ACCEPTANCE CRITERIA FOR CYCLIC RACKING SHEAR TESTS FOR METAL-SHEATHED SHEAR WALLS WITH STEEL FRAMING

AC154

Approved March 2000

Effective April 1, 2000

(Editorially revised July 2005 and April 2008)

PREFACE

Evaluation reports issued by ICC Evaluation Service, Inc. (ICC-ES), are based upon performance features of the International family of codes and other widely adopted code families, including the Uniform Codes, the BOCA National Codes, and the SBCCI Standard Codes. Section 104.11 of the *International Building Code*® reads as follows:

> The provisions of this code are not intended to prevent the installation of any materials or to prohibit any design or method of construction not specifically prescribed by this code, provided that any such alternative has been approved. An alternative material, design or method of construction shall be approved where the building official finds that the proposed design is satisfactory and complies with the intent of the provisions of this code, and that the material, method or work offered is, for the purpose intended, at least the equivalent of that prescribed in this code in quality, strength, effectiveness, fire resistance, durability and safety.

Similar provisions are contained in the Uniform Codes, the National Codes, and the Standard Codes.

This acceptance criteria has been issued to provide all interested parties with guidelines for demonstrating compliance with performance features of the applicable code(s) referenced in the acceptance criteria. The criteria was developed and adopted following public hearings conducted by the ICC-ES Evaluation Committee, and is effective on the date shown above. All reports issued or reissued on or after the effective date must comply with this criteria, while reports issued prior to this date may be in compliance with this criteria or with the previous edition. If the criteria is an updated version from the previous edition, a solid vertical line (**I**) in the margin within the criteria indicates a technical change, addition, or deletion from the previous edition. A deletion indicator (➜) is provided in the margin where a paragraph has been deleted if the deletion involved a technical change. This criteria may be further revised as the need dictates.

ICC-ES may consider alternate criteria, provided the report applicant submits valid data demonstrating that the alternate criteria are at least equivalent to the criteria set forth in this document, and otherwise demonstrate compliance with the performance features of the codes. Notwithstanding that a product, material, or type or method of construction meets the requirements of the criteria set forth in this document, or that it can be demonstrated that valid alternate criteria are equivalent to the criteria in this document and otherwise demonstrate compliance with the performance features of the codes, ICC-ES retains the right to refuse to issue or renew an evaluation report, if the product, material, or type or method of construction is such that either unusual care with its installation or use must be exercised for satisfactory performance, or if malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use of the product, material, or type or method of construction.

Acceptance criteria are developed for use solely by ICC-ES for purposes of issuing ICC-ES evaluation reports.

ACCEPTANCE CRITERIA FOR CYCLIC RACKING SHEAR TESTS FOR METAL-SHEATHED SHEAR WALLS WITH STEEL FRAMING

1.0 INTRODUCTION

1.1 Purpose: The purpose of this acceptance criteria is to establish requirements for metal-sheathed shear walls with steel framing to be recognized in an ICC Evaluation Service, Inc. (ICC-ES), evaluation report under the 2003 *International Building Code*® (IBC), the 2003 *International Residential Code*® (IRC) and the 1997 *Uniform Building Code*™ (UBC). Bases of recognition are IBC Section 104.11, IRC Section R104.11 and UBC Section 104.2.8.

1.2 Scope: This criteria provides a basis for testing metal-sheathed shear walls consisting of metal sheathing that is attached directly to steel framing complying with Section 2209 of the IBC, Section R603 of the IRC, and/or Chapter 22, Divisions VI or VII, of the UBC. The walls are alternatives to the cold-formed steel light framed shear walls described in Section 2211 of the IBC, Section R603 of the IRC or Division VIII, Chapter 22, of the UBC. The metal-sheathed shear walls consist of a sheet metal panel and a non-wood-based sheathing that are applied to the exterior side of the metal framing.

1.3 Codes and Referenced Standards:

1.3.1 2003 *International Building Code*® (IBC), International Code Council, Inc.

1.3.2 2003 *International Residential Code*® (IRC), International Code Council, Inc.

1.3.3 1997 *Uniform Building Code*™ (UBC).

1.3.4 SEI/ASCE 7-02, Minimum Design Loads for Buildings and Other Structures, American Society of Civil Engineers (ASCE 7).

2.0 BASIC INFORMATION

2.1 General: The following information shall be submitted:

2.1.1 Shear Wall Assembly:

2.1.1.1 General: The wall assembly shall use sheathing, fasteners, connectors, and framing consistent with those intended for recognition in the evaluation report.

2.1.1.2 Material Requirements:

2.1.1.2.1 Steel Framing Members: The steel framing members shall comply with the ICC-ES Acceptance Criteria for Steel Studs, Joists and Tracks (AC46). The steel framing members used in the tests described in this criteria shall comply with the standard specified for the steel for which recognition is sought.

2.1.1.2.2 Fasteners: The standards and specifications applicable to the fasteners shall be disclosed, and the minimum structural quality of the fasteners shall be specified. Fasteners shall be properly described, including fastener type, size, length, location and edge distance. Wall assemblies shall be constructed with fasteners having approved values. Where no values are recognized by the applicable code, the fasteners shall be recognized in a current evaluation report or a national product standard, or shall otherwise be justified to the satisfaction of ICC-ES.

2.1.1.2.3 Sheet Metal Panels: The sheet metal panels shall comply with the standard specified for the product for which recognition is sought.

2.1.1.2.4 Non-wood-based Sheathing: The non-wood-based sheathing shall comply with the standard specified for the product for which recognition is sought.

2.1.2 Packaging and Identification: A description of the method of packaging and field identification of the metal-sheathed shear walls with steel framing. Identification provisions shall include the evaluation report number.

2.2 Testing Laboratories: Testing laboratories shall comply with Section 2.0 of the ICC-ES Acceptance Criteria for Test Reports (AC85) and Section 4.2 of the ICC-ES Rules of Procedure for Evaluation Reports.

2.3 Test Reports: Test reports shall comply with AC85.

2.4 Product Sampling: Sampling of the shear walls' components for tests under this criteria shall comply with Section 3.1 or 3.2 of AC85.

3.0 TEST AND PERFORMANCE REQUIREMENTS

3.1 Wall Size: The tested wall assemblies shall have aspect ratios (wall height-to-length ratios) and dimensions consistent with the intended use, and such aspect ratios shall be the maximum permitted for recognition. Tests shall be performed, at a minimum, with an aspect ratio of 1:1.

3.2 Test Procedures: Tests shall be done in accordance with Section 4.0 of this criteria.

3.3 Data Analysis:

3.3.1 The racking shear design values for the wall assemblies described in Section 4.0 may be based on the average of the test values if variation limits set forth in Section 4.3 are satisfied. Otherwise, the lowest of the test values shall be used.

3.3.2 Load values for both ASD and LRFD shall be based on the envelope curve defined by the second cycle for the input target displacements. The actual design capacities shall be determined as outlined in Section 3.3.3 or 3.3.4.

3.3.3 Allowable Stress Design (ASD):

3.3.3.1 IBC: The ASD resistance load shall be taken as the lesser of the allowable loads based on drift and the ultimate strength of the wall assembly as follows:

3.3.3.1.1 Drift: The ASD resistance load shall be determined on the basis of the requirements of ASCE 7, Sections 9.5.2.8 and 9.5.5.7.1, as follows:

3.3.3.1.1.1 The Maximum Inelastic Response Displacement δ_x shall be taken as the lesser of the code-specified allowable story drift Δ_a and the drift Δ_{USL} corresponding to the maximum strength load from the test.

3.3.3.1.1.2 Using δ_x and the C_d factor determined for the wall, the Strength Design level response displacement, δ_{xe}, shall be calculated as $\delta_{xe} = \delta_x IE/C_d$, where I_E is the seismic factor determined in accordance with

IBC Section 1616.2.

3.3.3.1.1.3 From the envelope curve defined in Section 3.3.2, the force F_s corresponding to δ_{xe} shall be determined. This force corresponds to a Strength Design factored resistance load.

3.3.3.1.1.4 In accordance with Section 2.4.1 of ASCE 7, this Strength Design factored resistance load shall be multiplied by a factor of 0.7 to determine the appropriate ASD resistance load.

3.3.3.1.1.5 The drift corresponding to the ASD resistance load shall be included in the evaluation report.

3.3.3.1.2 Ultimate Strength: From the envelope curve defined in Section 3.3.2, the ASD resistance load shall be taken as the maximum test strength of the shear wall assembly divided by a factor of safety of 2.5.

3.3.3.2 UBC: The ASD load shall be established based on the lesser of the following:

3.3.3.2.1 The lesser of the load at a wall drift that meets the requirements of UBC Section 1630.10.2, or the load defined at Δ_{ULT} (displacement corresponding to the maximum strength load) divided by 0.7R.

3.3.3.2.2 The maximum test strength of the shear wall divided by a factor of safety of 2.5 (= 1.4/0.55).

3.3.4 Load and Resistance Factor Design (LRFD):

3.3.4.1 IBC: The LRFD nominal resistance load shall be taken as the lesser of the strength load based on drift and the ultimate strength of the wall as follows:

3.3.4.1.1 Drift: The LRFD nominal resistance load shall be determined as 2.5 times the ASD resistance load defined in Section 3.3.3.1.1. The drift corresponding to the LRFD nominal resistance load shall be included in the evaluation report.

3.3.4.1.2 Ultimate Strength: The LRFD nominal resistance load shall be taken as the maximum test strength of the shear wall.

3.3.4.2 UBC: The LRFD load shall be established based on the lesser of the following:

3.3.4.2.1 The lesser of the load defined at a story drift that meets the requirements of UBC Section 1630.10.2 or 2.5 (= 1.4/0.55) times the load defined at Δ_{ULT} (displacement corresponding to the maximum strength load) divided by 0.7R.

3.3.4.2.2 The maximum test strength of the shear wall.

3.3.4.3 For the tested walls, the resistance factor (ϕ = 0.55) in Section 2211.2.1 of the IBC or Section 2219.3 of the UBC shall be applied to the LRFD values.

3.3.5 The maximum test strength of a wall shall be taken as the average of the positive and negative maximum strength loads of the second hysteretic loop of the last set of stable hysteretic load/displacement loops. The maximum strength and stable loops are defined in Sections 4.4.1.2 and 4.4.1.3, respectively.

4.0 TEST METHODS

4.1 Steel Framing Members and Sheet Metal Panels: The base-metal thickness (uncoated) of all steel framing members shall be measured and reported. Base-metal thickness is the thickness of the steel exclusive of any coating, such as galvanization.

The yield strength and ultimate tensile strength of the steel shall be measured. The measured strengths shall meet the minimum specified strengths for the particular steel grade when tested in accordance with ASTM A 370.

4.2 Test Setup and Procedure:

4.2.1 The bottom track of the wall assembly shall be attached to a fixed base in such a manner that in-plane displacement of the sheathing is not restricted.

4.2.2 The bottom track of the wall assembly shall be adequately connected to the fixed base so as to exceed the expected shear transfer requirements.

4.2.3 Holdowns shall be installed at each end of the wall assembly. The capacity of the holdowns shall exceed the anticipated maximum load of the wall assembly.

4.2.4 A loading plate connected to the wall assembly top track shall be used to distribute the applied load along the top of the wall. The loading plate shall be attached to the wall assembly in such a manner that in-plane displacement of the sheathing is not restricted.

4.2.5 Each test assembly shall be instrumented to measure the following displacements at the locations indicated:

4.2.5.1 Lateral in-plane displacement at top of wall.

4.2.5.2 Uplift and compression at each end of wall.

4.2.5.3 Base slip.

4.2.6 Applied racking loads shall be measured. Holdown load measurement is optional.

4.2.7 Test equipment shall be capable of recording hysteretic loops of the load and displacement at a minimum rate of 50 readings per cycle.

4.3 Test Procedure:

4.3.1 A minimum of two identical wall assemblies of a given construction shall be tested. If the difference between the results of the two assemblies is more than 10 percent of the lower value, one additional identical assembly shall be tested, for a total of three test assemblies. If three tests are conducted, the average of the three test results may be used if each of the three values is within 15 percent of the average.

4.3.2 The racking shear loads shall be applied to the top of the wall assembly, displacing the top of the wall in accordance with the sequential phased displacement (SPD) schedule described in Figure 1. The frequency used in the test shall be in the range of 0.2 to 1.0 cycle per second.

4.4 Cyclic Load Test Protocol:

4.4.1 Definitions:

4.4.1.1 Approximate Elastic Displacement (AED): The first significant change to occur in the applied force-drift displacement response of a monotonic test or cyclic test (per

Section 4.4.2) of the shear wall. In the monotonic test, the wall shall be displaced laterally at approximately 0.3 inch per minute to failure. In the cyclic test, a value of 0.8 inch (20.3 mm) may be assumed for the AED (per Section 4.4.2) to establish the AED for the other tests.

4.4.1.2 Maximum Strength: The point in the graphed force-displacement relationship corresponding to the peak force attained by the shear wall at the second cycle of the last stable set of hysteretic loops.

4.4.1.3 Stable Loops: A stable set of loops represents loops for which the difference in peak force between the second and fourth cycles, at a target displacement, does not exceed 10 percent of the peak force at the second cycle.

4.4.2 Overall Test Procedure: Racking shear loads shall be applied horizontally to the top of the wall along the axis of the frame, as illustrated in Figure 2. The cyclic displacement of the actuator shall be controlled to follow the cyclic displacement protocol described in Figure 1 and Table 1.

The loading procedure consists first of applying three cycles of fully-reversing displacement at each displacement increment representing 25%, 50% and 75% of AED. The wall displacement is then increased to 100% of AED for one cycle. Next, decay cycles of displacement consisting of one cycle each of 75%, 50% and 25% of maximum displacement (i.e., 100% of AED) are applied, followed by three cycles of displacement at maximum displacement (100% AED), to stabilize the force-displacement response of the wall. The next increment of increased displacement (125% of AED) is then applied, followed by similar decay and stabilization cycles. The incremental force-displacement and decay cycles shall be continued to 150%, 175%, 200%, 250%, 300%, 350%, and 400% of AED, or until the applied force diminishes to 25% of the maximum strength.

Displacements shall be continuously measured using displacement transducers having a minimum resolution of 0.005 inch (0.13 mm). Continuous measurement implies a minimum sampling rate of 50 readings per cycle. Displacement measurements will include:

(a) Horizontal displacement of the wall at the top plate.

(b) Vertical displacement (uplift and compression) of both end posts relative to the rigid base.

(c) Horizontal displacement (lateral in-plane sliding) of the bottom plate relative to the rigid base.

ACCEPTANCE CRITERIA FOR CYCLIC RACKING SHEAR TESTS FOR METAL-SHEATHED SHEAR WALLS WITH STEEL FRAMING

TABLE 1

CYCLE NO.	% AED	CYCLE NO.	% AED
0	0.0	38	200.0
1	25.0	39	150.0
2	25.0	40	100.0
3	25.0	41	50.0
4	50.0	42	200.0
5	50.0	43	200.0
6	50.0	44	200.0
7	75.0	45	250.0
8	75.0	46	187.5
9	75.0	47	125.0
10	100.0	48	62.5
11	75.0	49	250.0
12	50.0	50	250.0
13	25.0	51	250.0
14	100.0	52	300.0
15	100.0	53	225.0
16	100.0	54	150.0
17	125.0	55	75.0
18	93.8	56	300.0
19	62.5	57	300.0
20	31.3	58	300.0
21	125.0	59	350.0
22	125.0	60	262.5
23	125.0	61	175.0
24	150.0	62	87.5
25	112.5	63	350.0
26	75.0	64	350.0
27	37.5	65	350.0
28	150.0	66	350.0
29	150.0	67	350.0
30	150.0	68	350.0
31	175.0	69	400.0
32	131.3	70	300.0
33	87.5	71	200.0
34	43.8	72	100.0
35	175.0		
36	175.0		
37	175.0		

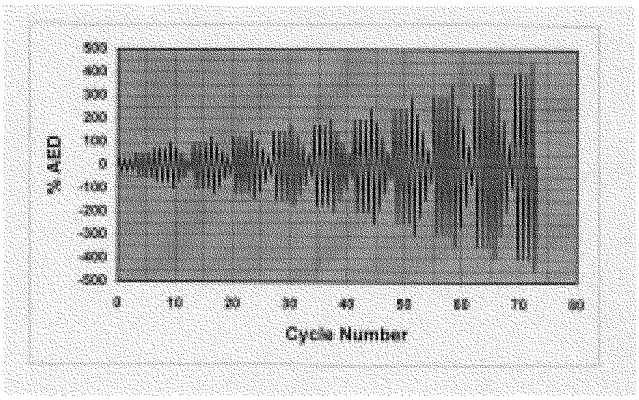

FIGURE 1

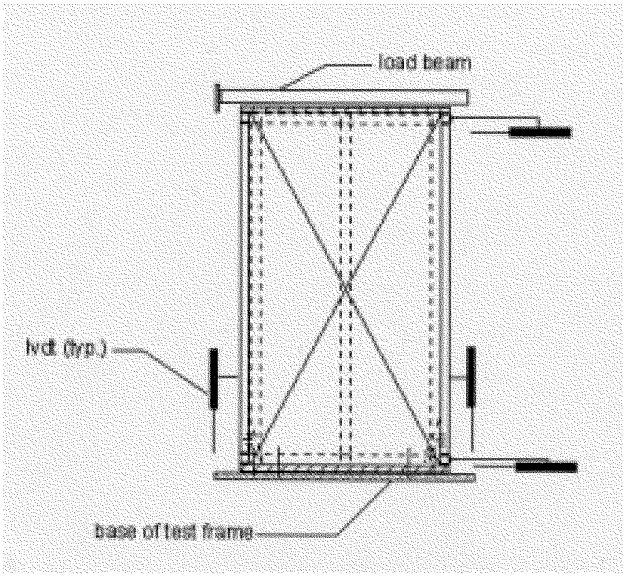

FIGURE 2