Critical Concepts Surrounding Deployment of ASTM E72, E564 and E2126 to Establish IRC/IBC Braced Wall Panel Design Values

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Introduction:
The International Residential Code (IRC), International Building Code (IBC) and AF&PA’s Special Design Provisions for Wind and Seismic (SDPWS) rely heavily on shear wall design values obtained from ASTM E72\(^1\) and ASTM E564\(^2\) single element testing methodology. The IRC and SDPWS design values obtained from tests using these procedures provide ultimate strength\(^3\) or the method for evaluating the shear capacity of a typical section of a framed wall. For a wall supported on a rigid foundation, load is applied in the plane of the wall along the edge opposite the rigid support and in a direction parallel to it. The objective is to determine the shear stiffness and strength of any structural light-frame wall configuration used as a shear wall on a rigid support. Sheathing variations are assessed by holding all other variables constant. The results can be used for cross-study comparisons of sheathing contribution to wall shear capacity via a shear wall test panel placed within a single braced wall line using boundary conditions that simulate the building construction within which it is placed (ASTM E564).

Issue:
While these ASTM test methods are great for comparing one sheathing product to another in a single element test setting, they were never designed to generate design values reflective of actual field (“in-situ”) conditions.

Recommendation:
Determining the true performance of wall sheathing products as braced wall panels is critical to our knowledge of building design and performance. By examining how braced wall panels perform in braced wall lines in an actual building, the industry will be able to influence more efficient value engineering in those designs.

Background & Analysis:

ICC Ad Hoc Wall Bracing (AHWB) Committee:
The ICC Ad Hoc Wall Bracing (AHWB) Committee sought to codify braced wall panel design values. It drafted a methodology using these design values to provide prescriptive braced wall applied load resistance.

“Over the past several years, both AHWB committees considered a significant amount of data toward the goal of providing a consistent rational basis for bracing of conventional wood frame homes against lateral wind loads. A white paper and test database documented much of the available wall bracing test data dating from the 1920’s to present.\(^4\) The purpose of this database was to help characterize in-plane shear performance of conventional bracing methods under various standardized test methods.

Most of the historic test data tended to rely on idealized wall segment boundary conditions whereby braced wall segments were tested using rigid or full restraint against overturning (e.g. ASTM E 72, or ASTM E 564).

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\(^1\) ASTM E72 – 05 Standard Test Methods of Conducting Strength Tests of Panels for Building Construction: [www.astm.org/Standards/E72.htm](http://www.astm.org/Standards/E72.htm)

\(^2\) ASTM E564 – 06 Standard Practice for Static Load Test for Shear Resistance of Framed Walls for Buildings: [www.astm.org/Standards/E564.htm](http://www.astm.org/Standards/E564.htm)

\(^3\) “racking loads that evaluate the performance of sheathing materials on a standard wood frame”, ASTM E72

Also considered were some more recent large scale tests by APA, Simpson Strong Tie, and NAHB Research Center. These tests departed from standard test methods by exploring braced wall panel boundary or restraint conditions representative of actual end-use conditions in real, conventional framed buildings or wall assemblies. Some of these newer tests were additionally summarized in an expanded test database during the course of deliberations5……

In general, the test data demonstrated that the performance of a 4-foot braced wall panel without any overturning restraint provided by surrounding building components or test rigging was reduced by 75% compared to the fully restrained counterpart.6

The AHWB Committee’s task posed a number of challenges. Research findings and assertions already existed with respect to the testing methods that the committee used to base its judgments upon. For example, AF&PA (creator of the Wood Frame Construction Manual and SDPWS, which is often used for braced wall panel design) effectively states that we are not exactly sure what lateral resistance is really being provided by IRC braced wall panels in a braced wall line.

Independent Evaluation of ASTM E72, E564 and E2126 to Establish IRC/IBC Braced Wall Panel Design Values:

USDA Forest Products Laboratory (FPL) reported the following about ASTM E72 and E564 testing:

"ABSTRACT: Standard methods of testing the racking capacity of light-frame walls are inefficient and may give erroneous estimates of shear wall performance. This study is concerned with improving the data base for racking resistance of light frame walls with plywood and gypsum sheathings……

ANALYSIS
The small wall test was analogous to ASTM E 72 in that sheathing types, sheathing configurations, and wall length were compared using “standard” wood frame and boundary conditions. The full-size tests (ASTM E 564) were an attempt to simulate actual wall performance……

The current ASTM E 72 test does not represent a shear wall in a structure. This study shows smaller, less expensive tests could be used instead of ASTM E 72 to predict relative ultimate racking strengths of different sheathing materials.

The alternative test method, ASTM E 564 produces results that cannot easily be compared between researchers. However, ASTM E 564 may be a better indicator of shear wall performance in a structure.

A San Jose State University research paper summed up the assessment of ASTM E72 and E564 with the following statement, which a literature review suggests is a commonly held belief:

Current test specifications such as ASTM E72 and ASTM E564 provide test procedures to determine the capacity of shear walls but do not provide guidelines for the determination of allowable shears for design purposes. ASTM E72 is intended to provide comparative data for different construction elements or structural details and ASTM E564 provides methods for the determination of shear wall strength and stiffness.

Further, FPL shear wall testing provided additional insight with respect to these concepts:

Test Procedures
The information and design tools available for the evaluation of wall racking performance are of limited value. The majority of available wall racking test data were generated using a standard test procedure published by ASTM (2). This test was established to evaluate the relative performance of sheathing materials. However, additional information is needed regarding effects of other construction variables as well as design limitations.

Construction variables include framing, windbracing, door and window openings, wall length, and wall interaction with floor and ceiling diaphragms. Design limitations should include wall stiffness or deflection as well as ultimate strength.

The test procedure used to evaluate these factors is an important consideration. Currently two ASTM standards describe test procedures for the racking resistance of lightframe walls; ASTM E 72-77 (2) and ASTM E 564-76 (1). Standard E 564 is similar to E 72 except that it was intended for testing walls rather than evaluating panel performance. For this reason, it permits variation of wall frame configuration and boundary conditions to simulate construction practice. Standard E 72, however, specifies grade and species of framing lumber, as well as frame configuration and restraint conditions (fig. A-1).

Studies sponsored by gypsum manufacturers and conducted by private testing laboratories have covered a range of 8- by 8-foot wall fastening details. These tests were conducted in accordance with ASTM Standard E 72 (2). Underwriters Laboratory tests of walls with 1/2-inch gypsum, glued both sides of 2 by 3 framing members, spaced 16 inches O.C., indicated a shear capacity of 880 lb/ft (File MH 9733). Similar tests conducted by Pittsburgh Testing Laboratory using 2 by 4 framing showed average ultimate loads of 730 lb/ft (75). Tests of 1/2-inch gypsum, nailed to one side of a 2 by 4 frame, conducted by IIT Research Institute (IITRI) gave an average of 660 lb/ft (9). Assuming that nailing gypsum to both sides of the frame would double the ultimate load, the IITRI results suggest nailed shear wall capacities exceeding 1,300 lb/ft. This exceeds test values obtained for walls with glued gypsum board. Comparison of such test results suggests a weakness in the E 72 test procedure, which makes the comparison of data collected from various laboratories confusing. Conclusions regarding the effects of variations in wall configuration should, therefore, not be drawn on the basis of results reported from different testing laboratories until a test procedure is developed which will give consistent results independent of the test location.

Most of the research on gypsum shear walls has been to determine its ability to meet code requirements for common construction. The International Conference of Building Officials (ICBO) (11) lists allowable shear loads of 75 lb/ft for 1/2-inch gypsum fastened with 5d Common nails at 7-inch spacing, and 110 lb/ft for 4-inch nail spacing. The Uniform, and Standard Building Codes (UBC (11) and SBC (18)) cite values of 100 lb/ft and 125 lb/ft, respectively, for these same conditions. If the frame is blocked, UBC and SBC values are

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9 Seismic testing of light frame shear walls, McMullen, Kurt M.1 and Merrick, Daniel Assistant Professor and Instructor, Department of Civil and Environmental Engineering, San Jose State University, San Jose, CA.
125 lb/ft and 150 lb/ft, respectively. Some members of the building trades, such as mobile home manufacturers, base the design of shear walls on these values.

In comparing minimum results reported by testing labs to the highest value permitted by the building codes, it seems the code values have a factor of safety of at least 4.4 (660/150) for gypsum. However, this is not a valid conclusion.

The E 72 test only provides a means of evaluating relative performance of various wall covering materials. Values derived from this test are not representative of the performance of walls used in actual building construction. This standard does not provide for testing effects of wall length or building component interactions. Tests are confined to one wall frame configuration.¹⁰

**SBCRI’s Goal to Test Actual Code Complying Full Scale Building Construction:**

These limitations in regard to testing and design value development constrain the use of structural building components through the deployment of accepted engineering practice. As a result, the Structural Building Components Association (SBCA) created the Structural Building Components Research Institute (SBCRI). SBCRI performs full scale testing of structures, built in full compliance with any building code, allowing for more accurate design values to be created. The goal of this testing is to increase engineering knowledge so that design can be based on the actual resistance needed to resist the load flowing through the real load path to the foundation.

Given this strong desire for load and resistance accuracy, SBCRI constructed a standard comparative equivalency test structure – a 12’x30’ single-story building, in this case built in accordance with the *IRC*. The following is a graphic depiction:

![Figure 1: Maximum Braced Wall Panel End Distance Requirements per IRC Figure 602.10.1.4(2)](image)

Braced wall panel shall be permitted to be located away from the end of a braced wall line, provided the total end distance from each end to the nearest braced wall panel does not exceed 12.5’. If braced wall panel is located at the end of the braced wall line, then end distance is 0’.

**FIGURE 1:** Maximum Braced Wall Panel End Distance Requirements per IRC Figure 602.10.1.4(2)

For SBCRI’s 3/8” WSP test, the test wall was configured as follows:
1. Length was 30’.
2. Height was 8'.

3. Due to the 16" typical wall panel stud spacing available to SBCRI at the time of this test, the first 7/8" OSB braced wall panel was installed 64" from the south end of the wall. The north end side of this braced wall line had the OSB panel set 72" from the end of the wall.

4. There was no gypsum applied anywhere to the inside of the 30' wall.

5. As defined by the IRC, there was no OSB corner return deployed, and the end walls had a single sheet of OSB in the center of the 12' wide wall on both the exterior and interior faces. This provided end wall bracing support for both the lateral and rotational restraint as lateral loading was applied (see Photo 5). The end wall, which provided minimal resistance, was built in all other cases to the IRC wall requirements for bottom plate anchorage and truss-to-top-plate connections (see Photo 6).
6. Overturning restraint was provided by sole plate anchor bolts, as prescribed by the **IRC**, and by the roof truss assembly built so that the real dead load would be applied to the wall assembly from above.

**Concepts and Conclusions:**

1. ASTM E72 and E564/E2126 are not intended to provide design values for actual structural performance, but rather are great tests to use to make direct comparisons between wall sheathing/wall coverings and/or wall panel performance.

2. If direct comparisons are made, there is a serious question about the effect that the testing facility setup can have on the results that are generated from ASTM E72 and E564/E2126.
   
   a. Testing facility boundary conditions can have a significant impact on the testing results.
   
   b. For accurate comparative results, testing should be performed at a singular testing facility.

3. No testing has been performed to define how test results generated by ASTM E72 and E564/E2126 correlate to the actual load path and load resistance performance of a code conforming full scale building.

4. The effect of these testing and design value development limitations on accepted engineering practice constrains the implementation of structural building components. As a result of these limitations, SBCRI established the Structural Building Components Research Institute (SBCRI).
a. Built in full compliance with any building code requirement, SBCRI’s full scale testing of structures can be precisely performed. This allows for the load path to be measured and the creation of more accurate resistance design values.

b. ASTM E564 requires that testing be performed so that, “Provisions shall be made to resist rigid body rotation in the plane of the wall where this reflects the use of the assembly in actual building constructions. This shall be done by application of relevant gravity or other loadings simultaneously with the racking loads. The bottom of the assembly shall be attached to the test base with anchorage connections simulating those that will be used in service. Load distribution along the top edge of the wall shall simulate floor or roof members that will be used in the actual building construction…..”

i. SBCRI exceeds ASTM E564 requirements through the use of an actual code complying building for testing.

5. SBCRI’s goal is to develop sound engineering methods so that the actual resistance needed to resist the load flowing through the real load path to the foundation can be accurately designed.

6. Given this strong desire for load and resistance accuracy and greater engineering knowledge, SBCRI constructed a standard comparative equivalency test structure – a 12'x30' single-story building. In this case, it was built in accordance with the IRC in a manner that would meet all building inspection criteria.

7. For more information, please review:
   a. SBCRI Standard Comparative Equivalency Test Structure – A 12'x30' IRC Single-Story Building
      i. Specifications for the SBCRI Standard Comparative Equivalency Test Structure
   b. Background on the Development of the IRC Braced Wall Panel Section
   c. WSP 3/4" Test – A Baseline Comparison 12'x30' Single-Story IRC Building Tested by SBCRI
   d. IRC Braced Wall Panel Design Value Comparative Equivalency Testing – IRC Design Value Calibration Factors

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11 ASTM E564 – 06 Standard Practice for Static Load Test for Shear Resistance of Framed Walls for Buildings: [www.astm.org/Standards/E564.htm](http://www.astm.org/Standards/E564.htm)