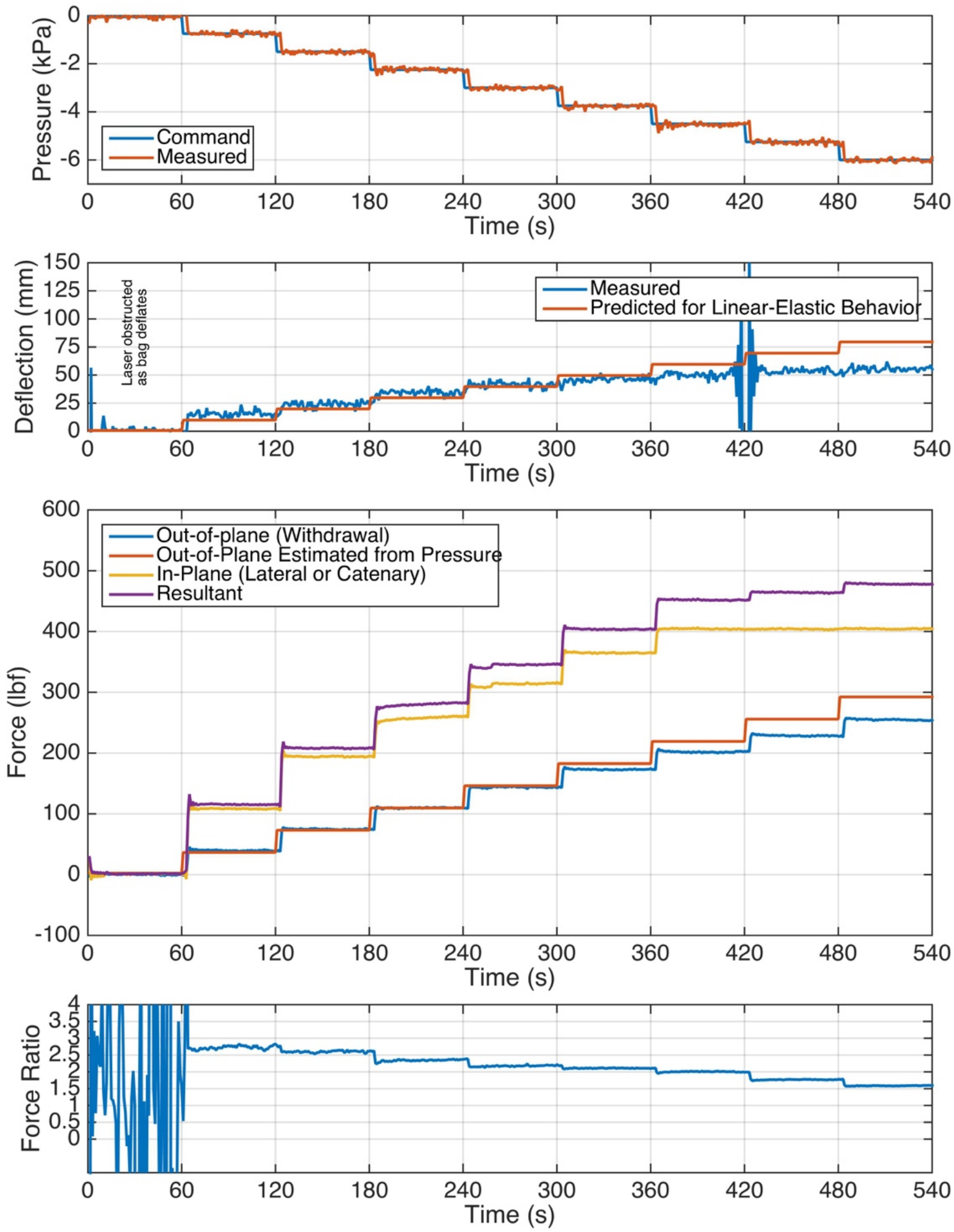


Figure 2. Data for 1.2 m (4 ft) 7/16 Category 24/16 Rated Span Exposure 1 OSB

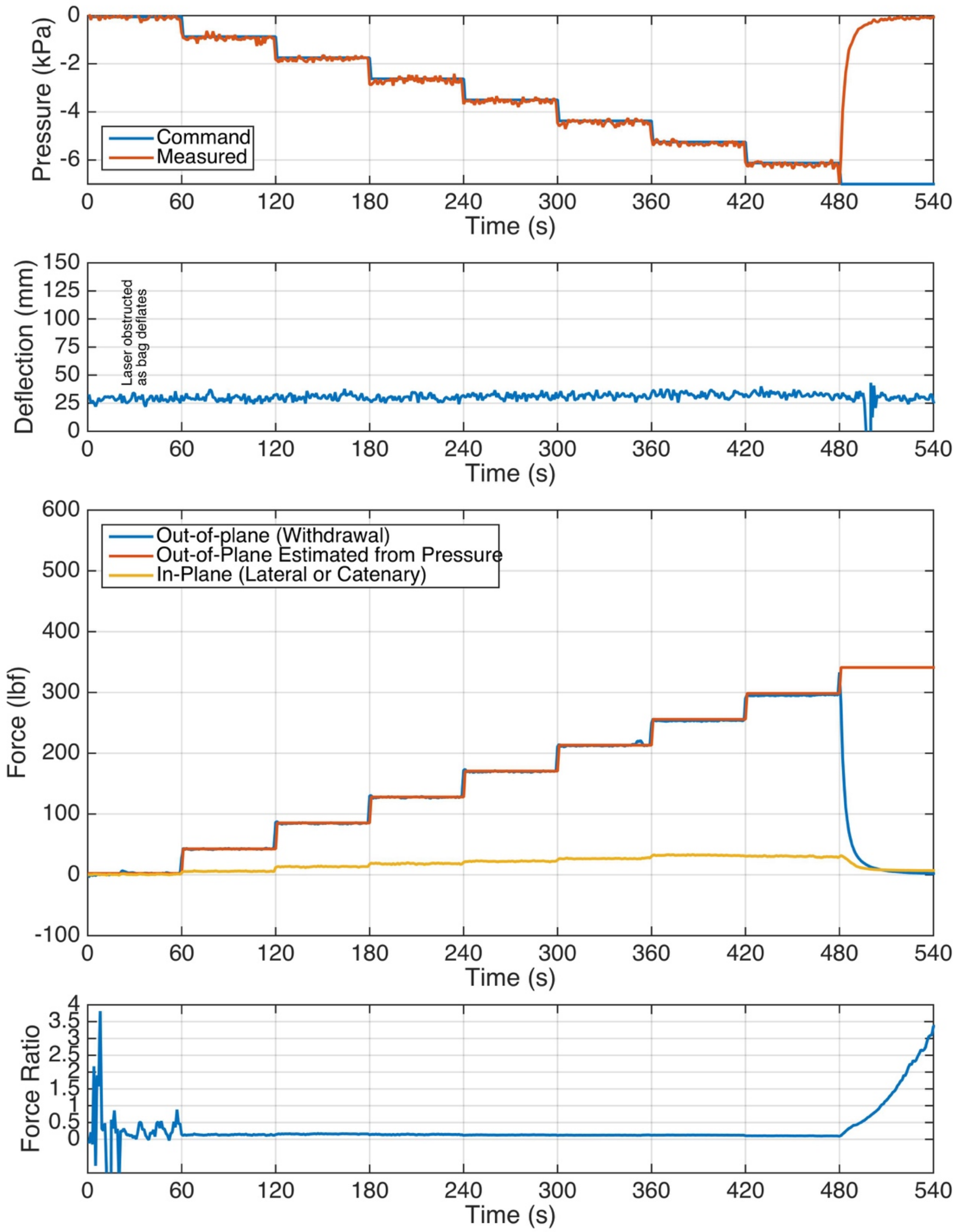


Figure 3. Data collected during testing of a 0.050 steel shutter system. The seal on the polyethylene failed at t = 480 s. Disregard data recorded after this timestamp.

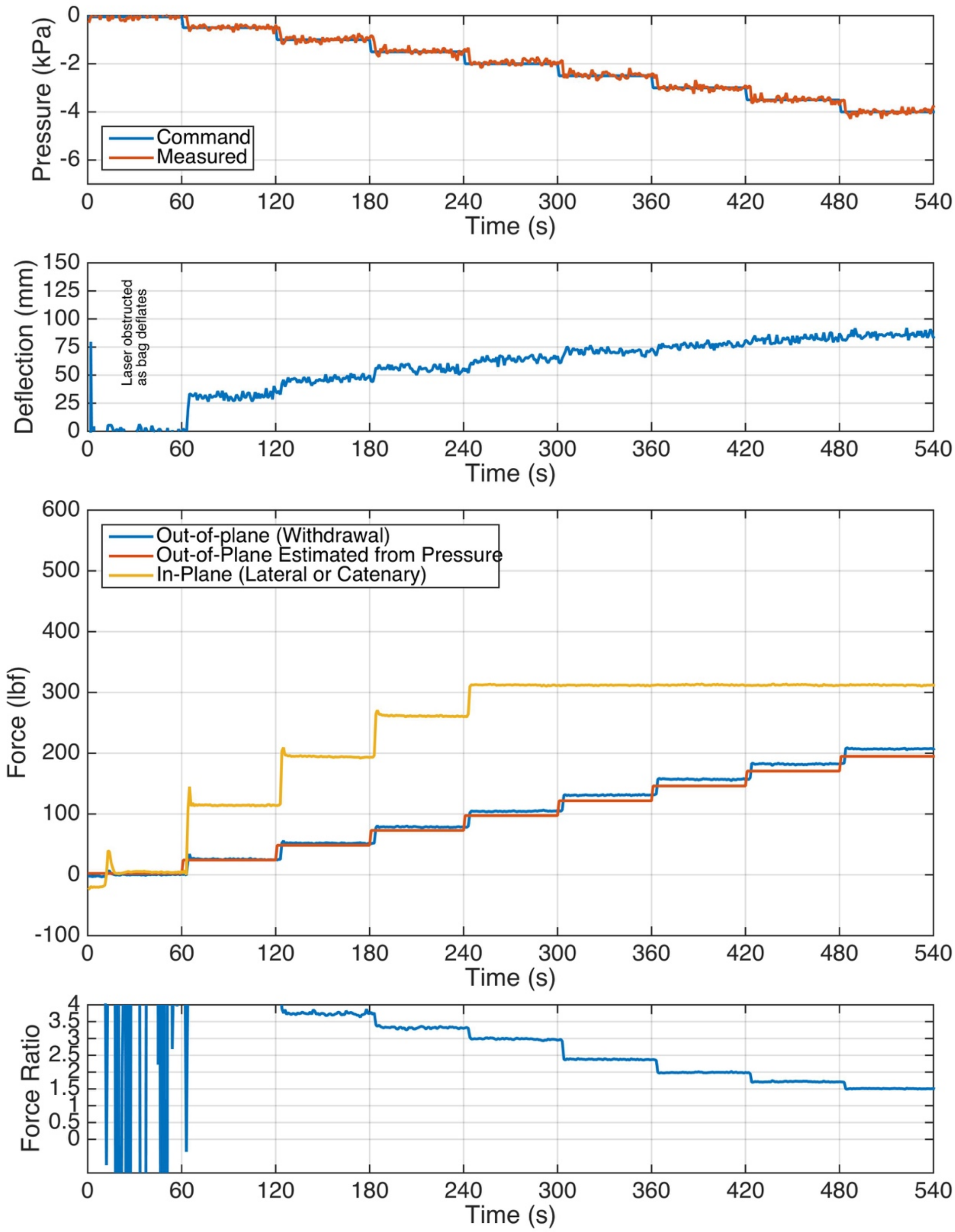


Figure 4. Data for fabric covering

7.2. Full-Scale Testing of Single and Dual Panel Systems

7.2.1. Overview

Six variations (two opening sizes, three substrates) were evaluated during the course of both phases of the research project. One-approach-fits-all, low-cost designs were developed and tested for Group R-3 or R-4 occupancy buildings with a mean roof height of 45 feet or less in locations where Vult is 180 mph or less. These systems did not exhibit damage during application of pressure loads exceeded 5.4 kPa (112 psf), which is the product of the service load derived from ASCE 7-10 and the 1.5 load factor specified in FBC-Building 1609.1.2.3.1.

The six variations tested during both projects phases are [ID]:

1. [W1] Single panel impact resistant covering for light frame wood construction (tested during the 2013-2014 project)
2. [W2] Double panel impact resistant covering for light frame wood construction (tested during this project)
3. [C1] Single panel impact resistant covering for a hollow CMU wall supporting the sill and a precast concrete lintel (tested during this project)
4. [C2] Double panel impact resistant for a hollow CMU wall supporting the sill and a precast concrete lintel (tested during this project)
5. [B1] Single panel impact resistant covering for a brick veneer separated from the same wood frame above by a 38 mm (1.5 in) air gap (tested during this project)
6. [B2] Double panel impact resistant covering for a brick veneer separated from the same wood frame above by a 38 mm (1.5 in) air gap (testing in progress)

Figures 5-6 show the schematics for for the single and dual-panel configurations, including maximum rough opening dimensions and fastener spacing. Note that the "dual" panel system consists of two panels that are stacked to cover a sliding glass door or another large opening. Because the the panels are identical, Figure 6 only shows one system.

Both systems have pinned-pinned boundary conditions, but the location of the panel connections vary. The single and dual panel systems are fastened at the panel edges and panel ends, respectively. Neither rely on developing flexural restraint along the free panel ends (for the single panel case) or panel edges (for the dual panel case) to resist out-of-plane loads. For consistency, the spacing between the rough opening, fastener and panel edge or end along the principal axis of loading were standardized for all cases (Table 1).

Table 1. Distances between the rough opening, fastener and panel edge or end

Substrate	Distance		
	Rough Opening to Panel Edge or End	**Rough Opening to Fastener**	**Fastener to Panel Edge or End**
Wood	76 mm (3 in)	25 mm (1 in)	51 mm (2 in)
Hollow CMU	89 mm (3.5 in)	38 mm (1.5 in)	51 mm (2 in)
Concrete	114 mm (4.5 in)	*64 mm (2.5 in)	51 mm (2 in)

*this distance should prevent interference with rebar in a standard lintel.

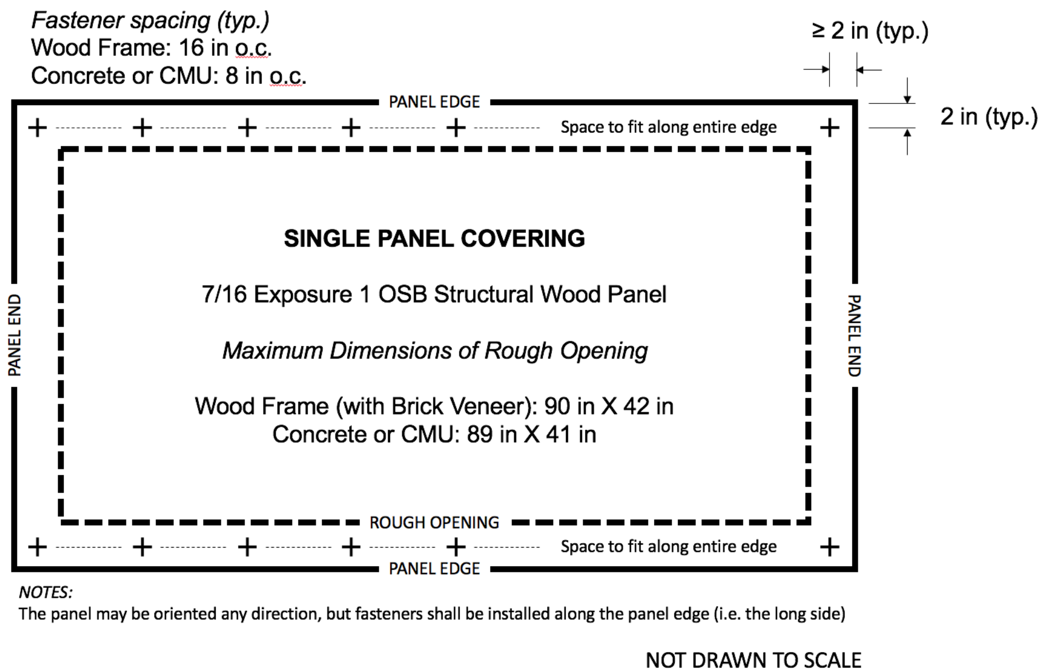


Figure 5. Single Panel Impact Resistant Covering. This system is intended for covering windows commonly found in single-family construction. The system is identical for concrete/CMU, brick and wood frame systems, however the fastener spacing for the CMU/concrete is reduced to account for the difference in withdrawal capacities

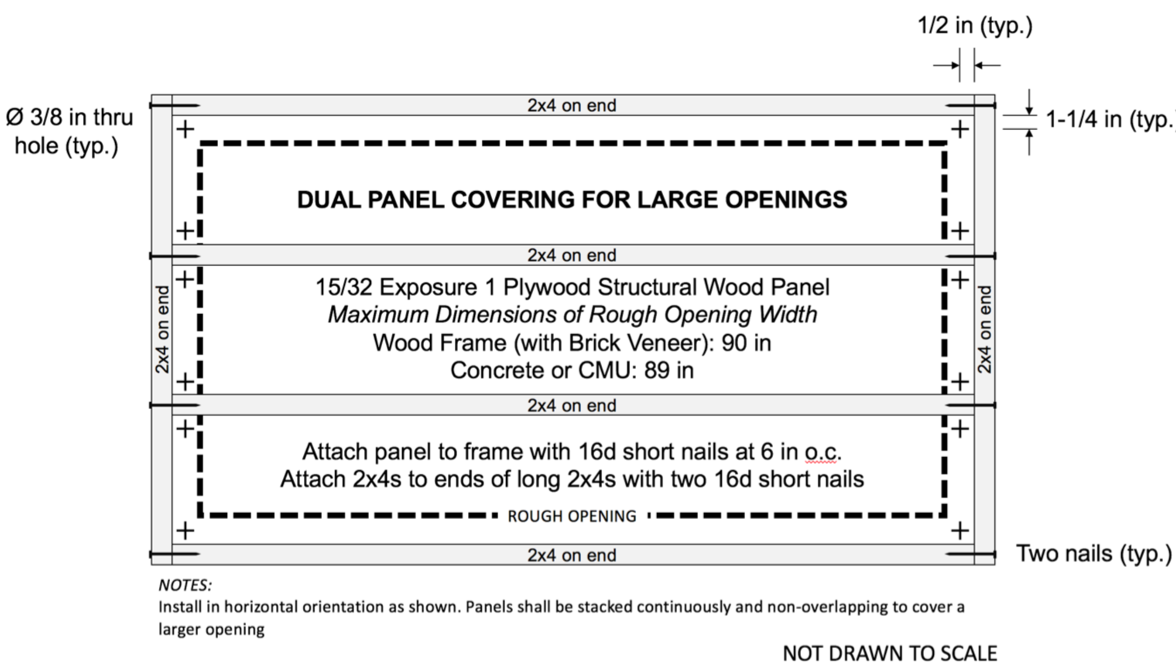


Figure 6. Dual Panel Covering for Large Openings. The panel is supported on the ends and does not require edge restraint, thus two panels may be stacked to cover a large opening

7.2.2. Research on the single panel systems

Recall that multiple changes were proposed to the basis specification set forth in Table 1609.1.2 during the first phase of the project:

- Installing the fasteners on the panel edges (long sides) to reduce the unsupported span from ~8 ft to ~4 ft. The Code currently allows fasteners to be installed on the ends of the panel (short sides)
- Choosing a single fastener configuration. Hanger bolts were chosen for ease of installation, assuming that a homeowner or contractor would choose this option over a No. 8 and 10 wood-screw-based anchor system. The fastening system that is the basis of the recommendations consists of:
  - 1/4 X 3-7/16 PanelMate Plus 305SS
  - 1/4 X 1 in Fender Washer
  - 1/4-20 Hexnut
- Increasing the distance from the fastener to the edge of the panel from 1 in to 2 in to prevent tear-out
- Requiring slightly oversized holes to reduce the catenary force (and to make it easy to hang)
- Requiring 3 in wall overlap to limit inward deflection
- Using large (1 in) washers or washered wingnuts to prevent pull-through

These recommendations were specific to light frame wood construction, but were adapted for the brick over wood and concrete / hollow CMU cases studied in this phase. The single panel systems (B1 and C1) were designed to be identical to the W1 system with several exceptions:

1. The fastener spacing for C1 was reduced from 406 mm (16 in) o.c. to 203 mm (8 in) o.c. to account for the reduced capacity in the allowable tension (see Table 2) and potential for installation errors

Table 2. Manufactured supplied technical data for shutter anchoring systems

Fastener	Substrate	Edge Distance	Embedment	Tension (lbs)		Shear (lbs)	
		in	in	Ultimate	Allowable	Ultimate	Allowable
ITW Red Head Tapcon SG	Grout-Filled CMU	1.750	1.250	3335	*667*	1207	*241*
ITW Red Head Tapcon SG	Concrete	1.750	1.250	2704	*541*	1375	*275*
ELCO PanelMate Plus	Concrete	1.000	2.000	2383	*477*	755	*151*
ELCO PanelMate Plus	Wood	0.750	1.875	2632	*526*	1152	*230*
ITW Red Head Tapcon SG	Hollow CMU	1.250	1.250	1955	*391*	536	*107*
ITW Red Head Tapcon SG	Hollow CMU	2.500	1.250	1940	*388*	1088	*218*
All Points Solid-Set Anchors	Concrete	*1.250*	*0.875*	N/A	328	N/A	187
All Points Sidewalk Anchors	Hollow CMU	2.000	0.875	N/A	286	N/A	200
ELCO PanelMate Plus	CMU	2.000	1.250	1091	*218*	1060	*212*
All Points Sidewalk Anchors	Hollow CMU	1.250	0.875	N/A	166	N/A	122

Italicized allowable force values calculated from Ultimate / 5

2. The distance from the rough opening to the fastener was increased to 38 mm (1.5 in) for the hollow CMU case and 64 mm (2.5 in) for the concrete lintel. The former was increased to improve the shear resistance, and the latter was increased to ensure that the hanger bolt was placed above the rebar in the lintel

3. A Panelmate Through Veneer Anchoring System for Track Systems (TVAS) was used for B1 case. This fastener is a 7-3/8 in hanger bolt. The additional length is required because of the brick and air gap

Both systems were experimentally evaluated at pressure >= 5.4 kPa. No visible sign of damage was observed in the fastener, panel and substrate. Figures 7-8 show the configurations as tested.

Figure 7. Configuration C1 (with structural wood panel installed)

Figure 8. Configuration B1 (without structural panel installed). Photo taken during construction. The bottom boundary condition (not shown) mirrored the top (shown)

7.2.3. Research on dual panel systems

In contrast to the design for the single panel opening, additional considerations had to be made for its larger counterpart. A review of technical specifications and installation guidelines for conventional sliding door systems identified several critical details for designing a versatile shutter system for a large opening.

First, attaching the shutter to a continuous slab or step-down landing is not a solution for a one-size-fits-all prescriptive design. Installing permanent hardware (required by the Code) that protrude from the concrete flatwork is not practical. Attaching to the vertical face of the step-down can also be problematic. The capacity of the fastener to reduce the lateral forces is dependent on the distance from the fastener to the edge, and the distance from the slab to the threshold is often only a few inches. This information also steered the design away from using a removable, intermediate support and two panels, which, although structurally efficient, would be potentially obtrusive (connection and deep member to carry the edge load). Second, sliding glass doors are often flush with the wall, therefore any stiffeners (such as the design in APA T460) could not be designed to recess in the wall opening.

Ease of installation was also considered. We decided that (a) no assembly should be required beyond installing the nuts and washers and (b) the system should break down into two panels to reduce weight.

Based on these considerations, we opted for a pinned-pinned beam design that attaches to the vertical extents of the opening. After some trial and error and rational engineering analysis of fastener capacities using the NDS manual, we selected a simple design that would be familiar to the trades. Essentially it is a light wood frame wall rotated horizontally and flipped so that the studs face outward.

During testing, we observed localized out-of-plane bending at the fastener that ultimately caused a sidewalk bolt to fail below design loads. Thus we added a vertical stiffener along the panel ends to add flexural rigidity and switched to anchor bolts. Fasteners were located adjacent 2x4s to equalize the tributary areas, which also reduces the local deformation near the fasteners.

Figure 9. Configuration W2 (with structural wood panel installed)

Figure 10. Configuration C2 (without structural wood panel installed)

Figure 11. Configuration B2 (without structural wood panel and perimeter blocking to seal the ends and edges)

8. Summary of Additional Information to be Provided

1. Primary testing concluded the week prior to the submission of this report. We are currently reviewing the strip panel data to identify the appropriate closed-form solutions for predicting catenary forces. It does appear that applying a first-order deflection equation for a double-cantilevered beam is conservative for predicting midspan deflection. A final recommendation will be made during the presentation to the TAC on June 25, and the report will be updated accordingly.
2. We are seeking guidance from the TAC regarding inclusion of language / figures for the Code modification provided in Appendix B. It is our opinion the Figures 5-6 should be included. As it stands, the section is written for single panel systems and must be updated for the dual panel systems.

9. References and Project Material

- Provided by IHPA
  - Letter to Florida Building Commission dated September 16, 2013
  - ATI Test Report dated December 1, 2011. Videos:
    - http://youtu.be/iDLzf0wF0Zc
    - http://youtu.be/2fcv5GD_qUM
    - http://youtu.be/BdSNDsScIcE
  - Letter from Engineering Express dated January 10, 2014
- Provided by APA
  - APA T460 Hurricane Shutter Design Considerations in Florida
  - Applied Research Associates. 2001. Impact and Pressure Testing of Hawaii Hurricane Relief Fund Window Protection Design.
  - Applied Research Associates. 2003. Impact and Pressure Testing of Florida Building Code Minimum Plywood and OSB Shutter Systems.
  - Institute for Business & Home Safety. 2012. Industry Perspective: Impact Resistance Standards. In: Natural Hazard Mitigation Insights No. 12
- Other resources
  - Kopp GA, Morrison MJ, Gavanski E, Henderson DJ, Hong HP. The Three Little Pigs' Project: hurricane rick mitigation by integrated wind tunnel and full-scale laboratory tests. Natural Hazards Review 2010; November, 151-161.
  - NDS (2005). National Design Specification for Wood Construction (2005). American Wood Council. Available at http://www.awc.org/standards/nds.php
  - Zahn, J. (1991). "Design Equation for Multiple-Fastener Wood Connection", Journal of Structural Engineering, ASCE, Vol. 117, No. 11, pp. 3477–3486.
  - Young, W. C. and Budynas, R. G. (2002). Roark's Formulas for Stress and Strain: 7th Edition, McGraw–Hill, New York, NY.

Appendix A. Letter from the International Hurricane Protection Association

JDB CODE SERVICES, INC.

September 16, 2013

Florida Building Commission
C/O Mo Madani, DBPR
1940 North Monroe Street
Tallahassee, FL 32399

SUBJECT: IHPA Request for Funding For Research Project Related to Fastening of Wood Structural Panels for Opening Protection

Florida Building Commission:

Please consider this a request for funding for an important research project related to the fastening of wood structural panels as specified by the Florida Building Code. During the August meetings at Fort Lauderdale the Florida Building Commission (Commission) adopted a definition for the term "research" as follows:

> "An important and necessary endeavor that aimed at studying specific code related issue(s)/topics for the purpose of providing solutions to a specific problem or future code change(s) directed at improving the implementation and enforcement of the FBC. The issue to be researched must be fully understood (i.e. with clear purpose and goals); clearly defined with specific scope of work/approach; and within budget."

The International Hurricane Protection Association (IHPA) requests up to $10,000.00 be expended for testing of the fastening specified at Tables 1609.1.2 and R301.2.1.2 of the Florida Building Code. This is an important and necessary endeavor because testing conducted and previously submitted to the Commission indicates the current code is inadequate for the intended task.

Testing conducted by Architectural Testing, Inc. for IHPA indicates there is a problem with the ability of the code specified fastening schedule to resist the structural loads specified by the code for opening protection products. The failures noted were under structural loading and would undoubtedly lead to failure of the panel if subjected to the cyclical loading specified by the code for opening protection products. Additionally, it was discovered during the testing that the fasteners specified by the code are not readily available in the marketplace.

The research proposal is to review the findings of the 2003 Loss Relativities for FBC Wood Panel Shutters[1] (LRWPS or the Study). The Study was used to develop the fastening tables for wood structural panels used in the FBC. The Study conducted testing on both the wet and dry condition. The technical approach of this project will involve:

1. Engineering Analysis. The performance of engineering analysis based on a review of the LRWPS and including catenary loading based on the findings of the testing previously sponsored by IHPA[2] to develop values for a table that incorporates edge distance on the buck, edge distance on the panel, tensile strength, deflection, end failure, and yielding or over-pulling of the anchors used for attachment of wood structural panels. A test strategy will be developed based on the final calculations considering

1 Loss Relativities for FBC Wood Panel Shutters, Department of Community Affairs DCA Contract 03-RC-11-14-00-22-034, ARA IntraRisk June 30, 2003, Final Report,
2 Architectural Testing, Inc. Test Report dated December 1, 2011.

41 Oak Village Boulevard ◆ Homosassa ◆ Florida ◆ 34446 ◆ 352-450-2631 ◆ Fax 813-925-4152 ◆ joe@jdbcodeservices.com

appropriate safety factors for wood structural panels installed using common anchors that are widely available in the marketplace.

2. The engineering analysis will be contributed to the project by an IHPA member. The estimated value of the analysis is $5,000.00.
3. Testing will be to ASTM E 330-02 for structural testing and ASTM E 1886-05 and ASTM E 1996-09 for impact and cyclic testing for large missile.
4. Testing Program. The testing will involve a maximum of three tests to validate the data generated in the engineering analysis.
    a. A dry test using an OSB wood structural panel in accordance with the methodology of the LRWPS.
    b. A wet test using an OSB wood structural panel in accordance with the methodology of the LRWPS.
    c. A dry test using a plywood structural panel in accordance with the methodology of the LRWPS.
5. Testing to be performed by a Florida Building Commission approved testing laboratory.
6. Responsibilities of the testing lab include:
    a. All testing will be on a wood test buck as constructed by the testing laboratory.
    b. Mounting test specimens.
    c. Conducting tests.
    d. Writing of sealed test report.
7. IHPA will provide test specimens of commonly available materials and fasteners purchased from a retail outlet.
8. IHPA will attend and witness testing.
9. IHPA will provide installation drawings which will indicate fastener type and spacing, required shim space, and any other details pertinent to installation of wood structural panels.
10. Installation drawings shall become a referenced document in the final test report.
11. IHPA estimates the cost of Items 7, 8, and 9 at $1,000.00
12. Testing is estimated to cost $8,775.00 and shall not exceed $10,000.00. The total funding requested is to cover the testing costs only.
13. The results of the engineering analysis and testing will be used to validate the existing values or, as indicate, to develop final recommendations for new table values to replace those of Tables 1609.1.2 and R301.2.1.2 of the Florida Building Code, Building and Residential, respectively.
14. If indicated, new values will be submitted to the Florid Building Code as proposed code changes.

Respectfully submitted,

Joseph D. Belcher

Joseph D. Belcher, Code Consultant

Cc. Frank Browning, IHPA President
Tom Johnston, Immediate Past President

Appendix B. Recommendation for changes to the 5th Edition (2014) Florida Building Code

Note: These recommendations are based on FY 2013-14 research. These recommendations will be updated with findings resulting from the FY2014-15 research.

Red text = edits made by project investigators

Note 1: The 5th Edition (2014) Florida Building Code - Post Commission Post Glitch revisions call out Section 1609.1.2.3. That section (now edited) appears as 1609.1.2.4

Note 2: Corresponding changes will need to be made to FBCR R301.2.1.2.

Note 3: The version corresponds to the Post Commission Post Glitch document

CHAPTER 16
STRUCTURAL DESIGN

SECTION 1609
WIND LOADS

1609.1.2 Protection of openings. In *wind-borne debris regions*, ~~glazing~~ glazed openings in buildings shall be impact resistant or protected with an impact-resistant covering meeting the requirements of ~~, an *approved* impact-resistant standard or ASTM E 1996 and ASTM E 1886 referenced herein as follows: ,~~ SSTD 12, ANSI/DASMA 115 (for garage doors and rolling doors) or TAS 201, 202 and 203, AAMA 506. ASTM E 1996 and ASTM E 1886 referenced herein, or an *approved* impact-resistant standard as follows:

1. Glazed openings located within 30 feet (9.1 m) of grade shall meet the requirements of the Large Missile Test of ASTM E 1996.

2. Glazed openings located more than 30 feet (9.1 m) above grade shall meet the provisions of the Small Missile Test of ASTM E 1996.

3. Storage sheds that are not designed for human habitation and that have a floor area of 720 square feet (67 m2) or less are not required to comply with the mandatory windborne debris impact standards of this code.

4. Openings in sunrooms, balconies or enclosed porches constructed under existing roofs or decks are not required to be protected provided the spaces are separated from the building interior by a wall and all openings in the separating wall are protected in accordance with Section 1609.1.2 above. Such spaces shall be permitted to be designed as either partially enclosed or enclosed structures.

Exceptions:

1. Wood structural panels with a minimum thickness of 7/16 inch (11.1 mm) ~~and maximum panel span of 8 feet (2438 mm)~~ shall be permitted for opening protection in Group R-3 or R-4 occupancy buildings with a mean roof height of 45 feet (13 716 mm) or less in locations where Vult is 180 mph (80 m/s) or less ~~as Group R-3 or R-4 occupancy~~. The

opening shall not exceed 42 inches (1 067 mm) X 90 inches (2 286 mm). Panels shall be precut to overlap the wall by 3 inches (76.2 mm) on all sides and so that they shall be attached to the framing surrounding the opening containing the product with the glazed opening. Panels shall be predrilled as required for the anchorage attachment method and shall be secured with the corrosion-resistant attachment hardware permanently installed on the building provided. Attachments shall be designed to resist the components and cladding loads determined in accordance with the provisions of ASCE 7, with corrosion-resistant attachment hardware provided and anchors permanently installed on the building. At a minimum, panels shall be fastened at 16 inches (406.4 mm) o.c. along the edges of the opposing long sides of the panel. Fasteners shall be located 1 inch (25.4 mm) from the opening and 2 inches (50.8 mm) inward from the panel edge. The hardware shall consist of ¼-inch hanger bolts and either (a) 1/4 inch (6.3 mm) washer with a 1 inch (25.4 mm) flange and a ¼-20 hexnut or (b) a ¼-20 washered wingnut with a minimum of a 1 inch (25.4 mm) flange. Fasteners shall penetrate through the external wall covering with sufficient embedment length to provide a minimum of 300 lbs of withdrawal resistance. Where panels are attached to CMUs, fasteners shall be located 1.5 inch (38.1 mm) from the opening and 2 inches (50.8 mm) inward from the panel edge. Where panels are attached to concrete (e.g., lintels), fasteners shall be located above the bottom rebar and 2 inches (50.8 mm) inward from the panel edge. Alternatively, attachments may be designed to resist the components and cladding loads determined in accordance with the provisions of ASCE 7. These systems shall meet the requirements of Section 1609.1.2.4 below. Attachment in accordance with Table 1609.1.2 with corrosion-resistant attachment hardware provided and anchors permanently installed on the building is permitted for buildings with a mean roof height of 45 feet (13 716 mm) or less where Vult does not exceed 180 mph (80 m/s) Vasd, determined in accordance with Section 1609.3.1 does not exceed 140 mph (63 m/s).

2. Glazing in Risk Category I buildings as defined in Section 1604.5, including greenhouses that are occupied for growing plants on a production or research basis, without public access shall be permitted to be unprotected.

3. Glazing in Risk Category II, III or IV buildings located over 60 feet (18 288 mm) above the ground and over 30 feet (9144 mm) above aggregate surface roofs located within 1,500 feet (458 m) of the building shall be permitted to be unprotected.

4. Exterior balconies or porches under existing roofs or decks enclosed with screen or removable vinyl and acrylic panels complying with Section 2002.3.3 shall not be required to be protected and openings in the wall separating the unit from the balcony or porch shall not be required to be protected unless required by other provisions of this code.

TABLE 1609.1.2
WIND-BORNE DEBRIS PROTECTION FASTENING SCHEDULE FOR WOOD STRUCTURAL PANELS[a, b, c, d]

FASTENER TYPE	FASTENER SPACING (inches)		
	Panel Span ≤ 4 feet	4 feet < Panel Span ≤ 6 feet	6 feet < Panel Span ≤ 8 feet
No. 8 wood-screw-based anchor with 2-inch embedment length	16	10	8
No. 10 wood-screw-based anchor with 2-inch embedment length	16	12	9
$^1/_4$-inch diameter lag-screw-based anchor with 2-inch embedment length	16	16	16

For SI: 1 inch = 25.4 mm, 1 foot = 304.8 mm, 1 pound = 4.448 N, 1 mile per hour = 0.447 m/s.

a. This table is based on a V_{asd}, determined in accordance with Section 1609.3.1 of 140 mph and a 45-foot mean roof height.

b. Fasteners shall be installed at opposing ends of the wood structural panel. Fasteners shall be located a minimum of 1 inch from the edge of the panel.

c. Anchors shall penetrate through the exterior wall covering with an embedment length of 2 inches minimum into the building frame. Fasteners shall be located a minimum of $2^1/_2$ inches from the edge of concrete block or concrete.

d. Where panels are attached to masonry or masonry/stucco, they shall be attached using vibration-resistant anchors having a minimum ultimate withdrawal capacity of 1,500 pounds.

1609.1.2.1 Louvers. Louvers protecting intake and exhaust ventilation ducts not assumed to be open that are located within 30 feet (9144 mm) of grade shall meet requirements of ANSI/AMCA 540 or shall be protected by an impact resistant cover complying with the large missile test of ASTM E 1996 or an approved impact-resistance standard. Louvers required to be open for life safety purposes such as providing a breathable atmosphere shall meet the requirements of AMCA 540.

1609.1.2.2. Application of ASTM E 1996. The text of Section 6.2.2 of ASTM E 1996 shall be substituted as follows:

6.2.2 Unless otherwise specified, select the wind zone based on the strength design wind speed, *Vult*, as follows:

6.2.2.1 *Wind Zone 1*—130 mph ≤ ultimate design wind speed, *Vult* < 140 mph.

6.2.2.2 *Wind Zone 2*—140 mph ≤ ultimate design wind speed, *Vult* < 150 mph at greater than one mile (1.6 km) from the coastline. The coastline shall be measured from the mean high water mark.

6.2.2.3 *Wind Zone 3*—150 mph (58 m/s) ≤ultimate design wind speed, *Vult* ≤ ~~160~~ 170 mph (63 m/s), or 140 mph (54 m/s) ≤ ultimate design wind speed, *Vult* ≤ ~~160~~ 170 mph (63 m/s) and within one mile(1.6 km) of the coastline. The coastline shall be measured from the mean high water mark.

6.2.2.4 *Wind Zone 4*— ultimate design wind speed, *Vult* > ~~160~~ 170 mph (63 m/s)

~~R~~1609.1.2.2.1 Modifications to ASTM E 1886 and ASTM E 1996.

Table 1 of ASTM E 1886 and ASTM E 1996 – revise the third column to read as follows:

Air Pressure Cycles

0.2 to 0.5 P_{pos}[1]

0.0 to 0.6 P_{pos}

0.5 to 0.8 P_{pos}

0.3 to 1.0 P_{pos}

0.3 to 1.0 P_{neg}[2]

0.5 to 0.8 P_{neg}

0.0 to 0.6 P_{neg}

0.2 to 0.5 P_{neg}

Notes:

1. P_{pos}= 0.6 x positive ultimate design load in accordance with ASCE 7.
2. P_{neg} = 0.6 x negative ultimate design load in accordance with ASCE 7.

1609.1.2.4 Impact resistant coverings.

1609.1.2.4.1 ~~Impact resistant coverings shall be tested at 1.5 times the design pressure (positive or negative) expressed in pounds per square feet as determined by the Florida Building Code, Building Section 1609 or ASCE 7, for which the specimen is to be tested. The design pressures, as determined from ASCE 7, are permitted to be multiplied by 0.6.~~

Impact resistant coverings shall be tested for resistance to uniform static air pressure using ASTM E330 or TAS 202 and resistance to uniform cyclic air pressure using ASTM E1996, TAS 202 or TAS 203 at the pressures defined in Table 1609.1.4.X. These pressures are defined for Vult = 181 mph (80.9 m/s) or equivalently Vasd = 140 mph (62.6 m/s). For Vult larger than 181 mph, the pressures in the table shall be multiplied by the squared ratio of the wind speeds:

$$p_{Vult} = p_{181\,mph}\left(\frac{V_{ult}}{181}\right)^2 \qquad \textbf{(Equation 16-X)}$$

The loads shown in the table are based on an Effective Wind Area of 10 square feet (0.93 square meters). For larger Effective Wind Areas, the values in Table 1609.1.X may be adjusted to consider the area-dependent external pressure coefficients shown in Figure 30.4-1 in ASCE 7. Topographic effects may also be considered following the guidelines set forth in ASCE 7.

Table 1609.1.4.X. WIND LOAD REQUIREMENTS FOR IMPACT RESISTANT COVERINGS (Vult = 181 mph)

Height (ft)	Ultimate Neg. Pressure[A]			Ultimate Pos. Pressure[A]			ASD Neg. Pressure[B]			ASD Pos. Pressure[B]			Height (ft)
	B	C	D	B	C	D	B	C	D	B	C	D	
15	-65	-95	-116	+48	+71	+86	-39	-57	-69	+29	+43	+52	15
20	-70	-101	-122	+52	+76	+91	-42	-61	-73	+31	+45	+54	20
25	-75	-106	-126	+56	+79	+94	-45	-64	-76	+33	+47	+57	25
30	-79	-110	-131	+59	+82	+97	-47	-66	-78	+35	+49	+58	30
40	-85	-117	-137	+64	+88	+102	-51	-70	-82	+38	+52	+61	40
45	-88	-120	-140	+66	+90	+105	-53	-72	-84	+40	+54	+63	45
50	-91	-123	-143	+68	+92	+107	-55	-74	-85	+41	+55	+64	50
60	-96	-128	-147	+72	+95	+110	-57	-76	-88	+43	+57	+66	60
70	-100	-132	-151	+75	+98	+113	-60	-79	-91	+45	+59	+68	70
80	-104	-136	-155	+78	+101	+116	-62	-81	-93	+47	+61	+69	80
90	-108	-139	-158	+80	+104	+118	-64	-83	-95	+48	+62	+71	90
100	-111	-142	-161	+83	+106	+120	-66	-85	-96	+50	+64	+72	100
120	-117	-148	-166	+87	+110	+124	-70	-88	-99	+52	+66	+74	120
140	-122	-153	-171	+91	+114	+127	-73	-91	-102	+55	+68	+76	140
160	-127	-157	-175	+95	+117	+130	-76	-94	-105	+57	+70	+78	160
180	-131	-161	-178	+98	+120	+133	-79	-96	-107	+59	+72	+80	180
200	-135	-164	-182	+101	+123	+136	-81	-98	-109	+61	+74	+81	200
250	-144	-172	-189	+108	+129	+141	-86	-103	-113	+64	+77	+84	250
300	-152	-179	-195	+113	+134	+145	-91	-107	-117	+68	+80	+87	300
350	-159	-185	-200	+119	+138	+149	-95	-111	-120	+71	+83	+89	350
400	-165	-190	-205	+123	+142	+153	-99	-114	-123	+74	+85	+92	400
450	-171	-195	-209	+127	+146	+156	-102	-117	-125	+76	+87	+93	450
500	-176	-199	-213	+131	+149	+159	-105	-119	-127	+79	+89	+95	500

[A]Proof load in ASTM E330, Test load in TAS 202-94
[B]Test load in ASTM E330, Design Pressure in TAS 202-94, P_{pos} and P_{neg} in ASTM E1996 and Design Wind Load in TAS 203-94

1609.1.2.4.2 Impact resistant coverings. Impact resistant coverings shall be labeled in accordance with the provisions of Section 1710.8.

1609.1.3 Optional exterior door component testing. Exterior side-hinged door assemblies shall have the option to have the components of the assembly tested and rated for impact resistance in accordance with the following specification: SDI 250.13.

1609.1.4 The wind-borne debris regions requirements shall not apply landward of the designated contour line in Figure 1609A or 1609B. A geographical boundary that coincides with the contour line shall be established.

1609.1.5 Testing to allowable or nominal loads. Where testing for wind load resistance is based on allowable or nominal wind loads, the design wind loads determined in accordance with ASCE 7 or Section 1609 are permitted to be multiplied by 0.6 for the purposes of the wind load resistance testing.

1609.2 Definitions. The following words and terms shall, for the purposes of Section 1609, have the meanings shown herein.

HURRICANE-PRONE REGIONS. Areas vulnerable to hurricanes defined as:

1. The U. S. Atlantic Ocean and Gulf of Mexico coasts where the basic wind speed for Risk Category II buildings is greater than 115 mph (40 m/s) and
2. Hawaii, Puerto Rico, Guam, Virgin Islands and American Samoa.

WIND-BORNE DEBRIS REGION. Areas within hurricane-prone regions located:

1. Within 1 mile (1.61 km) of the coastal mean high water line where the ultimate design wind speed Vult is 130 (48 m/s) or greater; or
2. In areas where the ultimate design wind speed Vult is 140 mph (53 m/s) or greater.

For Risk Category II buildings and structures and Risk Category III buildings and structures, except health care facilities, the windborne debris region shall be based on Figure 1609A. For Risk Category IV buildings and structures and Risk Category III health care facilities, the windborne debris region shall be based on Figure 1609B.

WIND SPEED, V_{ult}. Ultimate design wind speeds.

WIND SPEED, V_{asd}. Nominal design wind speeds.

1609.3 Basic wind speed. The ultimate design wind speed Vult, in miles per hour, for the development of the wind loads shall be determined by Figures 1609A, 1609B and 1609C. The ultimate design wind speed Vult for use in the design of Risk Category II buildings and structures shall be obtained from Figure 1609A. The ultimate design wind speed Vult for use in the design of Risk Category III and IV buildings and structures shall be obtained from Figure 1609B. The ultimate design wind speed Vult for use in the design of Risk Category I buildings and structures shall be obtained from Figure 1609C. The exact location of wind speed lines shall be established by local ordinance using recognized physical landmarks such as major roads, canals, rivers and lake shores wherever possible.

1609.3.1 Wind speed conversion. When required, ultimate design wind speeds of Figure 1609A, B and C shall be converted to nominal design wind speeds, Vasd, using Table 1609.3.1 or Equation 16-32.

$$V_{asd} = V_{ult}\sqrt{0.6}$$ **(Equation 16-32)**

where:

V_{asd} = nominal design wind speed
V_{ult} = strength design wind speeds determined from Figures 1609A, 1609B, or 1609C.

Appendix C. Experimental Configuration for Phase 2 Research

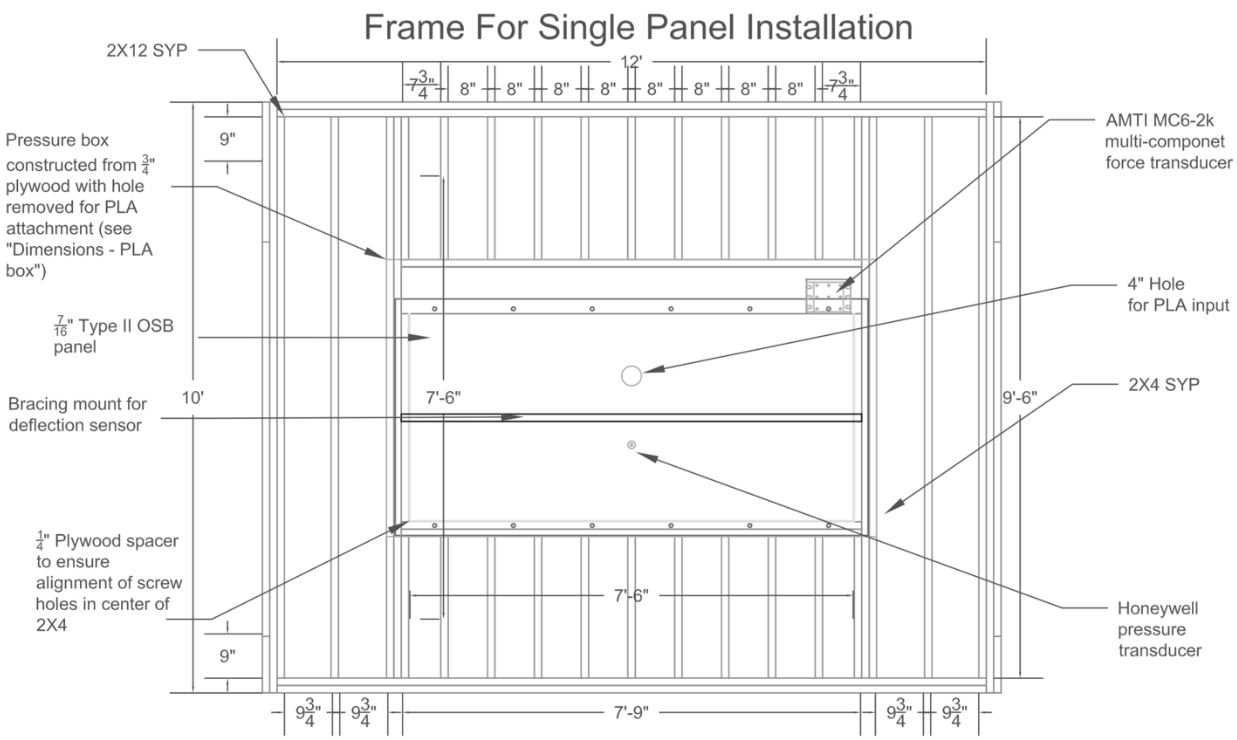


Figure 12. Wall assembly to test single panel installations onto light frame wood construction and same with brick veneer (mounting assembly not shown)

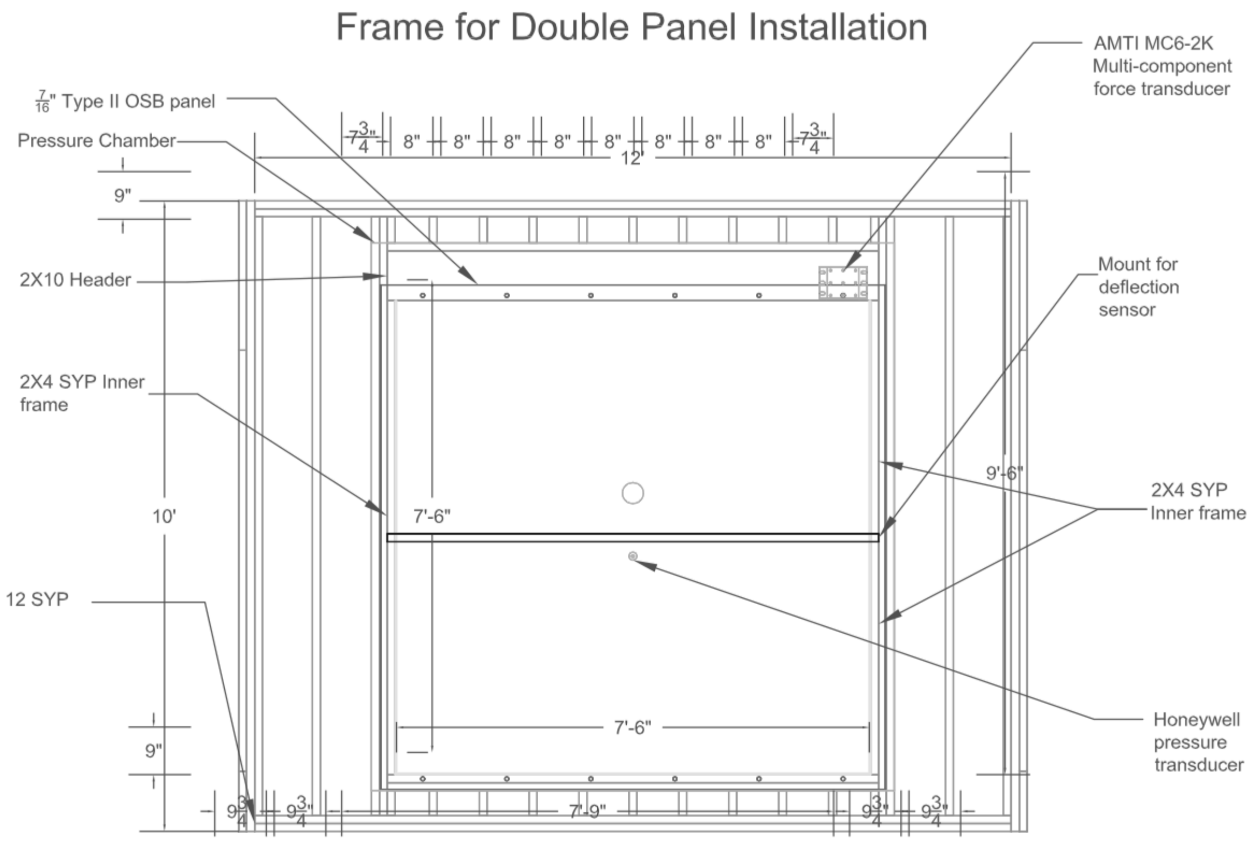


Figure 13. Wall assembly to test double panel installations onto light frame wood construction and same with brick veneer (mounting assembly not shown)