FLORIDA INTERNATIONAL UNIVERSITY

A Resource for the State of Florida

HURRICANE LOSS REDUCTION

FOR

HOUSING IN FLORIDA:

Performance of Gable End Wall Bracing Retrofit for Hurricane Protection

PHASE II

A Research Project Funded by
The State of Florida Division of Emergency Mangement

Submitted by:

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ABSTRACT

The aftermath of past hurricanes in Florida has shown that one of major damaged structural components in residential homes is the gable-end wall or the gable-end truss for timber wall or masonry wall constructions, respectively. As a result, a revised building code, "Standard for Hurricane resistant residential Construction" (SBCCI, 1993, 1999) and later adopted by the unified Florida Building Codes, was developed to require all gable-ends to be designed to resist hurricane force wind. While the new code provide sufficient design requirement for the gable end wall in new construction, there are very little information on the retrofitting of the gable-end wall of existing homes.

This research project investigates two different retrofit systems: (1) X-bracing and (2) C-bracing to determine their structural performance under hurricane wind. This project is divided into two phases, where the first phase has already been completed and reported in August 2008. Phase I was a preliminary phases and focused on full-scale static load test. Phase II, which will be described in detail in this report, is focused on the two retrofit systems. Result of Phase II reinforces the conclusion of Phase I that the damage in the gable-end wall could be minimized if the sheathings are properly secured. Thus, any new technology that could prevent the sheathing from detaching from the trusses will also prevent gable end wall from damaging.

1.0 INTRODUCTION

After hurricane Andrew many homes in Miami-Dade, primarily region from Miami to Florida City, suffered from a loss of gable-end walls (Keith and Rose, 1994). The cause of the gable-end wall damage is twofold. The first cause of failure is a stability problem that occurred after the roof sheathing is detached from the top cord of the gable-end truss. Once the roof sheathing is gone, the gable-end wall is essentially acting as a weak pin with no lateral stability. The second cause of failure is the weak connection between the gable-end truss framing and the top plate of the end wall (Keith and Rose, 1994). The common method of connection between the gable-end truss framing and the top plate before Andrew was using 10d toe-nails spaced 4 to 6 ft on center, which are proven inadequate for the Hurricane forces. Consequently, preventive measures have been developed and published in the "Standard for Hurricane resistant residential Construction" (SBCCI, 1993, 1999) and later adopted by the unified Florida Building Codes that requires the gable-end wall to be designed to withstand the hurricane force wind.

Although the new code provides protection to newly constructed gable-end wall, there is little information on how to retrofit existing homes, since the code calls for a professional engineer to provide the engineering calculation. However, a common practice for retrofitting gable-end wall is to brace the gable end using "X" bracing from the top center of the gable end to the top center of the fourth truss (Figure 1). Despite this general guidelines on retrofitting the gable end, it is too general and do not address specific hurricane zone. Hence, Richard Reynolds and Tim Reinhold (both served on the Florida Home Builders Association Codes and Standard Committee) developed a new prescriptive retrofit method that provides different retrofit method for the various hurricane zones.

The newly developed prescriptive method no longer rely on the X brace and truss bracing but on 6ft lateral braces that run along the top and bottom chords of the trusses and gable end at the location of each existing gable-end stud greater than 3 ft. in length and spaced no more than 24 in. on center (Figure 3). In addition, lateral braces are tied with timber studs using steel angles. In other words, the prescriptive method is similar to a C brace, which will be used from hereunto to describe the prescriptive method. The prescriptive method also provides various retrofit configurations depending on the exposure and wind speed subjected by the existing homes using different timber's size, nailing schedule, and brackets sizes.

Although the C brace can provide the retrofitted gable ends with "the strength equal to the structural provisions of the latest building code requirements for new buildings" (FBC, 2007), they are based on engineering calculations that may or may not reflect the actual conditions of existing buildings. There are many unforeseen problems (such as undersized studs and/or permanently attached obstacles) that prevent the horizontal braces to be correctly installed. While these problems are addressed in the revised provisions, the solutions may alter the load path causing the building to be subjected to torsion or other modes of failure that are not accounted for in the design of existing buildings. Moreover, the retrofitted gables ends could become significantly stronger than the connections that tie down the wall and/or the roof, which deviate the failure from the gable ends to other components of the buildings. Thus, there is a need to better understand the ultimate load carrying capacity of gable ends in existing buildings and the performance of the prescriptive solutions through full-scale structural testing.

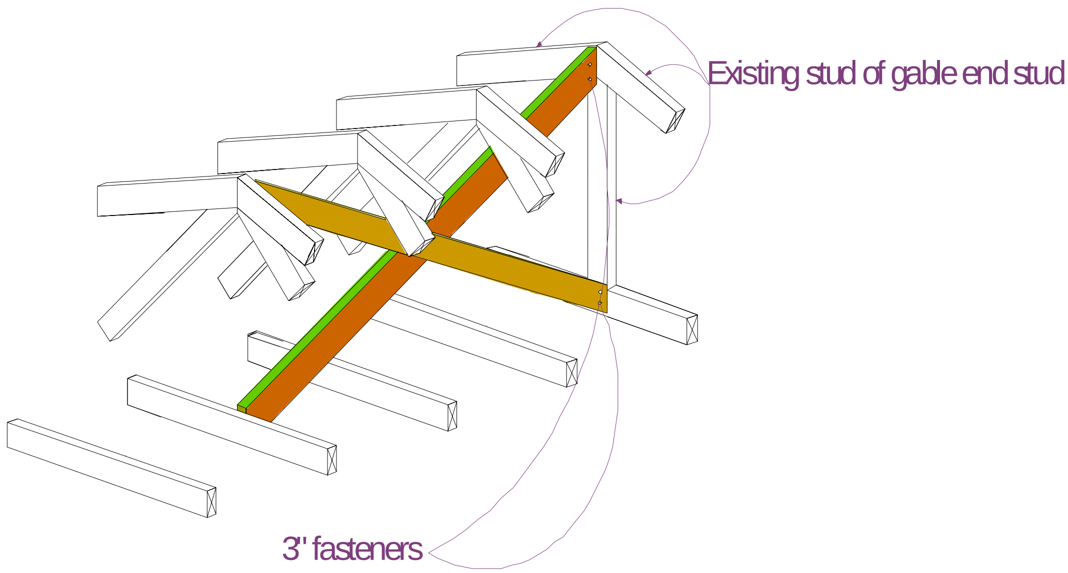


Figure 1. X Brace

RETROFIT DETAILS FOR TRUSS GABLE ENDS

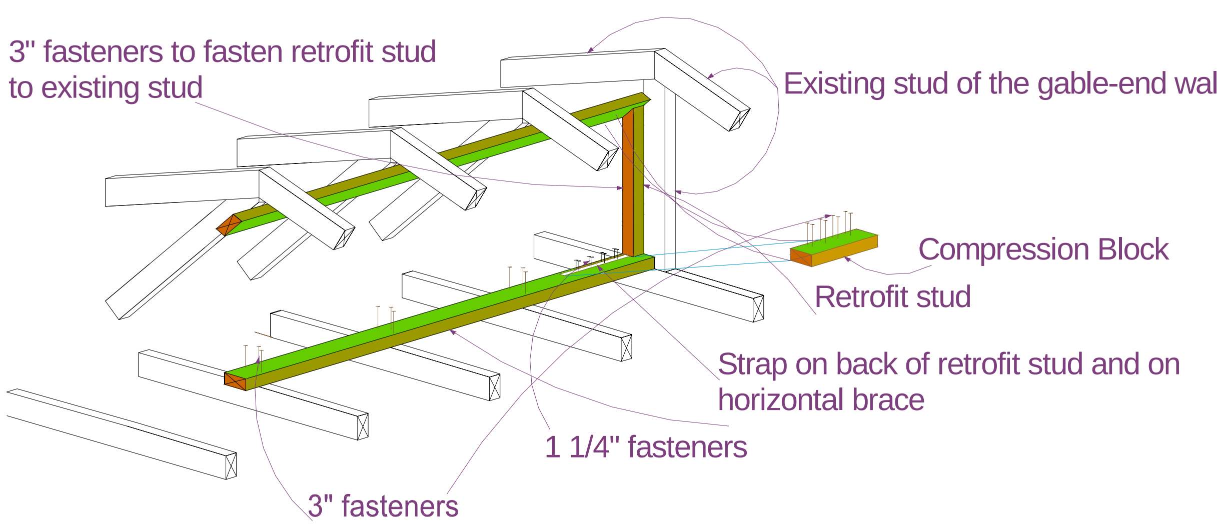


Figure 2. C Brace

2.0 OBJECTIVE

The primary objective of this research is to determine the performance of existing gable-end wall and retrofitted gable-end wall. The research is divided into two phases. Phase I is the preliminary test setup phase where a full-scale static load testing system is design and constructed to determine the performance of gable ends. Phase II involves the testing of the prescriptive solutions and parametric study. This phase is described in detail in this report. The following objectives are identified for each phases:

Phase I (2007-2008):

1. Design and construct a full-scale static load testing system for the gable-end wall.
2. Perform structural load tests of gable-end wall in existing building using the full-scale structural testing system.

Phase II (2008-2009):

3. Perform structural load tests of retrofitted gable ends using the full-scale structural testing system.
4. Determine the failure mechanism and load path of the retrofitted gable ends.

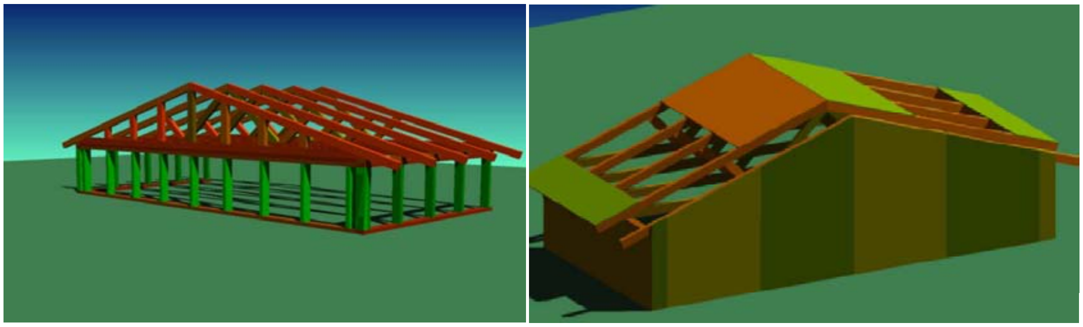
3.0 METHODOLOGY

Part of this study involves the design and construction of the three full scale specimens for analyzing the performance of an existing gable-end wall, as well as the retrofit systems. These specimens were constructed in the Structure and Construction Laboratory (SCL). The full scale test was performed using a jack that was positioned to apply the load in the horizontal line center of the gravity of the gable end wall. The load test was used to establish the level of performance of the retrofits systems of the gable-end walls, the weak spot, and failure mechanism of the retrofits of the gable-end wall.

3.1 TEST SPECIMENS

The test specimens were constructed using four Fink trusses and a gable-end wall, the trusses and the gable-end wall and the walls were constructed using 2×4 spruce pine fir; the span of the trusses were 17 ft wide, the slope of the roof was 4:12. The specimen had two side walls that are 8 ft long and 16 in tall, and one front wall with the dimension of 17 ft long and 16 in tall. The gable-end wall and roof trusses were attached to the top plate using steel hurricane clips. The roof trusses were spaced 24in. on center and braced with 5/8 in. plywood sheathings. All wall framing was also enclosed with 5/8 in. plywood sheathings that were fastened with 10d 1 ¼ in nails. The gable-end wall and part of the roof was also enclosed with 5/8 in plywood sheathings to complete the gable end wall specimen. Figure 3 illustrates the framing and complete view of the test specimens.

Because the emphasis of the research is to determine the performance of the retrofits, the sheathing covering the gable-end wall and the first truss was removed such that the only resistance to the lateral forces would sole be the retrofit system. However, base on the conclusion drawn from Phase 1 that suggested that "the sheathing can play a major role in preventing the collapsing of the gable-end if they remain intact during a hurricane", another test setup with sheathing material covering the gable-end wall and the first truss was also studied. Figure 4 illustrates the semi-covered structure and fully-covered structure used in this study.



(a) Framing (b) Complete structure

Figure 3. Test Specimen

Figure 4. Test Setup with Semi-Covered and Fully-Covered Sheathing.

3.2 RETROFIT

Two retrofit systems were investigated: (1) X brace and (2) C brace. Both systems were constructed using standard 2 × 4 lumber and were installed in the center of the trusses. For the X brace, toe nails were used to fasten the X brace to the gable-end wall and the third truss. Whereas, metal straps and screws were used for the C brace. Figures 5 and 6 illustrate the X and C braces, respectively.

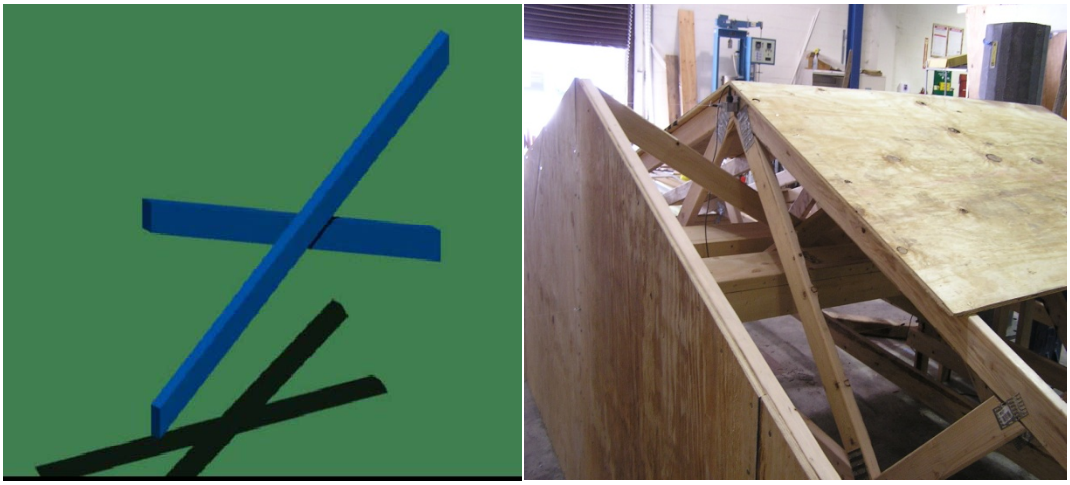


Figure 5. Test Specimen with X Brace Retrofit

Figure 6. Test Specimen with C Brace Retrofit

3.3 LOADING

ASCE 7-05 “Minimum Design Loads for Buildings and Other Structures” was used to determine the worst load case scenario. More detail of the calculation can be found in Phase 1 report in the appendix. Figure 7 illustrates the worst load case where the gable-end wall is subjected to a negative pressure of -71.91 psf, which corresponded to a concentrated force of 2340 lb acting outward. Thus, for testing the gable end wall it was decided to load the wall from inside out. The load was applied using a jack and pump system as a concentrated load at the center of gravity of the gable-end wall. Figures 8 and 9 illustrate the jack setup and the method of applying the load.

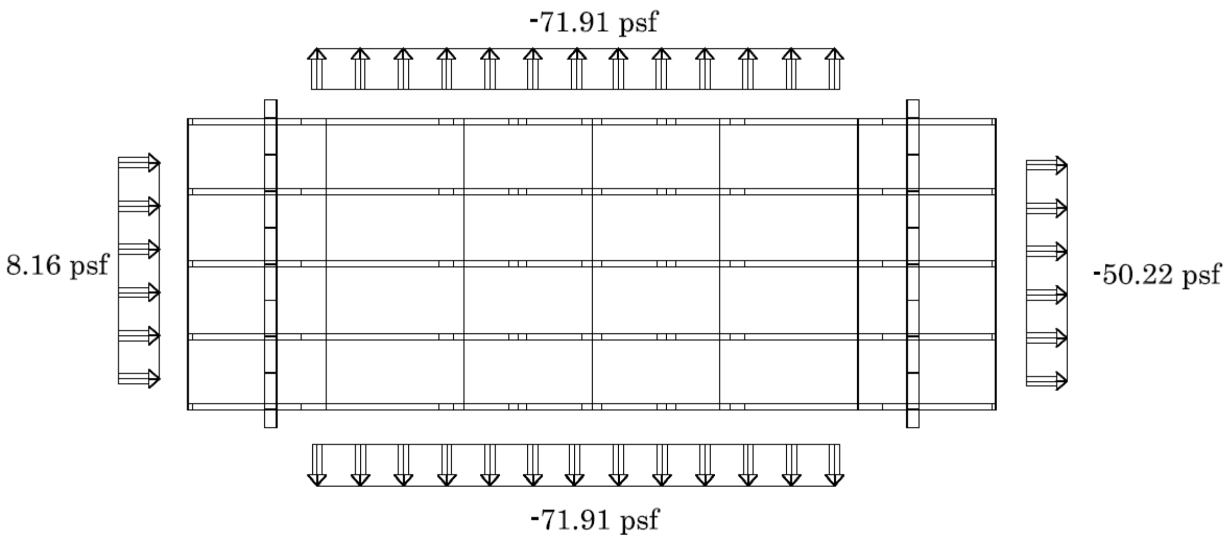


Figure 7. Wind Pressure Calculation

Figure 8. Jack Setup

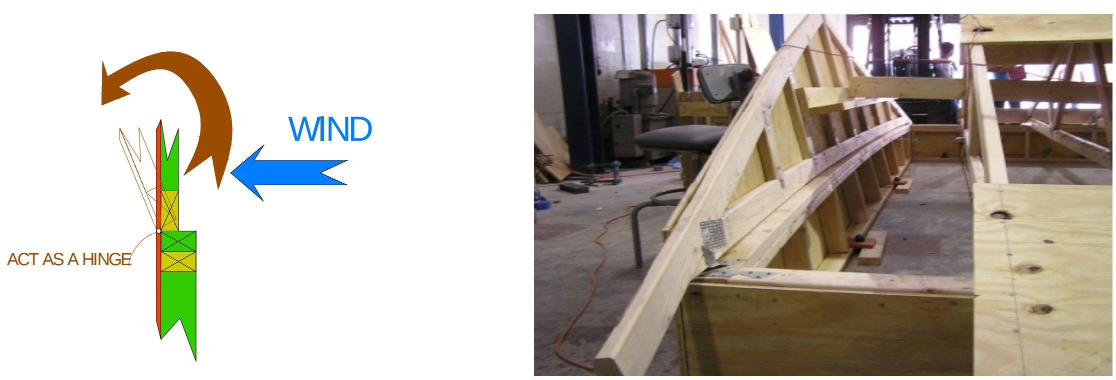


Figure 9. Loading Setup

3.4 INSTRUMENTATION

The gable-end wall specimen was instrumented with five string pots: One string pot was used to measure the absolute displacement at the central of gravity (C.G.); one string pot was used to measure the relative displacement of the top of the gable end wall; one string pot was used to measure the relative displacement of the bottom part of the gable end wall in the center of the span; one was used to measure the relative displacement of the center of the bottom part of the fourth truss; and one string pot was used to measure the absolute displacement of the top part of the fifth truss. The applied load was measured using a load cell mounted to the jack. A Megadac data acquisition system was used to collect the data from all sensors. Figure 10 illustrates the schematic of the sensors location.

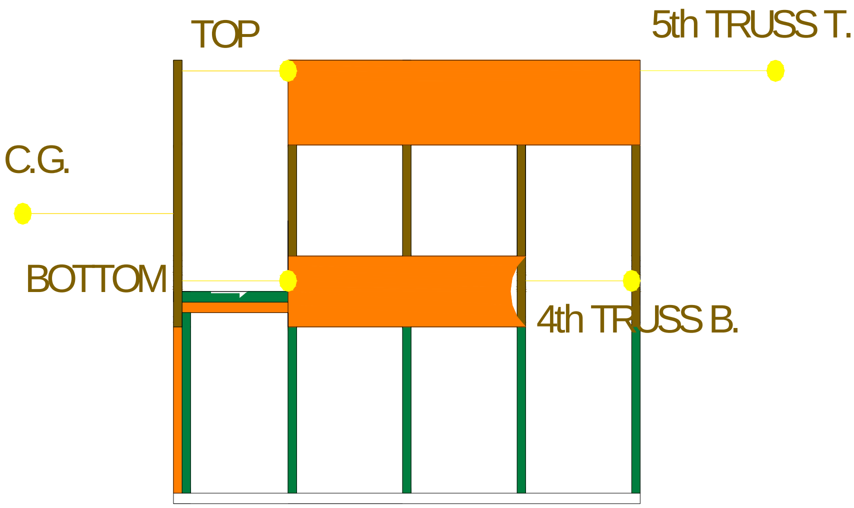


Figure 10. Sensor Location

4.0 RESULT

Figure 11 illustrates the load-deflection curve comparing different retrofit system for semi-covered sheathing specimen. It can be seen clearly in this figure that the C-brace perform the best in the test and is the only system that can withstand the designed wind load acting on the gable-end wall of 2340 lb. However, this is only true if the sheathing is blown off. For a fully covered sheathing system, there is no significant deviation between the retrofit systems and the no retrofit. In fact, the failure mode seems to be controlled by the sheathing failure. Figure 12 illustrates the load-deflection curve of the test specimen with fully covered sheathing. Thus, this reinforced the conclusion drawn in Phase 1 that the damage in the gable-end wall could be minimized if the sheathing is properly secured.

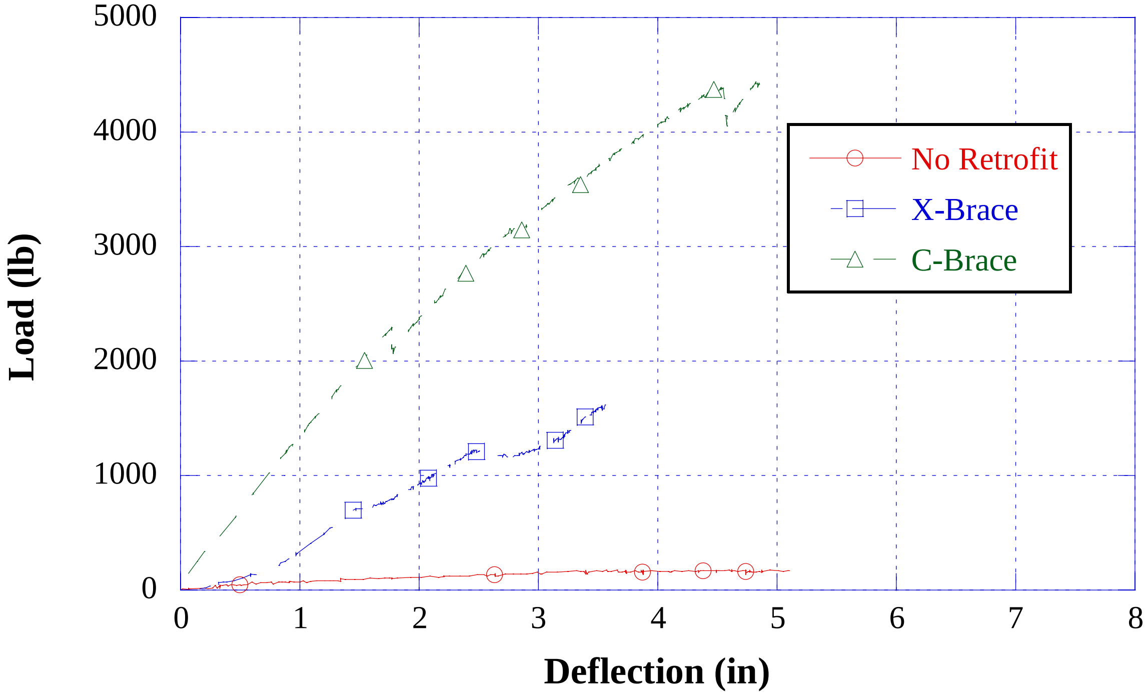


Figure 11. Load-Deflection of Test Specimen with Semi-Covered Sheathing

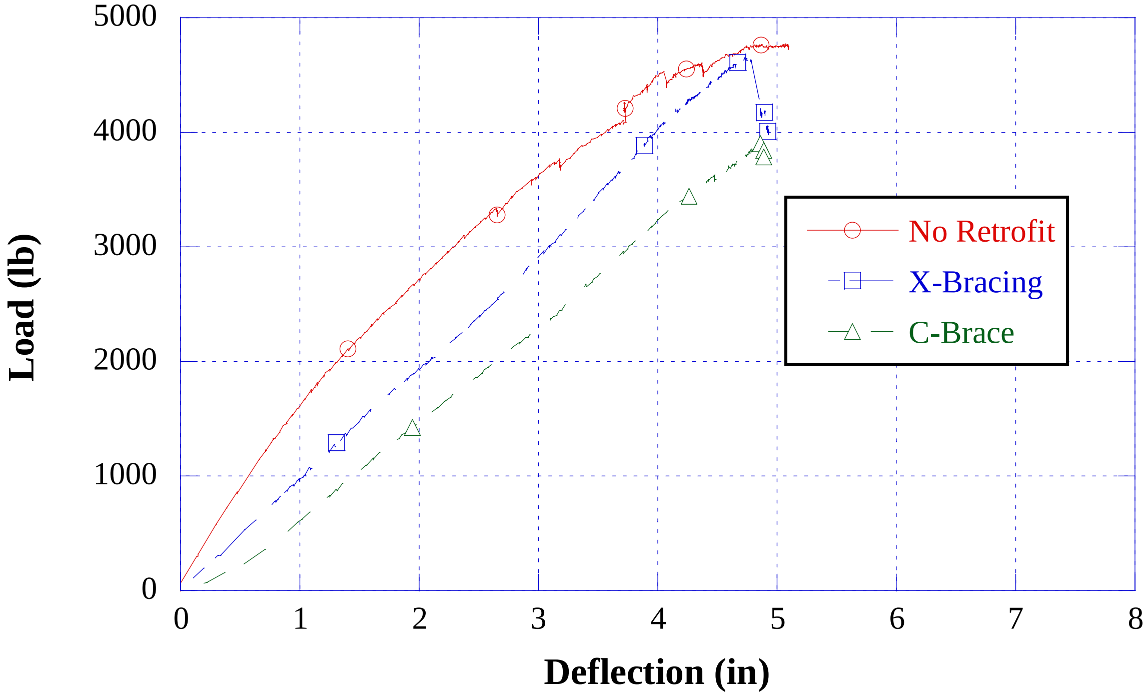


Figure 12. Load-Deflection of Test Specimen with Fully-Covered Sheathing

5.0 CONCLUTIONS

The following conclusions can be made:

1) The C brace system that is currently being added to the Florida Building Code as a prescriptive method for retrofitting the gable-end provide the best option for home owner to prevent the gable-end damage to their homes.
2) The X retrofit will does not provide sufficient strength to resist the current hurricane wind load specified by the current code and should not be recommended to the consumer.
3) The sheathing can provide lateral stability if they remain intact after a hurricane. It is recommended that the remediation methods put more focus on the fastening of the sheathing.