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ACCEPTANCE CRITERIA FOR CLINCHED CONNECTIONS OF COLD-FORMED STEEL STRUCTURAL MEMBERS

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PREFACE

Evaluation reports issued by the ICBO Evaluation Service, Inc. (ICBO ES), are based upon performance features of the *Uniform Building Code*™, ICBO *Uniform Mechanical Code*™ and related codes. Section 104.2.8 of the *Uniform Building Code* is the primary charging section upon which evaluation reports are issued. Section 104.2.8 reads as follows:

> The provisions of this code are not intended to prevent the use of any material, alternate design or method of construction not specifically prescribed by this code, provided any alternate has been approved and its use authorized by the building official.
>
> The building official may approve any such alternate, provided the building official finds that the proposed design is satisfactory and complies with 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 suitability, strength, effectiveness, fire resistance, durability, safety and sanitation.
>
> The building official shall require that sufficient evidence or proof be submitted to substantiate any claims that may be made regarding its use. The details of any action granting approval of an alternate shall be recorded and entered in the files of the code enforcement agency.

The attached acceptance criteria for the general code sections noted has been issued to provide all interested parties with guidelines on implementing performance features of the codes. The attached acceptance criteria was developed and adopted following public hearings conducted by the Evaluation Committee and is effective on the date shown above. All reports issued or reissued on or after this date must comply with this criteria. If the criteria is an updated version from a previous edition, solid vertical lines (▌) in the outer margin within the criteria indicate a technical change or addition from the previous edition. Deletion indicators (➧) are provided in the outer margins where a paragraph or item has been deleted if the deletion resulted from a technical change. This criteria may be revised from time to time as the need dictates.

ICBO ES may consider alternate criteria, provided the proponent submits valid data demonstrating that the alternate criteria are at least equivalent to the attached criteria and otherwise meet the applicable performance requirements of the codes. Notwithstanding that a material, type or method of construction, or equipment, meets the attached acceptance criteria, or that it can be demonstrated that valid alternate criteria are equivalent and otherwise meet the applicable performance requirements of the codes, if the material, product, system or equipment is such that either unusual care in its installation or use must be exercised for satisfactory performance, or malfunctioning is apt to cause unreasonable property damage or personal injury or sickness relative to the benefits to be achieved by the use thereof, ICBO ES retains the right to refuse to issue or renew an evaluation report.

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1.0 INTRODUCTION

1.1 Purpose: The purpose of this criteria is to establish requirements for recognition of clinched connections of cold-formed steel structural members in ICBO Evaluation Service, Inc. (ICBO ES), evaluation reports under the 1997 *Uniform Building Code*™.

1.2 Scope: Since the composition and configuration of clinched connections of cold-formed steel structural members are such that calculation of their strength and stiffness cannot be made in accordance with the code, their structural performance shall be established from the test protocol and the procedures for evaluation of data described in this criteria. The strength of proprietary clinched connections shall be determined for allowable strength design, or for load-and-resistance factor design.

Shear wall framing, using clinched connections of cold-formed steel structural members, subjected to either seismic forces or wind forces must demonstrate compliance with the cyclic racking shear test requirements for seismic forces, found in Section 5.0 of this acceptance criteria, or the racking shear test requirements for wind forces, found in Section 6.0, respectively.

The provisions in this criteria do not apply to cold-formed steel diaphragms.

1.3 References:

1.3.1 1997 *Uniform Building Code*.

1.3.2 Specification for the Design of Cold-formed Steel Structural Members, 1996, published by the American Iron and Steel Institute (AISI), 1101 17th Street, NW, Suite 1300, Washington, DC.

1.3.3 AISI Test Methods for Mechanically Fastened Cold-Formed Steel Connections (CF 92-1), February 1992.

1.3.4 ASTM A 370, Standard Test Method for Steel Sheets.

1.3.5 AC85, the ICBO ES Acceptance Criteria for Test Reports and Product Sampling.

1.4 Definitions: Clinched Connections: Clinched connections of cold-formed sheet steel are connections formed by means of special proprietary clinching tools that draw the sheets into interlocking projections. Clinched connections transmit shear or tension forces, or both, between the connected members.

2.0 BASIC INFORMATION

2.1 Description: The following information shall be provided by the evaluation report applicant:

2.1.1 Type and description of clinched connections. Description shall include dimensions of the connections, including the residual bottom thickness (ST), or either the button diameter (∅D) (for round connections) or the button width (W) (for rectangular connections) as defined in Figure 1. The configurations illustrated in Figure 1 are proprietary clinch connections using proprietary dimension labeling. Other configurations or proprietary dimensions may be considered, provided they are properly identified.

2.1.2 Type and description of the proprietary clinching tools.

2.1.3 Steel description, including material specification, yield and tensile strengths, and minimum uncoated steel thickness.

2.1.4 Method of identifying the clinched connections.

2.2 Testing Laboratories and Reports of Tests:

2.2.1 Testing Laboratories: Testing laboratories shall comply with the ICBO ES Acceptance Criteria for Laboratory Accreditation (AC89).

2.2.2 Test Reports and Test Specimen Sampling: Test reports and test specimen sampling shall comply with the ICBO ES Acceptance Criteria for Test Reports and Product Sampling (AC85). All reports of tests shall be prepared by an ICBO ES or NES recognized independent testing agency. The reports shall include a description of sampling procedures, test specimen preparation and test procedures; results of all tests; clinching tool model numbers; and photographs of specimens and test results.

3.0 MATERIAL SPECIFICATIONS

3.1 Steel: Steel used in the tests described in this criteria shall comply with the standard specified for the steel for which recognition is sought.

3.2 Complying Data: Evidence of compliance with the specified standard is provided either by analysis or tests. Submitted analysis or test results shall be in the form of test reports of tests performed by an independent testing agency.

3.3 Coupon Testing: Where the number of steel coupon specimens is not specified in the specific standard, a minimum of three, single, sheet-type coupon specimens shall be tested to demonstrate compliance with the appropriate standard and to determine the minimum uncoated steel thickness and strength of the steel sheet used in the fabrication of the connection-test specimens. Three additional tests are required if any single test yields a maximum load that differs from the mean maximum load by more than 10 percent. The tension test coupon shall be taken from a flat undamaged area of the sheet component. When the sheet component is corrugated or profiled, the tension test coupon shall be oriented parallel to the corrugations or ribs. The sheet tension tests shall be conducted in accordance with ASTM A 370, and the yield point, tensile strength, and percent elongation at fracture shall be measured. The average of the three respective test values shall be regarded as the yield point, tensile strength and elongation.

3.4 Steel Ductility: Ductility requirements shall be in accordance with Chapter 22, Division VI or VII, Section A3.3, of the 1997 *Uniform Building Code* or the AISI Specification, 1996 edition.

4.0 CONNECTION TESTING REQUIREMENTS

4.1 General: Each specific punch type and material of the clinched metal connection shall be tested in a manner representative of field installation conditions.

4.2 Load Tests:

4.2.1 Before the clinched connection specimens are tested, a minimum of three measurements shall be recorded for the following: thickness (uncoated); and the residual bottom thickness (ST), or either the button diameter (∅D) or the button width (W), depending on the shape of the connection as noted in Section 2.1.1.

4.2.2 Tension and shear testing of clinched connections shall comply with the AISI Test Method for Mechanically Fastened Cold-Formed Steel Connections (CF 92-1) document.

4.2.3 Testing shall be performed in tension and shear to determine the minimum spacing and minimum edge distances of clinched connections.

4.3 Evaluation of Test Results: Evaluation of test results shall be made on the basis of the average value from the test

data from not fewer than three identical specimens, provided the deviation of any individual test result from the average value obtained from all tests does not exceed 15 percent. If deviation from the average value exceeds 15 percent, more tests of the same kind shall be performed until the deviation of any individual test result from the average value obtained from all tests does not exceed 15 percent, or until at least three additional tests have been done. No test result shall be eliminated unless a rationale for its exclusion can be given. The average value of all tests made shall be regarded as the nominal strength, R_n, for the series of tests. The nominal strength, R_n, and the coefficient of variation, V_p, of the test results shall be determined by statistical analysis.

4.4 Calculations:

4.4.1 Allowable Stress Design: The allowable nominal strength of a clinched connection shall be calculated as follows:

$$R_a = \frac{R_n}{\Omega}$$

where:

R_a = Allowable nominal strength of the connection.

R_n = Average value of all test results.

Ω = Factor of safety to be computed as follows:

$\Omega = {}^{1.6}/_{\phi}$

where:

$$\phi = 1.65e^{-3.5\sqrt{0.0766 + C_p V_p^2}}$$

where:

e = Natural logarithmic base (2.718...).

C_p = Correction factor, either 5.7, for the number of test specimens (n) = 3

or

$\frac{\left(1 + \frac{1}{n}\right)m}{(m-2)}$, for the number of test specimens (n) ≥ 4.

where:

n = Number of tests performed.

m = Degrees of freedom, for $n - 1$.

V_p = Coefficient of variation of the test results, but not less than 6.5 percent.

4.4.2 Load-and-resistance Factor Design: The nominal strength of the clinched connection shall be calculated as follows:

$$\Sigma\gamma_i Q_i \le \phi R_n$$

where:

R_n = Average value of test results.

$\Sigma\gamma_i Q_i$ = Required strength based on the most critical load combination determined in accordance with Section A6.1.2 of the AISI Cold-formed Specification. γ_i and Q_i are load factors and load effects, respectively.

$$\phi = 1.65e^{-3.5\sqrt{0.0766 + C_p V_p^2}}$$

where:

e = Natural logarithmic base (2.718...).

C_p = Correction factor, either 5.7, for the number of test specimens (n) = 3

or

$\frac{\left(1 + \frac{1}{n}\right)m}{(m-2)}$, for the number of test specimens (n) ≥ 4.

where:

n = Number of tests performed.

m = Degrees of freedom, for $n - 1$.

V_p = Coefficient of variation of the test results, but not less than 6.5 percent.

4.4.3 Adjustments:

4.4.3.1 If the yield strength of the steel, determined in accordance with Section 3.3, from which the tested specimens are formed is greater than the specified minimum yield strength, the test results shall be adjusted down to the specified minimum yield strength of the steel the manufacturer intends to use. The adjustment shall be made by using the following ratio: F_y (specified) / F_y (actual). The test results shall not be adjusted upward if the yield strength of the test specimen is less than the minimum specified yield strength. Where tensile strength is the critical factor, similar adjustments shall be made on the basis of tensile strength instead of yield strength.

4.4.3.2 Adjustment of test results shall be made when any variation or differences exist between the design thickness and the thickness of specimens used in testing.

5.0 CYCLIC RACKING SHEAR TESTS FOR SEISMIC FORCES (optional)

5.1 General: The cyclic racking shear tests establish the basis of recognition of the steel studs-to-track clinched connection, as an alternate to the framing screws specified in Table 22-VIII-C of the code, for shear walls framed with cold-formed steel studs. In addition to testing shear walls with clinched connections, shearwalls with framing screws are also tested as control assemblies. Recognition in the evaluation report will not include use of the clinched connection method for shear wall framing subjected to seismic forces, unless compliance with Section 5.0 of this acceptance criteria is demonstrated.

5.2 Wall Assemblies:

5.2.1 General: The clinched connection wall assemblies must use the materials, connections of sheathing to framing, and framing spacing specified in Table 22-VIII-C of the code, and must use the studs-to-track clinched connection method instead of the framing-screw method. The control wall assemblies must use the identical materials, framing spacing, and connections of sheathing to framing as the clinched connection assemblies, except they must have framing-screw studs-to-track connections consistent with that specified in Table 22-VIII-C of the code.

5.2.2 Material Requirements:

5.2.2.1 Steel Framing and Track Members:

5.2.2.1.1 The steel of the clinched connection assemblies must be the same as the steel of the control assemblies.

5.2.2.1.2 The base metal (uncoated) thickness of all steel framing members must be measured. Base metal thickness is the thickness of the steel exclusive of any coating, such as galvanization. The steel framing members, studs and track shall have an uncoated base metal thickness of 0.033 inch (No. 20 gage) plus or minus 10 percent.

5.2.2.1.3 The yield and ultimate tensile strength of the steel framing members must be measured. The measured strengths must comply with ASTM A 653 SQ Grade 33, with a minimum yield strength of 33 ksi to less than 37 ksi.

5.2.2.1.4 The studs shall have a C-stud configuration of $3^1/_2$ inches (width) by $1^5/_8$ inches (flange), and a $^3/_8$-inch lip. The track shall have a channel-track $3^1/_2$ inches wide with a $1^1/_4$-inch flange (leg).

5.2.2.2 Sheathing: Plywood sheathing must be $^{15}/_{32}$-inch-thick Structural 1 and must comply with UBC Standard 23-2. OSB sheathing must be $^7/_{16}$ inch thick and must comply with UBC Standard 23-3.

5.2.2.3 Fasteners: The studs-to-track framing screws of the control assemblies shall be No. 8 by $^5/_8$-inch, wafer-head, self-drilling, steel framing screws. The studs-to-track clinched connection must be as described in Section 2.1.

The plywood and OSB sheathing connection to steel framing members shall be No. 8 by 1-inch flathead steel screws having a minimum-0.292-inch head diameter, and Type 17 point, coarse high threads.

5.2.3 Wall Size: Tested wall assemblies must be 8 feet high and 4 feet wide.

5.3 Test Setup:

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

5.3.2 The bottom track of the wall assembly must be adequately connected to the fixed base.

5.3.3 Holddowns must be installed at each end of the wall assembly.

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

5.3.5 Each test assembly must be instrumented to measure the following displacements at the noted locations:

5.3.5.1 Lateral, in-plane displacement at the top of the wall.

5.3.5.2 Uplift, at each end of the wall.

5.3.5.3 Base slip.

5.3.6 Applied loads must be measured. Holddown load measurement is optional.

5.3.7 Test equipment must be capable of recording hysteretic loops of the load and displacement.

5.4 Test Specimens and Procedure:

5.4.1 A minimum of two identical clinched connection wall assemblies must be tested for each assembly described in Table 1 for plywood and OSB facing materials.

5.4.2 A minimum of one framing-screw control wall assembly must be tested for each assembly described in Table 1 for plywood and OSB facing materials.

5.4.3 The racking shear load must be applied to the top of the wall assembly, displacing the top of the wall with the sequential phased displacement described in Figure 2, with the walls cycled at 1.5 seconds per cycle.

5.5 Data Analysis:

5.5.1 Clinched Wall Assemblies: The nominal racking shear seismic load for the clinched connection wall assemblies is the average of the nominal racking shear seismic loads (see Section 5.5.3) of the two tested wall assemblies. The nominal racking shear seismic load shall be compared to, and must be equal to or greater than, the nominal shear values of the framing-screw control wall assemblies determined in accordance with Section 5.5.2. The nominal racking shear seismic load shall be equal to or greater than the nominal shear values for seismic forces noted in Table 22-VIII-C of the code for the same construction. In addition, the average ultimate load of the test specimens at a displacement of $^1/_2$ inch must be greater than or equal to the corresponding nominal shear value for seismic forces from Table 22-VII-C of the code divided by 2.5.

5.5.2 Control Wall Assemblies: The nominal racking shear seismic load for the framing-screw control wall assemblies is the nominal racking shear seismic load (see Section 5.5.3) of the one wall test assembly. The nominal racking shear seismic load shall be compared to, and must be no greater than 10 percent greater than, the nominal shear values for seismic forces noted in Table 22-VIII-C of the code for the same construction.

5.5.3 The nominal racking shear seismic load of each wall test assembly is the average of the positive and negative loads of the lowest hysteretic loop of the last set of stable hysteretic load/displacement loops. Stable loops are defined as consecutive cycles at a given level of displacement in which the strength does not change by more than 5 percent between consecutive cycles at that displacement.

6.0 RACKING SHEAR TESTS FOR WIND FORCES (optional)

6.1 General: The racking shear tests establish the basis of recognition of the steel studs-to-track clinched connection, as an alternate to the framing screws specified in Table 22-VIII-A of the code, for shear walls framed with cold-formed steel studs. In addition to testing shear walls with clinched connections, shearwalls with framing screws are also tested as control assemblies. The clinched connection method for shear wall framing subjected to wind forces will not be included in the evaluation report, unless compliance with Section 6.0 of this acceptance criteria is demonstrated.

6.2 Wall Assemblies:

6.2.1 General: The clinched connection wall assemblies subjected to wind forces must use the materials, connections of sheathing to framing, and framing spacing specified in Table 22-VIII-A of the code, and must use the studs-to-track clinched connection method instead of the framing-screw method. The control wall assemblies must use materials, framing spacing, and connections of sheathing to framing identical to that of the clinched connection assemblies, except they must have framing-screw stud-to-track connections consistent with those specified in Table 22-VIII-A of the code.

6.2.2 Material Requirements:

6.2.2.1 Steel Framing and Track Members: See Section 5.2.2.1 for requirements.

6.2.2.2 Sheathing: See Section 5.2.2.2 for requirements.

6.2.2.3 Fasteners: See Section 5.2.2.3 for requirements.

6.2.3 Wall Size: Tested wall assemblies must be 8 feet high and 8 feet wide.

6.3 Test Setup:

6.3.1 Tests shall be performed in a setup that is in accordance with the ASTM E 72 racking load test.

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

6.3.3 The bottom track of the wall assembly must be adequately connected to the fixed base.

6.3.4 Holddowns must be installed at each end of the wall assembly.

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

6.3.6 Each test assembly must be instrumented to measure the following displacements at the noted locations:

6.3.6.1 Lateral, in-plane displacement at the top of the wall.

6.3.6.2 Uplift, at each end of the wall.

6.3.6.3 Base slip.

6.3.7 Applied loads must be measured. Holddown load measurement is optional.

6.3.8 Test equipment must be capable of recording the load and displacement.

6.4 Test Specimens and Procedure:

6.4.1 A minimum of two identical clinched connection wall assemblies must be tested for each assembly described in Table 2 for plywood and OSB facing materials.

6.4.2 A minimum of one framing-screw control wall assembly must be tested for each assembly described in Table 2 for plywood and OSB facing materials.

6.4.3 The racking shear tests must be conducted in accordance with ASTM E 72-80.

6.5 Data Analysis:

6.5.1 Clinched Wall Assemblies: The nominal shear load for the clinched connection wall assemblies is the average ultimate load of the two wall test assemblies of each test series for the specific facing material shown in Table 2. The nominal shear load for the clinched wall assemblies shall be compared to, and must be equal to or greater than, the shear values of the framing-screw control wall assemblies. The nominal shear load of the clinched wall assemblies shall be compared to, and must be equal to or exceed, the nominal shear values for wind forces noted in Table 22-VIII-A of the code for the same construction. In addition, the average ultimate load of the test specimens at a displacement of $^1/_2$ inch must be greater than or equal to the corresponding shear value from Table 22-VIII-A of the code divided by 3.0.

6.5.2 Control Wall Assemblies: The nominal shear load for wind forces of the framing-screw control wall assemblies is the nominal shear load from a single wall test of the specific specimen facing material shown in Table 2. The nominal ultimate shear loads of each control wall assembly test series shall be compared to, and must be no more than 10 percent greater than, the nominal shear values for wind forces noted in Table 22-VIII-A of the code for the same construction.

7.0 QUALITY ASSURANCE

7.1 Factory-fabricated Clinched Connections: Clinched connections shall be fabricated at facilities operated by the evaluation report applicant or by fabricators recognized by ICBO ES as evaluation report holders having an "FA" number (FA-xxx) listed in the current edition of the *Index of Evaluation Reports.* In either case, the fabricator shall, for the fabrication of clinched connections, maintain a quality control program administered by an ICBO ES or NES recognized quality control agency. The approved quality control manual shall detail the following information:

7.1.1 Sufficient detail to demonstrate that the equipment used to manufacture clinched connections is consistent with the equipment used to fabricate the specimens for the qualifying tests.

7.1.2 Internal quality control testing procedures. Testing shall be performed at regular intervals to verify acceptable performance of the on-going production of clinched connectors recognized in the evaluation report. Testing shall be performed in accordance with Section 4.0 of this criteria, at a frequency sufficient to maintain an in-house control process. Testing shall be performed in-house or by an independent testing laboratory.

7.2 Site-fabricated Clinched Connections: Site-fabricated clinched connections shall require special inspection in accordance with Section 1701.6.2 of the code. The special inspector need not be present continuously during the fabrication of clinched connections, provided the following are approved by the local building official:

7.2.1 A field quality control manual, supplied by the evaluation report applicant, is made available to the contractor and is on the jobsite at all times. The manual shall include the necessary information and test requirements to fabricate consistent clinched connections. Tabulated minimum and maximum steel thickness measurements recognized in the evaluation report for each type of punch shall be included in the field quality control manual.

7.2.2 The special inspector measures either the residual bottom thickness, or button width, or button diameter of the site-fabricated clinched connections. One out of every 100 connections shall be measured.

7.2.3 Data required in Sections 6.2.1 and 6.2.2, demonstrating that the performance of the clinched metal connections is consistent with performance recognized in the evaluation report, shall be submitted to the building official.

TABLE 1—NUMBER OF CYCLIC RACKING SHEAR TESTS FOR SEISMIC FORCES[1]

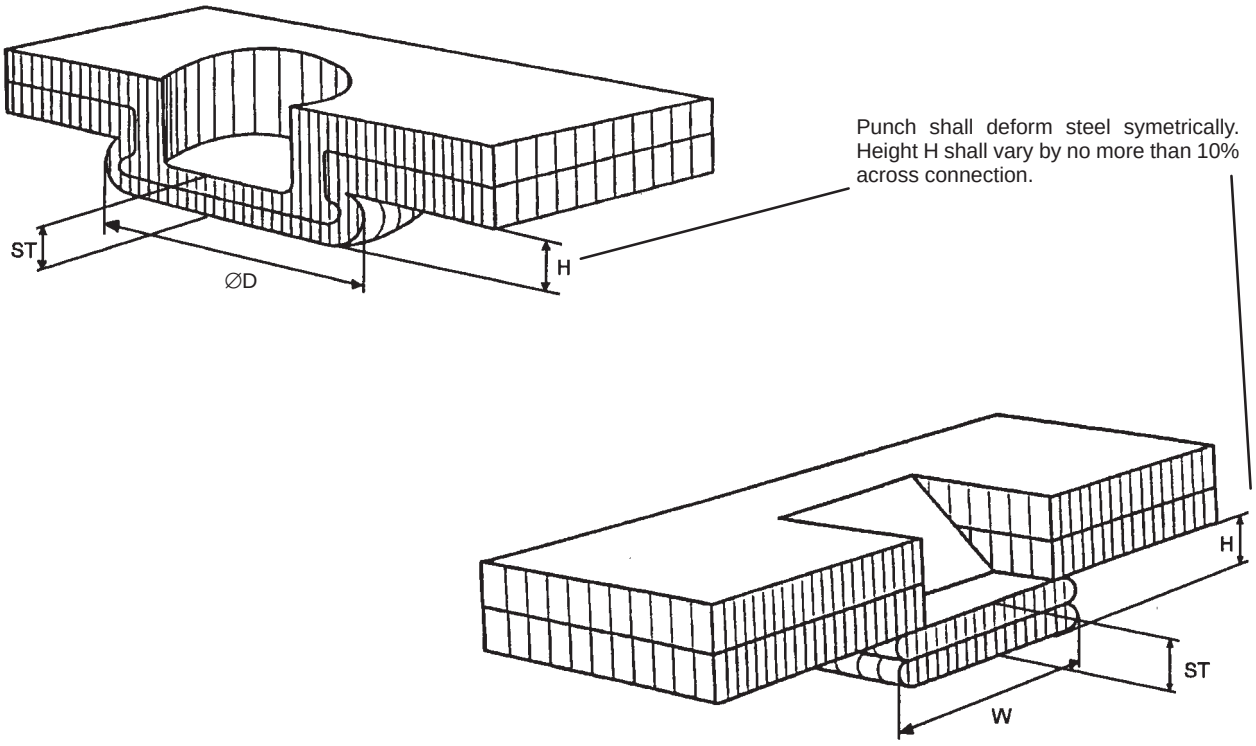
WALL DESCRIPTION	SPECIMEN FACING MATERIAL	PERIMETER SPACING AT PANEL EDGES	
		6 inches	2 inches
Clinched connection wall assemblies	Plywood	2	2
	OSB	2	2
Framing-screw control wall assemblies	Plywood	1	—
	OSB	1	—

[1]See Table 22-VIII-C of the 1997 UBC for a complete description of assemblies.

TABLE 2—NUMBER OF RACKING SHEAR TESTS FOR WIND FORCES[1]

WALL DESCRIPTION	SPECIMEN FACING MATERIAL	PERIMETER SPACING AT PANEL EDGES	
		6 inches	2 inches
Clinched connection wall assemblies	Plywood	2	—
	OSB	2	2
Framing-screw control wall assemblies	Plywood	1	—
	OSB	1	—

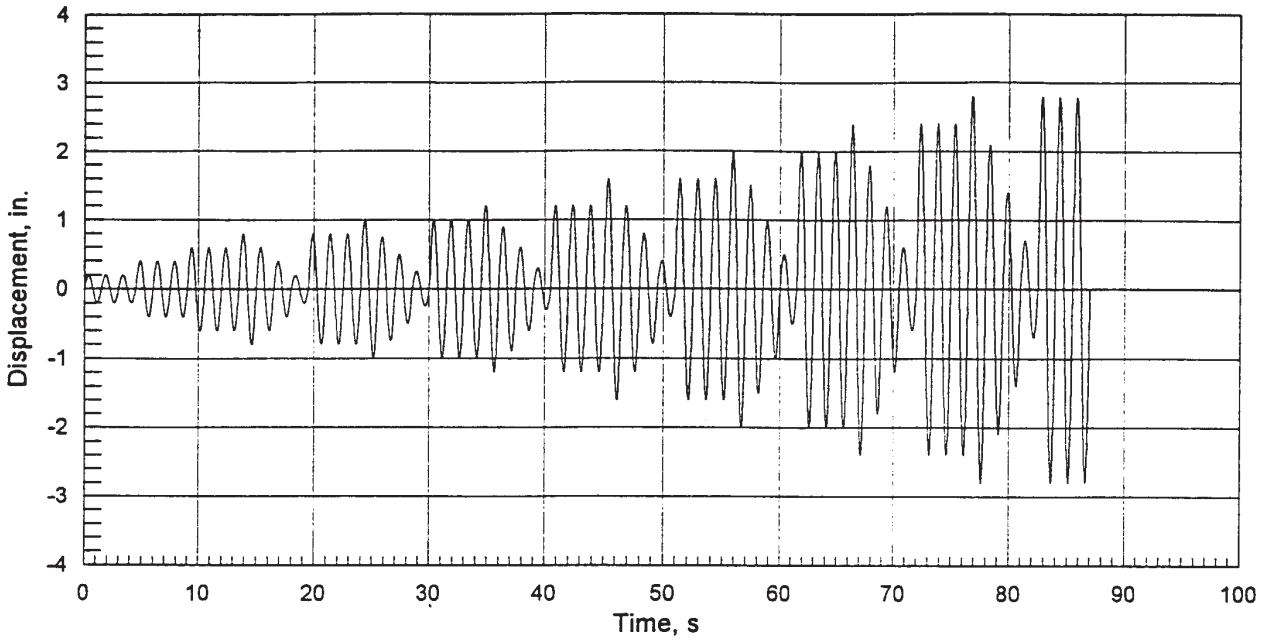
[1]See Table 22-VIII-A of the 1997 UBC for a complete description of assemblies.



where:

ST = Residual bottom thickness.
∅D = Button diameter for round connections.
W = Button width for rectangle connections.

FIGURE 1—TYPICAL CLINCHED CONNECTIONS



Displacement, in.	No. of Cycles
0.2	3
0.4	3
0.6	3
0.8	1
0.6	1
0.4	1
0.2	1
0.8	3
1	1
0.7	1
0.5	1
0.2	1
1	3
1.2	1
0.9	1
0.6	1
0.3	1
1.2	3
1.6	1
1.2	1
0.8	1

Displacement, in.	No. of Cycles
0.4	1
1.6	3
2	1
1.5	1
1	1
0.5	1
2	3
2.4	1
1.8	1
1.2	1
0.6	1
2.4	3
2.8	1
2.1	1
1.4	1
0.7	1
2.8	3

FIGURE 2—CYCLIC TEST