CONFIDENTIAL

LABORATORY TEST REPORT:

PLYLOX™ CLIPS FOR INSTALLATION AND FASTENING OF WOOD STRUCTURAL PANEL WINDOW AND DOOR OPENING PROTECTION IN HURRICANE REGIONS

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INTRODUCTION

Plylox™ clips provide an alternative method to secure wood structural panels to recessed window and door openings for protection against wind borne debris as optionally required in the 2000 International Residential Code (IRC) for hurricane-prone regions. The applicable wind borne debris protection fastening schedule for wood structural panels is found in IRC Section R301.2.1.2 (Table R301.2.1.2).

The purpose of this test report is to investigate the performance of the Plylox™ fastening approach. The evaluation factors of concern include:

1. Ability of the Plylox™ clip fastening method to secure wood structural panels when subjected to wind pressures at least equivalent to that provided by methods required in the IRC.
2. Ability of the Plylox™ clips to maintain a secure attachment of wood structural panels when subjected to wind-borne debris impacts.

The application of results from this test program are intended to:

1. Provide adequate performance data for building code evaluation (i.e., code evaluation report).
2. Provide data for refinement of manufacturer installation instructions commensurate with required performance (e.g., table showing clip spacing vs. wind speed zone and opening span).
3. Identify appropriate limitations to and guidance for successful end-use.

All of the tests reported herein were conducted by the NAHB Research Center, Inc. at their laboratory facility in Upper Marlboro, MD. The test program was started on February 10, 2003, and completed on February 21, 2003.

PRODUCT DESCRIPTION

General - Plylox™ clips are designed for simple installation and attachment of wood-structural panels to recessed window and door openings made of wood, stucco, or brick materials. They provide a simple method of "boarding-up" for protection of windows and doors against wind-borne debris in hurricanes. A picture of the type of clip tested in this program is shown in Figure 1 along with the dimensions measured as received. The clip is designed to work with wood structural panels (i.e., oriented strand board or plywood) with thicknesses ranging from 7/16 inch to 3/4 inch. Another type of Plylox™ clip is also available for attachment of wood structural panels to aluminum frame windows, but it is not addressed in the scope of this report.

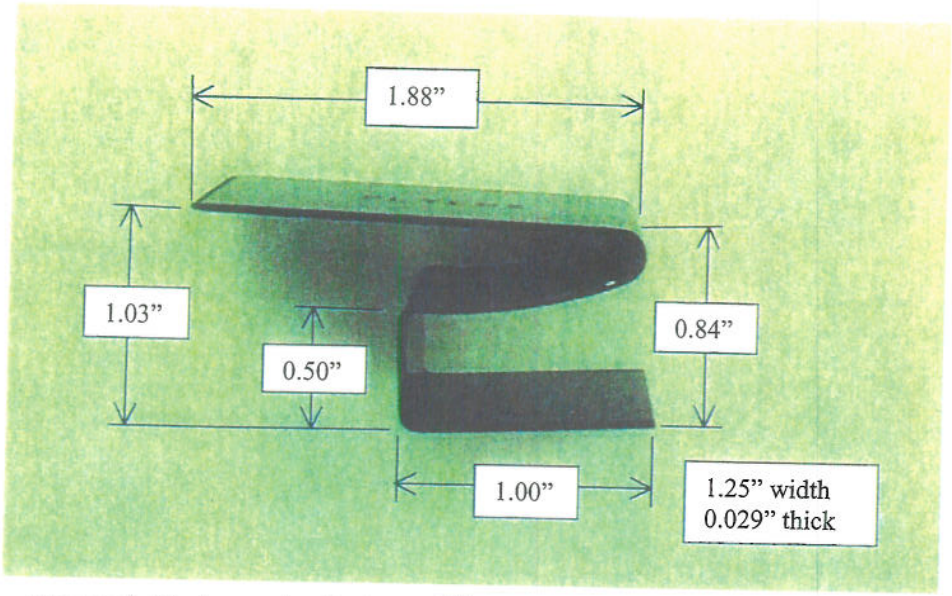

Figure 1. Photograph of a Plylox™ clip with dimensions as recieved.

The shape of Plylox™ clip is designed to provide a leveraging action that increases the holding force of the clip as suction pressure on the panel increases. The clip is installed with a modest force fit into a recessed window or door opening to create an initial gripping action of the toothed leg of the clip. The initial gripping action is established by a spring force created by the toothed leg of the clip when a properly sized panel with clips is inserted into the opening (see Installation Procedure below). This establishes an initial embedment of the clip's teeth into the recessed opening's surface material (i.e., wood, stucco, or brick). As suction force is applied to the panel, the compression force on the toothed leg of the clip increases proportionately and further embeds the teeth into the recessed opening substrate. Inward acting forces (positive pressure and wind debris impact) are resisted by the panel bearing on the perimeter frame of the window or door.

Installation Procedure - Detailed installation instructions are found in the manufacturer's literature which has been modified as a result of findings in this testing program. The installation process involves a simple process of cutting a wood structural panel to fit within a recessed window or door opening made of brick, stucco, or wood. The panel dimensions are cut approximately 1/4" less than the rough opening (a tolerance of 1/4" + 1/8" = 3/8" was found to be acceptable in this test program). Once the panel is cut to proper dimension, the correct number of clips are applied to the panel's vertical edge at the prescribed spacing. (A proposed table for this purpose is included in the Results section and is based on the test findings and analysis described later in this report). The clip spacing is determined according to design wind speed zone and by panel span (i.e., window or door width). Once prepared with the clips in place, the panel is inserted into the recessed window or door opening. Removal requires modest prying of the toothed leg of the clips on one side of the panel to release it from the window or door recess.

Materials - The Plylox™ clip is cold-formed from strapping (banding) steel by Signode to the shape shown in Figure 1. The specifications of the Signode steel material (as provided by Plylox™) are as follows:

Product Description	Part No. 1419 MAG Product No. 2X1668 Finish PW
Width (in.)	1.255 maximum 1.250 nominal 1.245 minimum
Thickness (in.)	0.031 maximum 0.029 nominal 0.028 minimum
Break Strength (lbs)	4900 minimum 5400 typical 6390 maximum
Elongation (%)	6.5 minimum 7 typical
Ductility (Bends)	2 minimum

The thickness of sampled clip specimens used in this test program were measured and found to have an average thickness of 0.0304 inches with a coefficient of variation (COV) of 2 percent and a minimum thickness of 0.0294 inches for a sample size of six. Tensile tests were not conducted due to the inability to make suitable coupons from the clips.

EVALUATION APPROACH

MATERIAL SAMPLING

Plylox™ clips used in the testing program were randomly selected from the manufacturer's warehouse (Friendsville, TX) by a NAHB Research Center, Inc., quality assurance field representative. Clips were sampled from three different lots (manufacturing dates). Wood structural panels, brick, stucco mix, and other materials were purchased from distributors local to the NAHB Research Center, Inc. (Upper Marlboro, MD). These materials were manufactured in compliance with applicable industry standards (i.e., USDOC PS1 and PS2 for wood structural panels, USDOC PS20 for dimension lumber, ASTM C387 for Type 2 mortar mix, etc.).

TEST PLAN

The test plan included several preliminary exploratory tests to demonstrate the general behavior of the Plylox™ clip and to give direction to an appropriate full study matrix. To achieve the objectives of this test program, the following performance characteristics and conditions were determined to be critical for testing:

1. Pressure resistance of panels secured by Plylox™ clips.
2. Impact resistance of panels secured by Plylox™ clips.

3. Pressure resistance of panels secured in accordance with IRC Table R301.2.1.2 (baseline performance comparison).

Plylox™ Pressure Tests

Parameters were varied in the test program to fully explore the range of intended applications and performance. These parameters included:

- Recessed window/door opening construction – Wood, Stucco, and Brick
- Nominal panel span (recessed opening span) – 2 ft, 4 ft, and 8 ft
- Spacing (Number) of clips per vertical side of opening – 24"(2), 16"(3), 12"(4)
- Minimum clip metal thickness – 0.029 inches
- Panel pre-cut dimension – 1/4" less than opening dimension

Panels were stiffened by 2x4s (No 2 SPF) placed edgewise at a spacing of 2 ft. on center for the nominal 8 foot panel span condition only. The 2x4 stiffeners were attached to the wood structural panel using #8 by 2-1/2 inch long bugle head screws at 12 inches on center with two screws 3 inches from each end of the brace separated by 3 inches. The brace was cut 4 inches less than the panel length to give 2 inches of clearance at each end of the panel. Nominal panel spans of 4 ft. and 2 ft. were tested without the use of 2x4 stiffeners.

Except in cases where exploratory testing was conducted, a minimum of three repetitions of each combination of parameters was tested.

Exploratory pressure testing of Plylox™ clips investigated the following additional conditions to determine the effect on performance:

1) Smoothness of brick surface (a synthetic brick paver was used for this purpose);
2) Tolerance for panel pre-cut dimensions (0.25" to 1" less than opening dimension);
3) Distance of toothed end of clip from edge of opening (i.e., depth of recessed opening);
4) Minimum clip metal thickness (0.044 inches);
5) Panels with and without edgewise 2x4 stiffeners (8 foot panel spans only) - all other panel spans were tested without stiffeners.
6) Use of 15/32-inch-thick plywood panel in lieu of 7/16-inch-thick OSB (one 4 ft span specimen only).

Plylox™ Wind Debris Impact Tests

Following the pressure testing phase (described above), a worst-case condition was selected for impact testing of a panel secured by Plylox™ clips. The condition selected used the brick recessed opening condition and a nominal 4 foot by 4 foot opening size (actual rough opening 48.5 inch by 49.5 inch) because the clip behavior during static pressure testing demonstrated that this condition was most susceptible to a slipping failure mode.

IRC Panel Pressure Tests

To confirm a performance baseline for evaluation of the Plylox™ clip performance, the following 'IRC Panel' conditions were fabricated in accordance with the 2000 IRC (Table R301.2.1.2) and tested:

IRC panel #1 (four reps) – 7/16" OSB panel (without 2x4 stiffeners), 8 foot span (94.5" rough opening width), #8 bugle head deck screws (2.5 Inches long) spaced at 12 inches on center along the panel vertical (4 foot) edge and driven into a 2x wood jamb member (No 2 SPF).

IRC Panel #2 (three reps) – 7/16" OSB panel (without 2x4 stiffeners), 4 foot span (46.5" rough opening width), #6 bugle head screws (2.5 inches long) spaced at 16 inches on center along the panel vertical (4 foot) edge and driven into a 2x wood jamb member (No 2 SPF).

IRC Panel #3 (one rep) – 7/16" OSB panel (without 2x4 stiffeners), 4 foot span (46.5" rough opening width), 10d common nails spaced at 16 inches on center along the panel vertical (4 foot) edge and driven into a 2x wood jamb member (No 2 SPF).

As discussed in the Results and Analysis sections of this report, the IRC panel performance varied widely with safety factors either above or below the factor of 1.5 recommended in the ASTM E330 test standard [1]. Therefore, a consistent safety factor of 1.5 relative to design wind pressure was used in this study to determine Plylox™ clip installation requirements rather than a direct comparison to the IRC panel conditions tested.

TEST METHODS

The following test methods (modified as described below) were used to perform the tests required in the test plan.

Pressure Tests (ASTM E330-02)

The ASTM 330-02 Standard Test Method [1] was used in this test program. This test method is typically used to determine the structural performance of exterior window and door products by applying a uniform static pressure to the devices or components being tested. The apparatus used to apply uniform static pressure to the specimens is shown in Figure 2.

Figure 2. Pressure test apparatus without specimen installed (showing airbags).

The pressure test duration exceeded the minimum 10 second duration as recommended in ASTM E330-02 and varied from a minimum of 20 seconds to a maximum of 6.7 minutes depending on the stiffness of the systems tested and the failure mode. A manometer was used to read pressure differentials at a precision of 0.1" H_20 as deemed suitable for the intended use of the data and range of pressures investigated. A dial caliper was used to read deflection at mid-span of one edge of the specimen to the nearest 1/100 of an inch (Procedure A).

All tests were conducted by applying a increasing load (pressure) until failure occurred. Only negative (suction) pressure performance was investigated as a worst-case loading condition due to the nature of the device tested (i.e., for positive pressures the panel bears against the window or door frame and is restrained against movement or failure of the Plylox™ clip attachment). The test method was not used to conduct a 'proof load' test as contemplated in the ASTM E330 standard. The method was used instead to develop ultimate load data for use in determining design values for the Plylox™ clips (see Analysis section). Therefore, a monotonic loading procedure was substituted for the loading step and recovery time procedures prescribed by the standard for proof testing.

Wind Debris Impact Tests (ASTM E1886-02)

Wind debris impact tests were conducted using an air-cannon apparatus and procedure as described in ASTM E1886-02[2]. A 4.47 lb 2x4 missile (No 2 Southern Pine) was used for all impacts. The missile speed and target locations were varied as described below.

The application of the impact test used in this study was not intended to determine the adequacy of the wood structural panel product (i.e., OSB) protecting the opening. In this testing program, the impact test method was used to determine the ability of Plylox™ clips to continue to restrain the panel under multiple significant missile impacts that do not penetrate the panel as well as those that do penetrate the panel. Therefore, the impact test sequence used the following test procedure for each of the three specimens tested:

1. Center of panel impact – two moderate impacts (ranging from 19 fps to 29 fps) and one high impact (approximately 34 to 38 fps).
2. Corner of panel – same as above.

The panel was not visibly damaged (penetrated) by the moderate impact levels so that the Plylox™ clips were subject to the highest possible dynamic loading as limited by the impact resistance of the wood structural panel (7/16" OSB). The high impact level created a puncture penetration of the panel (within approximately 1/2" of the cross-sectional size of the 2x4) and was the final blow imparted at each target zone of each specimen tested. Thus, each panel was subjected to a minimum of six significant impacts (4 not penetrating the panel and 2 penetrating the panel). After each impact, movement in the Plylox™ clip attachments were recorded and the panel was checked for continued ability to secure the panel by applying force manually to the back of the specimen at the center of the wood structural panel.

The debris impact testing sequence described above is considered to be highly improbable and conservative relative to statistical data and field observations on debris impacts collected by the NAHB Research Center, Inc., for the U.S. Department of Housing and Urban development following Hurricane Andrew [3] and similar statistical debris impact data collected for a recent F4 tornado [4].

Analysis Method

The pressure test results were used to determine an ultimate load capacity on a per clip basis for each test. This value was determined directly from the test data by multiplying the ultimate pressure attained at failure by the area of the panel and dividing that value by the number of clips securing the panel. A design value for the clip was determined by dividing the ultimate load capacity by a safety factor of 1.5 (ASTM E330-02). This design value was subsequently used to determine clip spacing requirements according to wind pressures taken directly from Table R301.2(2) of the 2000 IRC (determined using ASCE 7-98[5]) and a prescribed range of recessed window or door opening widths to which the panels are applied. As discussed later in this report, use of a safety factor of 1.5 was found to be conservative relative to the average performance of wood structural panels attached to wall openings in accordance with IRC Table R301.2.1.2.

TEST RESULTS

This section summarizes the relevant test data obtained following the test methods and procedures described previously. Detailed data for each test is included in Appendix A.

IRC Panel Pressure Tests

The following results (Table 1) were obtained for the IRC Panel specimens described in the Test Plan section of this report. Test methods used are also described in the Test Plan section. These tests are used to confirm appropriate minimum performance criteria for the intended Plylox™ product applications (see Analysis section).

TABLE 1
PRESSURE TEST RESULTS FOR IRC PANEL SPECIMENS

Specimen Type	n	Average Pressure at Failure (psf)	Deflection Prior to Failure (in)	Failure Mode	Design Pressure (psf)	Safety Margin (Factor)
IRC Panel #1	4	28.1 [COV 15%]	4.5	Screw head pull-thru	-36.6	0.8
IRC Panel #2	3	82.2 [COV 18%]	2.6	Screw head pull-thru	-39.2	2.1
IRC Panel #3	1	56.2	--	Nail withdrawal	-39.2	1.4
					Average Safety Margin	**1.4**

Table Notes:
1. Specimens are as described in the Test Plan section.
2. 'n' is the number of repetitions.
3. COV is the coefficient of variation (standard deviation divided by mean).
4. Safety margin is determined by dividing average pressure at failure by the panel design pressure according to Table R301.2.1.2 of the 2000 IRC (interpolated for tributary area equal to opening area). Wall Zone 5, Exposure B, and mean roof height of 30 ft are assumed conditions. For different conditions, adjustments can be made in accordance with Table R301.2(3) of the 2000 IRC.
5. Pressure equalization (i.e., venting of air-space behind the panel) during an actual wind event may reduce design suction pressures by as much as 50 percent and may be applicable to the type of system tested.

Figure 3 shows a nominal 8 ft span IRC Panel test specimen in the pressure test apparatus immediately after failure.

Figure 3. IRC panel specimen (nominal 8 ft opening span) showing pull-thru and edge tear-out of one #8 screw at one end of the panel.

Results for the IRC Panel specimens constructed in accordance with IRC Section R301.2.1.2 (Table R301.2.1.2) demonstrated a widely varying safety margin relative to code prescribed design wind pressures. For this reason, a safety factor of 1.5 relative to design wind pressures specified in IRC Table R301.2(2) is used as a performance basis for determining Plylox™ clip installation requirements according to panel span and wind speed condition. This approach results in a more consistent safety margin (performance basis) than would be obtained by direct comparison of Plylox™ panel pressures to IRC panel pressures. It also ensures that the Plylox™ evaluation is not based on equivalence to a prescriptive building code provision that may change in the future.

The following values were obtained for average withdrawal resistance of the fasteners used in the IRC Panel tests.

#8 x 2-1/2 inch bugle head deck screw – 105 lbs (COV = 15%)
#6 x 2-1/2 inch bugle head deck screw – 205 lbs (COV = 18%)
10d common nail (0.148 in diam. x 3 in) – 140 lbs (one sample)
(NOTE: 2x edge material was No. 2 SPF)

The lower value for the #8 screw is due to the combined loading comprised of (1) withdrawal due to reaction of pressure applied to the panel and (2) shear due to tension developed in the panel from bending with restrained ends. This condition is considered to be a defect in the code and is not used to establish a performance baseline in this study. It is recommended that a 2x4 brace (stiffener) be added to the provisions of 2000 IRC Table R301.2.1.2 to resolve this problem for spans greater than 4 feet. A minimum 2x4 stiffener detail should follow one similar to that used in this study for the 8 ft panel condition with Plylox™ clips.

According to the proponent of the existing provision in the IRC (Ed Keith, APA-The Engineering Wood Association, pers. comm.), the intention of the IRC committee was to have a simple and practical means to provide reasonable protection to windows and doors in typical wind debris regions (i.e., the table does not address wind speeds greater than 130 mph gust [110 mph fastest mile]). The committee's primarily concern was with regard to the panel's connection strength and not deflection or degree of impact resistance. Therefore, analysis for the IRC provision was based on connection strength alone, although it appears that secondary forces on fasteners (as described above for the 8 foot span condition) were not anticipated.

Plylox™ Pressure Tests

The following results (Table 2) were obtained for the IRC Panel specimens described in the Test Plan section of this report. Test methods used are also described in the Test Plan section. The Plylox™ clip ultimate capacity data (lbs/clip at failure) is used later in the Analysis section of the report to determine installation requirements. Figure 4, 5, and 6 show examples of the test set-up.

TABLE 2
PRESSURE TEST RESULTS FOR PLYLOX™ SPECIMENS

Specimen Parameters			Maximum Load at Failure		Deflection Prior to Failure (in)	Failure Mode
Recessed Opening Material	Nominal Panel Span	No. of Clips per Side	Average Pressure (psf)	Average Load per Clip (lbs/clip)		
1x10 Pine (No. 2 grade)	4	2	41.3 (6%)	154.3 (6%)	1.8 (19%)	B,S
	4	4	54.8 (9%)	102.4 (9%)	2.3 (9%)	B,O
	8	4	45.8 (3%)	173.3 (3%)	1.1 (14%)	B
Sand-Faced Clay Brick	4	2	40.2 (19%)	148.0 (19%)	1.7 (6%)	S,B
	4	4	56.9 (4%)	104.6 (4%)	2.5 (12%)	S,B
	8	3	32.6 (7%)	161.6 (7%)	0.7 (14%)	B
Portland Cement Stucco	4	2	39.5 (3%)	146.1 (3%)	1.8 (15%)	B
	4	4	54.4 (14%)	100.6 (14%)	2.2 (14%)	B

Table Notes:

1. Clip thickness used is 0.029 inches minimum.
2. Panels were cut to 1/4 in to 3/8 in less than the recessed opening dimension.
3. Nominal 8-foot panel spans are reinforced by 2x4 stiffeners oriented parallel to the panel span and nailed to the outside face of the panel using 12d (0.131 in diameter by 3 in long) pneumatic nails at 12 inches on center. The stiffeners were spaced at 2 ft on center at third-points of the panel's 4 foot width dimension. The stiffeners were cut to length such that the end of each stiffener was 3 inches short of each end of the panel. Nominal spans of 4-foot and less did not use stiffeners.
4. Failure modes are as follows: B = clip bending failure, S = clip slipping failure, O = failure of recessed opening frame material at clip location. If multiple or combined failure modes were observed, the predominant failure mode is listed first.

Figure 4. Pressure test of PlyloxTM clips with 1x10 wood opening recess material (Specimen #21, nominal 4 ft x 4ft panel, failure by clip bend on left side).

Figure 5. Pressure test set-up with sand-faced clay brick opening recess material (nominal 4 foot panel with Plylox™ clips not shown).

Figure 6. Pressure test of Plylox™ clips with Portland cement stucco opening recess finish material.

The trend of decreasing clip capacity with increasing numbers of clips per side of opening (reduced spacing) was observed in all of the test groups with the exception of the exploratory test group using the 0.044-inch-thick clip with the 1x10 recessed opening material (discussed below). The reason for this trend is not readily apparent from the test data or observations. However, the values in Table 2 are suitable for analysis of Plylox™ clip spacing requirements provided the trends are properly addressed (see Analysis section). A fairly low variability in the tested clip capacity was

found in most cases which indicates that the clip behavior is very predictable and consistent (i.e., COV less than 10 percent in most cases).

Exploratory Plylox™ Pressure Tests

As described in the Test Plan section of this report, several exploratory pressure tests were conducted to ascertain the effect of various conditions on the performance of panels secured using Plylox™ clips. The detailed results of these tests are shown in Appendix A. Findings important to this report are summarized as follows:

- Comparatives with 1x10 Wood Opening Recess Material

  Plywood Edge – Six tests were conducted using plywood as a recessed opening material to represent a wood material with significantly greater density (and hardness) than the 1x10 wood (No 2 Pine) edging used in the core group of tests. The value obtained for a 'three clip per side" condition was 126.9 lbs/clip (COV 18%) which is consistent with results of Table 2 (i.e., halfway between the reported values for the 2 clip and 4 clip conditions). The failure mode, however, was more likely to be a result of clip slipping rather than clip bending as before. Even so, the strength values were consistent.

  0.5 inch Gap – The gap in the core group of tests was 0.25 inches. Ten tests were conducted with various specimen parameters (panel span and number of clips per side) to determine the sensitivity of clip performance to gap between the panel and the opening. At this gap dimension, it was found that clip performance was governed primarily by bending of the toothed leg. As a result, the value obtained for the test group as a whole was 83.3 lbs/clip (COV 9 percent). Thus, as gap dimension increases, clip capacity decreases as expected. However, differences within a tolerance of 1/8 inch appear to have a small impact. For this reason, a maximum gap dimension of 3/8 inch is recommended when 1/4 inch gap is desired (allowing for a tolerance of 1/8 inch in field cutting the panels). However, a gap as large as 1 inch appeared to have only a minimal impact on the clip performance for one of the 'plywood edge tests' (see Appendix A). The gap dimension is defined as the difference between the opening size and the panel size.

  8ft Panel Span without 2x4 Stiffener – Without a 2x4 stiffener, the clip holding capacity was reduced by as much as one-third for the nominal 8 foot panel span. This effect is due to excessive panel bending deflection which increases the gap between the panel and opening sides until the panel essentially "pops out" of the clip. Using 2x4 panel stiffeners (see Figure 7) effectively reduced 8 foot panel span deflections to less than that observed for the 4 foot panel spans which were used successfully throughout this study without a stiffener and without noticeable problem or effects on clip performance (see Table 2).

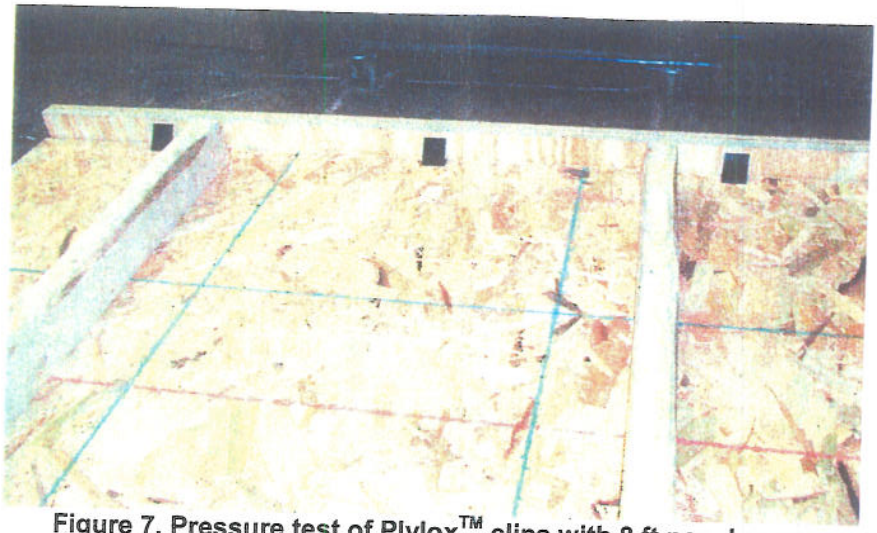

Figure 7. Pressure test of Plylox™ clips with 8 ft panel span and 2-2x4 stiffeners.

0.044 inch Clip Metal Thickness – In the core group of tests, clips with a nominal steel thickness of 0.029 inches were used (see Table 2). A number of tests were conducted with a prototype 0.044-inch-thick clip to determine the effect on clip performance. For the 1x10 recessed opening condition, the 0.044-inch-thick clip provided about 20 percent more capacity than the 0.029. At this level of increased clip capacity, other failure modes began to appear, such as fracturing of the OSB panel at the clip location and splitting of the 1x10 wood material forming the opening recess. (The 0.044 inch clips were supplied by the manufacturer and not sampled by the Research Center.)

- Comparatives with Sand-Faced Clay Brick Opening Recess Material

Synthetic Brick – In the core group of tests, a standard sand-faced fired clay brick was used (see Table 2). A synthetic brick paver was selected to simulate a smooth and hard glazed brick or ceramic surface. Several tests were conducted to determine the effect on clip performance (see Figure 8). As expected a slipping failure mode was more commonly observed. Relative to the sand-faced clay brick values in Table 2, clip capacity was reduced by nearly one-half. Therefore, it is recommended that the product not be used with glazed brick or ceramic exterior finish materials.

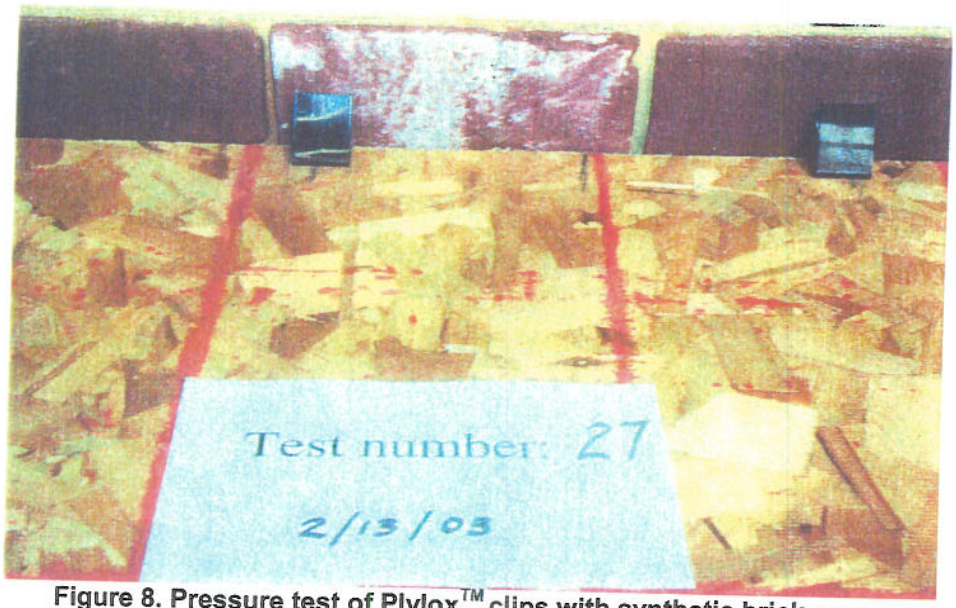

Figure 8. Pressure test of Plylox™ clips with synthetic brick paver for opening recess material.

0.044 inch Clip Metal Thickness – Use of a thicker metal for the clip, resulted in improved grip on the synthetic brick and sand-faced clay brick. Relative to the sand-faced clay brick values in Table 2, clip capacity was reduced by nearly one-third when the 0.044-inch-thick clip was used with the synthetic brick (a modest improvement over the effect of the synthetic brick on the 0.029-inch-thick clip). The improvement of grip of the 0.044-inch-thick clip on the sand-faced brick in comparison to values in Table 2 was a modest 13 percent.

- Comparatives with Stucco Opening Recess Material

  0.044 inch Clip Metal Thickness – Use of the thicker 0.044-inch-thick clip with the Portland cement stucco opening recess finish material provided only a moderate apparent improvement relative to the core tests reported in Table 2 for the 0.029-inch-thick clip. More testing is needed to determine a more exact benefit to use of a thicker bracket.

Plylox™ Wind-borne Debris Impact Tests

The Plylox™ clips passed all of the debris impact test conducted in accordance with the procedure described in the Test Method section. Table 3 summarizes the results.

TABLE 3
SUMMARY OF PLYLOX™ DEBRIS IMPACT TESTS

Impact Level (4.5 lb 2x4 Missile)	Specimen 1		Specimen 2		Specimen 3	
	Center	Corner	Center	Corner	Center	Corner
Non-penetrating (19 to 29 fps)	2 blows passed	1 blow passed	2 blows passed	2 blows passed	2 blows passed	2 blows passed
Penetrating (34 to 38 fps)	1 blow passed	1 blow passed	1 blow passed	1 blow passed	1 blow passed	1 blow passed

A specimen was judged to pass when the panel remained secure after each blow or sequence of blows as shown in Table 3. After each blow, any movement in the Plylox™ clips securing the panel was measured. Typically there was no measured movement in the clip. When movement did occur, it was no more than 1/4-inch total movement (outward) at the completion of all impacts (i.e., one of the clips of four in specimen #3 had this amount of movement). The clips were still functional and qualitative observations suggest that the impacts caused the clips to embed slightly into the brick substrate which tended to improve grip during the sequence of impacts. A specimen immediately following the test sequence is shown in Figure 9.

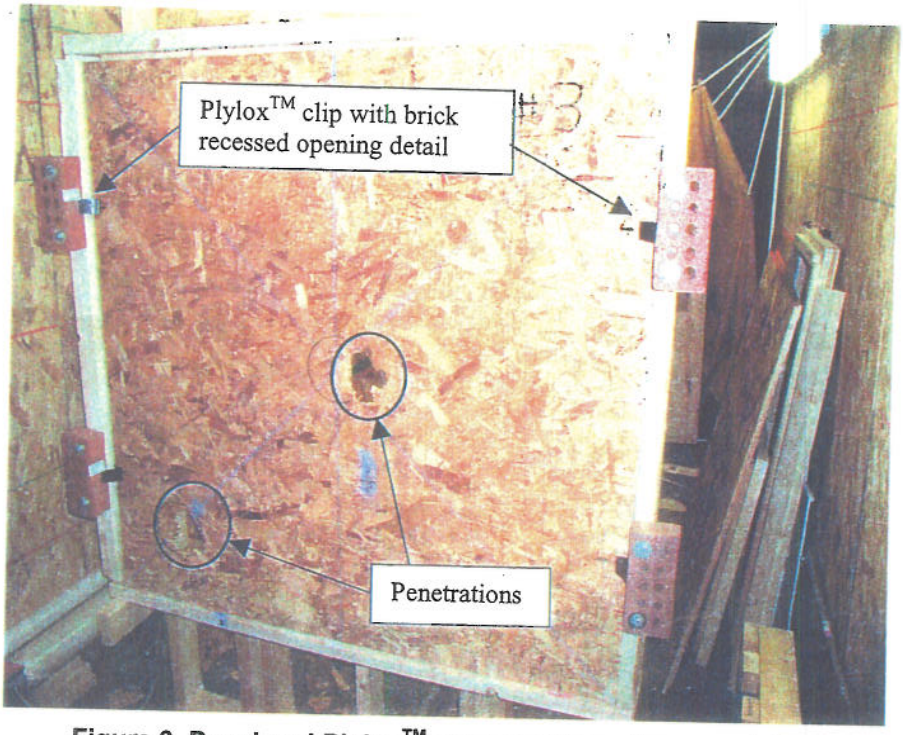

Figure 9. Panel and Plylox™ clip condition after completion of the entire impact test sequence (Specimen #3).

ANALYSIS OF DATA

In this section, data from the Plylox™ pressure tests are used to determine appropriate clip design values and a table for correct spacing of the Plylox™ clips based on design wind speed and opening span. From the data presented in Table 2, design values for the Plylox™ Clip are based on the worst-case opening recess material (i.e., Portland cement stucco) as shown in Table 4 below.

TABLE 4
PLYLOX 0.029-INCH-THICK CLIP DESIGN VALUES

Clip Spacing	Ultimate Capacity (lbs/clip)	Design Value (lbs/clip)
24" oc	146.1	97.4
12" oc	100.6	67.1

Table Notes:
1. Design values are derived using a safety factor of 1.5 for reasons discussed in earlier sections of this report.
2. Design value of clips varies linearly with spacing for the range of conditions tested.

Based on the above design values and the wind pressures required in Table R301.2(2) of the 2000 IRC (derived from ASCE 7-98 Standard), Plylox™ clip spacing requirements are determined as shown in Table 5. The analysis method follows a straight-forward engineering analysis comparing loads to clip strength to determine the required spacing for a range of applications (see Appendix B).

TABLE 5
DESIGN & INSTALLATION REQUIREMENTS FOR PLYLOX™ CLIP
(0.029 inch steel thickness)

Design Wind Speed (mph, gust)	Design Wind Pressure (psf)	Maximum Allowable Plylox™ Clip Spacing (inches)					
		Nominal Recessed Opening Width (inches)					
		24	36	48	60	72	96
110	20.4	24	24	24	24	16	8
120	24.3	24	24	24	16	8	6
130	28.5	24	24	16	8	8	n/a
140	33.0	24	24	12	8	6	n/a
150	37.9	24	16	8	6	n/a	n/a

Table Notes:
1. Table applies to window or door opening recesses with surface materials of wood, clay brick, or Portland cement stucco.
2. A minimum of 2 clips per vertical side of opening is required.
3. For opening spans (widths) greater than nominal 4 feet (48 inches), wood structural panels shall be stiffened with edgewise 2x4s spaced at 24 inches on center spanning horizontally across the opening on the outer face of the panel. The 2x4 stiffener shall be attached to the panel using #8 x 2-1/2 inch bugle head deck screws spaced at 12 inches on center with two screws located at each end of the 2x4.
4. Panels shall be seated firmly on all edges to window or door frame. The clips must have sufficient edge distance from the outer edge of the recess opening to prevent break out. Table values are based on testing done with a 3.25-inch recess from outside face of wall to outer edge of window or door frame.
5. Minimum dimension of wood structural panel shall be no more than 1/4 inch less than the opening dimension (tolerance of 1/8-inch is permitted).
6. Applicable wood structural panels types are minimum 7/16-inch-thick oriented strand board (OSB) and minimum 15/32-inch-thick plywood.
7. Wind pressures are based on ASCE 7-98 as tabulated in Table R301.2(2) of the 2000 International Residential Code. Pressures assume a maximum mean roof height of 30 feet and wind exposure category B (suburban exposure). Refer to Appendix B of this report for details on calculations to support table values.

CONCLUSIONS

Two key conclusions are supported by the findings in this report:

1. Plylox™ clips as tested in this study provide a suitable method for attachment of wood structural panels for window and door protection against wind-borne debris in hurricane prone regions.
2. Plylox™ clips as addressed in this study provide performance that meets or exceeds the performance provided by the wood structural panel covering

attachments described in Table R301.2.1.2 of the 2000 International Residential Code when installation is in accordance with Table 5 of this report.

REFERENCES

[1] ASTM E330-02 *Standard Test Method for Structural Performance of Exterior Windows, Doors, Skylights and Curtain Walls by Uniform Static Air Pressure Difference*, American Society of Testing and Materials, West Conshohocken, PA. 2002.

[2] ASTM E1886-02 *Standard Test Method for Performance of Exterior Windows, Curtain Walls, Doors, and Storm Shutters Impacted by Missile(s) and Exposed to Cyclic Pressure Differentials*, American Society of Testing and Materials, West Conshohocken, PA. 2002.

[3] *Assessment of Damage to Single-Family Homes Caused by Hurricanes Andrew and Iniki*, U.S. Department of Housing and Urban Development, Washington, DC. 1993.

[4] Crandell, J. H., *Housing Performance Assessment Report: F4 La Plata Tornado of April 28, 2002*, NAHB Research Center, Inc., Upper Marlboro, MD. 2002.

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