REPORT OF RESULTS: STORM CLAMPS™ FOR FASTENING OF WOOD PANEL WINDOW OPENING PROTECTION IN HURRICANE REGIONS

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Materials Tested:
Storm Clamps

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I. Introduction

GNT Enterprises has developed a clamp for attaching plywood and OSB sheathing materials to window openings for debris protection during hurricanes. GNT has requested testing on their Storm Clamps™ to evaluate their performance relative to building code requirements.

The IRC building code allows for attaching protective sheathing products with screws but does not explicitly permit an attachment such as developed by GNT. The design wind speeds where the system might be used will be a function of the wind zone, building height, and exposure. Typically, only the largest size panel needs to be tested as smaller panels will be considered to meet or exceed the performance of the larger panel. GNT requested that the clamps be tested for a 3' x 6' opening.

The clamps were subjected to a uniform load test in order to determine the design load for the clamps. The clamps were then tested to ASTM E1886/1996 in order to determine their performance in windborne debris.

The testing was conducted at the NAHB Research Center Laboratory between June 12 and June 26, 2009.

II. Product Description

The Storm Clamp™ product consists of a mounting base which is screwed into the building structure adjacent to the window opening, a clamping arm, and a bolt/wing nut to attach the clamping arm to the base. The base and the clamping arm are made of an injection molded plastic. The Storm Clamp™ product is shown in Figures 1 and 2.

The clamping arm's length was 5.4" and the wall thickness measured 0.15". The wall thickness of base measured 0.23" around the bolt. The bolt, washer, and wing nut to attach the clamp arm to the base is supplied with the Storm Clamps™. The bolt was ¼" in diameter. Screws to attach the base to the structure were not supplied with the clamp product.

Storm Clamps™ are available in several colors. The test clamps were white in color.

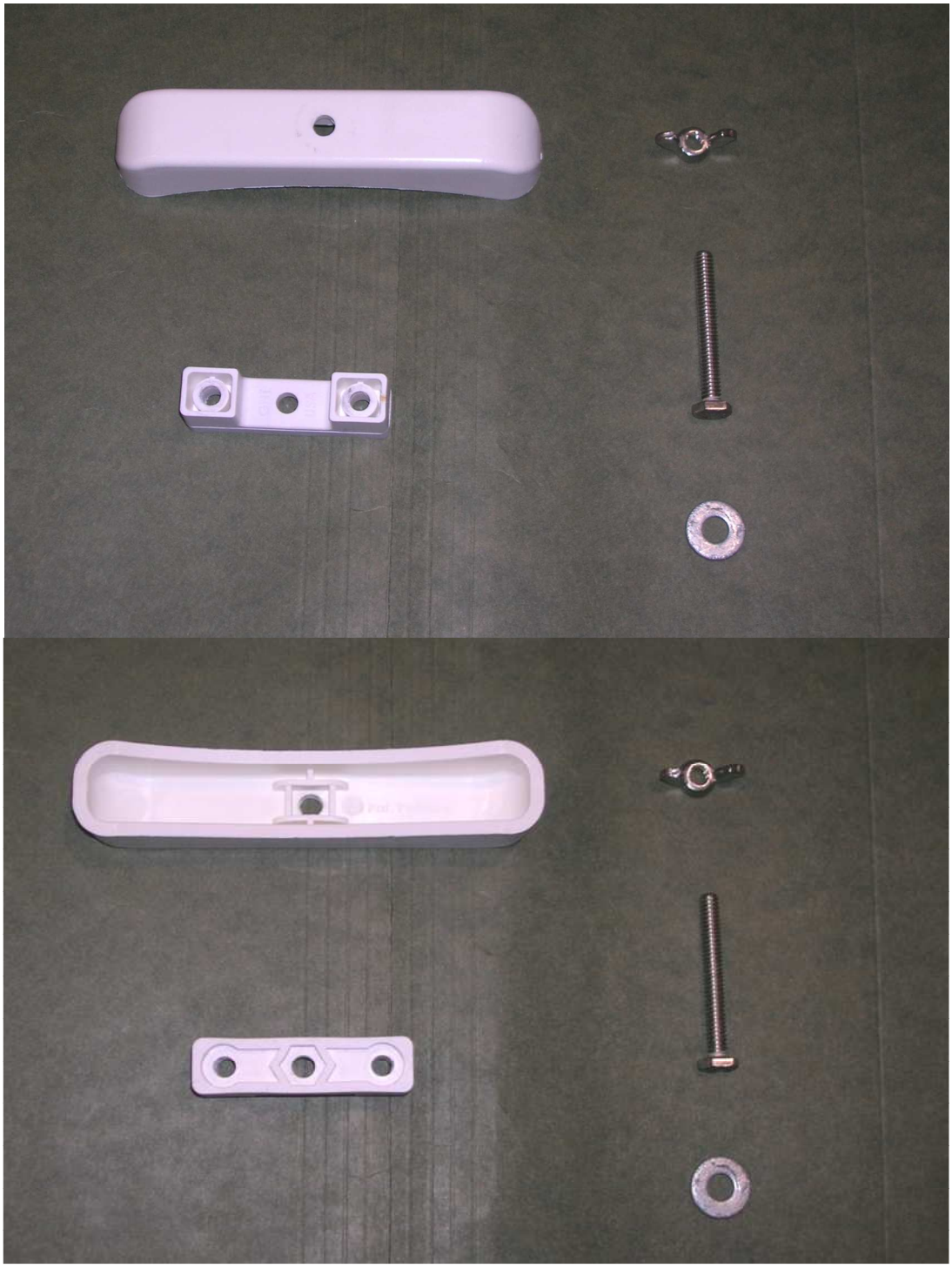

Figure 1: Top view and bottom view of Storm Clamp™

Figure 2: Installed Storm Clamp™

The Storm Clamps™ used in this testing were randomly sampled from inventory at the manufacturer by a representative of the NAHB Research Center.

GNT recommended utilizing 19/32" plywood for the wood panel and this product was purchased locally from a home center. The panel was stamped with a PS2 certification mark.

III. Test Methodology

Sample Preparation

In order to simulate a window opening, a wooden frame with an opening size of 3' x 6' was constructed out of 2x4 lumbers as shown in Figure 3.

Figure 3: Window frame used for testing
(Black lines indicate the area to be covered by plywood)

The plywood for covering the window opening was cut so that there was a 2" overlap of the plywood over the wooden frame in every direction.

The clamps were fastened to the frame using 2-inch-long #12 pan head screws so that there was a 1½" penetration into the frame. The clamps were installed vertically on the sides of the frame. The clamps were positioned 17" from the top and bottom of the plywood sheet respectively for a total of 4 clamps. Figure 2 shows the clamps installed on the frame. For all tests, the white clamps were used. Extensions to the sides of the frame were added at the clamp locations to simulate additional building structure.

Figure 4: Frame with clamps fastened and plywood secured.

The plywood was placed over the opening and the clamps were tightened so that the plywood was flat against the frame.

In order to provide the uniform pressure, an air bag was constructed which was inflated and deflated to reach the required pressures. The air bag was connected to an air compressor. The flow of air in or out of the bag was controlled by a valve system which was in turn controlled by a computer. The air bag had a pressure tap which was connected to a pressure transducer used to measure the pressure being applied.

Uniform Load ASTM E330

Because the Storm Clamp™ product did not specify a proof load or design load a uniform load test generally according to ASTM E330 was conducted in order to determine the maximum load the clamps would withstand. A monotonic loading procedure was substituted for the loading step and recovery time procedures prescribed by the standard for proof testing. The displacement of the plywood during loading was not measured.

Using the air bag, negative (outward) pressure was applied to the plywood. Only negative pressure was applied as this represents the worst case scenario. The pressure was measured and increased until failure. The pressure at failure was then used to determine the design pressure for the cyclic loading.

Analysis

During the uniform load test clamps failed at an ultimate load of 79.2 psf. By dividing this load by a factor of safety of 1.5 a suggested design load of 52.8 was obtained. This design load was then compared to the wind pressures in ASCE7. The nearest wind condition found was for a wind speed of 130 MPH at exposure C and a building height of 25 feet. For those conditions, the negative design wind pressure is 52.0 psf and the positive design pressure is 39.5 psf. These design pressures were used for the ASTM E1886/1996 test.

Debris Impact and Cyclic Loading (ASTM E1886/E1996):

Three additional specimens were tested to ASTM E1886/1996. From the maximum pressure obtained from the uniform load test a positive design pressure of 39.5 psf and the negative design pressure of 52.0 psf were chosen as is explained in the analysis section.

The test protocol calls for impacting the plywood panel with a large missile at 50ft/sec using Douglas Fir 2x4 weighing 4100 ± 100 grams and having a length of 7' 9". An air cannon was used to propel the missile using compressed air. The air cannon apparatus is shown in Figure 5.

Figure 5: Air cannon apparatus used for launching large missile

A pair of light sensors was used to time the missile as it left the air cannon. The velocity of the missile was calculated based on the distance between the sensors and the elapsed time. The speed measuring system was verified per ASTM E1886 Section 9.1.3. After impact the clamps were examined to confirm that they had not detached. The size of the missile penetration was examined to make sure a 3" diameter sphere would not be able to pass through the hole. Each test specimen is impacted once and then subjected to the cyclic pressure testing. The first specimen was impacted within a 2½" radius circle with the center of the circle being 6" from the

bottom and from the left of the plywood sheet. The second specimen was impacted within a 2½" circle in the center of the plywood sheet. The third specimen was impacted within a 2½" radius circle with the center of the circle being 6" from the top and from the right of the plywood sheet. After each impact the hole was covered with a small piece of cardboard to prevent splinters from piercing the air bag.

Figure 6: Cardboard used to cover hole after impact.

Following each large missile impact test the specimen was subjected to the cyclic loading test. Positive (inward) pressure loading was applied according to the following schedule:

0.2P – 0.5P for 3500 cycles
0.0P – 0.6P for 300 cycles
0.5P – 0.8P for 600 cycles
0.3P – 1.0P for 100 cycles
Where P represents the positive design pressure of 39.5 psf

The specimen was then loaded with negative (outward) pressure as follows:

0.3P – 1.0P for 50 cycles
0.5P – 0.8P for 1050 cycles
0.0P – 0.6P for 50 cycles
0.2P – 0.5P for 3350 cycles
Where P represents the negative design pressure of 52.0 psf

The clamps were judged to pass if the plywood remained secure after the impact and after the pressure cycling.

A new set of clamps and new panel was installed in the test frame for each of the three tests.

Laboratory temperature and relative humidity were not controlled but ranged from 53-62% RH and 62-72˚ F.

IV. Test Results

Uniform Load test (ASTM E330)

Table 1 shows the result of the uniform load test to which the clamps were subjected. The mode of failure consisted of the base of two of the clamps breaking by the pulling force of the tap bolt. Figure 7 shows a clamp base after failure.

Table 1: Uniform Load Test Results

Pressure at Failure (psf)	Failure Mode	Total load at failure (pounds)	Load per clamp (pounds)
79.2	Material failure of clamp base	1425	356

Figure 7: Failure of the clamp base during the uniform load.

Debris Impact and Cyclic Loading (ASTM E1886/E1996)

Table 2 shows the debris impact and cyclic loading results.

Table 2: Debris Impact and Cyclic Loading Results

Test Number	Impact Location	Missile Velocity (ft/s)	Missile Mass (g)	Impact Result	Positive Design Pressure (psf)	Positive Cycle Result	Negative Design Pressure (psf)	Negative Cycle Result
1	Left-Bottom	50.9	4 175	Pass	39.53	Pass	52.03	Pass
2	Center	50.0	4 193	Pass	39.53	Pass	52.03	Pass
3	Right-Top	51.1	4 175	Pass	39.53	Pass	52.03	Pass

During the first test, the bottom right clamp became loose to the touch after the positive pressure cycling. The clamp became snug again after the negative pressure cycling.

During the second test, the plywood slid down 3/16” after the large missile impact. Also, after the positive pressure cycle the top left clamp became loose to the touch. The clamp became snug after the negative pressure cycling.

There were no observations of note during the third test. In all three cases the clamp/plywood system appeared to be intact and functional at the conclusion of each test.

V. Discussion of Results

Debris Impact and Cyclic Loading (ASTM E1886/E1996):

This testing showed that the Storm Clamps™ passed the ASTM E1886/E1996 testing for wind speeds of 130 MPH and exposure C when used following the manufacturer's instructions on a 3' x 6' opening using 4 clamps. Storm Clamps, as tested in this report and when installed in accordance with manufacturer's instructions and using a minimum #12 screw with at least 1-1/2" penetration into the wood structural frame and attaching a 19/32 inch thick wood structural panel over openings measuring 3' x 6' or less, meet the requirements for window protection against wind-borne debris as required in 2006 International Building Code (IBC) and 2006 International Residential Code (IRC) for structures with a mean roof height of 25' subjected to basic wind speeds not to exceed 130 mph and exposure category C.

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