The material contained herein has been developed by the American Iron and Steel Institute Committee on Specifications for the Design of Cold-Formed Steel Structural Members. The organization and the Committee have made a diligent effort to present accurate, reliable, and useful information on testing of cold-formed steel members, components or structures. The Committee acknowledges and is grateful for the contributions of the numerous researchers, engineers, and others who have contributed to the body of knowledge on the subject.

With anticipated improvements in understanding of the behavior of cold-formed steel and the continuing development of new technology, this material may eventually become dated. It is anticipated that future editions of this test procedure will update this material as new information becomes available, but this cannot be guaranteed.

The materials set forth herein are for general information only. They are not a substitute for competent professional advice. Application of this information to a specific project should be reviewed by a registered professional engineer. Indeed, in most jurisdictions, such review is required by law. Anyone making use of the information set forth herein does so at their own risk and assumes any and all resulting liability arising therefrom.

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1. Scope

1.1 These performance test methods cover the determination of the strength and deformation of mechanically fastened connections for cold-formed steel building components. Connections in which the fasteners are stressed in shear (loads applied perpendicular to the shank of the fastener) and those in which the fasteners are stressed in tension (loads applied parallel to the shank of the fastener) are included. The objective is to evaluate field connections using standard test specimens and fixtures as provided in Section 8.

1.2 For circumstances in which geometric eccentricities exclude the use of the standard tests, alternative tests are permitted. Requirements for both standard tests and alternative tests are provided.

1.3 Connections of thin components (such as exterior building sheet steel) to relatively thick components (such as structural frame supports) are considered as well as connections between thin components.

1.4 Mechanical fasteners include rivets, screws, bolts, and power-actuated fasteners.

1.5 The mode of failure incurred during a test is critical and must be reported.

1.6 The subject test methods are concerned with determining the strength characteristics of connections.

1.7 The test methods are suitable for hydraulic or screw operated testing machines using force or displacement control.

2. Referenced Documents

The following documents or portions thereof are referenced within this Standard and shall be considered as part of the requirements of this document.

a. American Iron and Steel Institute (AISI), 25 Massachusetts Avenue, NW, Suite 800, Washington, DC 20001:
   S100-07 w/S2-10, North American Specification for the Design of Cold-Formed Steel Structural Members, 2007 Edition with Supplement 2

b. ASTM International, Inc, 100 Barr Harbor Drive, West Conshohocken, Pennsylvania 19428-2959:
   A370-07b, Standard Test Methods and Definitions for Mechanical Testing of Steel Products
   E6-07b, Standard Terminology Relating to Methods of Mechanical Testing

c. American Society of Mechanical Engineers (ASME), Three Park Avenue, New York, New York 10016-5990:
   ANSI/ASME B18.6.4-1999, Thread Forming and Thread Cutting Tapping Screws and Metallic Drive Screws, Inch Series
3. Terminology

Where the following terms appear in this Standard, they shall have the meaning as defined herein. Terms not defined in Section 3 of this Standard, AISI S100 or ASTM E6 shall have the ordinary accepted meaning for the context for which they are intended.

**Characteristic connection strength per fastener.** A statistically adjusted value for the mean maximum load per fastener measured for the test unit.

**Diaphragm.** Roof, floor or other membrane system that transfers in-plane forces to the lateral force resisting system.

**Gross distortion.** A failure mode where a steel sheet undergoes very large permanent deformation prior to failure at the fasteners.

**Load-deformation curve per fastener.** The load-deformation curve for the test connection with the load values divided by the number of fasteners.

**Maximum load per connection.** The maximum load recorded during a test.

**Maximum load per fastener.** The maximum connection load divided by the number of fasteners in the connection.

**(Fastener) Pull-out.** A failure mode where fasteners are pulled free from the support.

**Pull-over (or pull-through).** A failure mode where a steel sheet is pulled over the fastener head (i.e. the fastener head is pulled through the sheet steel).

**Stitch Connector.** A fastener connecting adjacent steel sheets to each other, but not connecting to the heavier frame or structural members. Also referred to as a sidelap connector.

**Structural Connector.** A fastener connecting one or more steel sheets to a heavier frame or structural member.

4. Symbols

The symbols used in this Standard shall be defined as follows:

- **A** = Elongation in a tension test
- **a** = Width of the end supports in the alternative tension tests
- **a_s** = Shear deformation or slip
- **a_t** = Deformation in a tension test
- **b** = Width of the troughs or flats in a profiled sheet
- **C** = Number of fasteners used in connector shear strength calculation
  - = 2 for test setups 1 and 2 as illustrated in Figures 1(a) and 1(b)
  - = 4 for test setup 3 as illustrated in Figure 1(c)
- **d** = Nominal diameter of a fastener
- **e_1** = End distance of a fastener in a standard test specimen
- **e_2** = Fastener gage distance in a standard test specimen
- **e_3** = Fastener edge distance in a standard test specimen
- **e_4** = Fastener edge distance in an alternative test specimen
- **F_y** = Yield stress
- **F_u** = Tensile strength
h = Height of the stiffening ribs in a profiled sheet
L_s = Free strap length in a standard shear test specimen
L_a = Test span for an alternative tension test specimen
\( \ell_g \) = Extensometer gage length in a shear test
M_u = Maximum bending moment per stiffening rib
n = Number of valid tests in a test unit
p = Fastener spacing or pitch
P = Estimated maximum connection load per fastener
P_K = Characteristic connection strength per fastener
P_m = Mean connection strength per fastener
P_{nov} = Structural connector pull-over strength for sheet to base steel
P_u = Maximum connection strength
Q_f = Structural connector strength for sheet to base steel in diaphragm
Q_s = Stitch connector strength for sheet to sheet steel in diaphragm
S_f = Structural connector flexibility for sheet to base steel in diaphragm
S_s = Stitch connector flexibility for sheet to sheet steel in diaphragm
s = Standard deviation
t = Base metal sheet thickness
u_s = Shear flexibility per fastener
u_t = Tensile (uplift) flexibility per fastener
w = Width of the shear test specimen
\( \alpha \) = Coefficient to convert the measured deflection \( \Delta_g \) to individual deflection at fastener
   = 1 for setups 1 and 3 as illustrated in Figures 1 (a) and 1(c)
   = 2 for setup 2 as illustrated in Figure 1 (b)
\( \Delta_g \) = Total elongation of extensometer gage length, \( \ell_g \), at 40 percent of \( P_u \) in a standard or alternative shear test

5. Units of Symbols and Terms

Any compatible system of measurement units is permitted to be used in this Standard, except where explicitly stated otherwise. The unit systems considered in this Standard shall include U.S. customary units (force in kips and length in inches) and SI units (force in Newtons and length in millimeters) in accordance with IEEE/ASTM-SI-10. Quantities for SI units are provided in parentheses.

6. Apparatus

6.1 The rate of loading shall be controlled, constant loads shall be maintained, and the applied load shall be measured accurately to within \( \pm 2 \) percent.

User Note:
It is recommended that any testing machine used complies with the requirements of ASTM E4-07, *Standard Practices for Force Verification of Testing Machine*. 
6.2 The test specimen support fixtures and the testing machine grips shall have the capability of maintaining a constant loading direction throughout the test.

6.3 The devices used to measure deformation shall provide an accuracy of $\pm 0.001$ in. (0.02 mm) for shear tests and $\pm 0.002$ in. (0.05 mm) for tension tests.

6.4 The devices used to measure the dimensions of the test specimens shall be accurate to within $\pm 0.0005$ in. (0.01 mm) for sheet base metal thickness, $\pm 0.05$ in. (1 mm) for sheet profile dimensions, and $\pm 0.005$ in. (0.1 mm) for fastener dimensions.

7. Test Unit

7.1 For connections that include a single cross-section, a single nominal sheet thickness, and a single nominal tensile strength for the critical connection components, a minimum of three (3) specimens shall be tested, provided the deviation of any individual test result from the average value obtained from all tests does not exceed $\pm 15$ percent. If such deviation from the average value exceeds $\pm 15$ percent, more tests of the same kind shall be made until the deviation of any individual test result from the average value obtained from all tests does not exceed $\pm 15$ percent or until at least three additional tests have been made.

7.2 For evaluations that include one connection cross-section with several nominal values for the thickness or tensile strength of the critical connection components, at least three (3) tests shall be required for each (thickness and/or strength) value. The differences necessary to define distinct nominal values for sheet thickness and tensile strength shall be at least 0.005 in. (approximately 0.1 mm) and 20 ksi (approximately 30 N/mm²), respectively.

7.3 Three (3) sheet-type tension test coupons shall be tested for each thickness and strength of steel sheet used in the fabrication of the test specimens. 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 A370 and the yield stress, tensile strength, and percent elongation at fracture shall be measured. The average of the three (3) respective test values shall be regarded as the yield stress, tensile strength, and elongation.

8. Test Specimens and Fixtures

8.1 General

8.1.1 Standard shear and tension tests shall be used whenever possible. Alternative shear and tension tests shall be permitted only when the standard tests are unsuitable for evaluating the connection properties under consideration. Standard or alternative test specimens shall be permitted to be used to conduct shear tests on specimens with a single or multiple fasteners. When such tests are conducted to study the influence of end distance or edge distance, the dimensions given in Tables 1 and 2 are permitted to be changed as required.

8.1.2 The dimensions of the test specimen components shall be measured to an accuracy of $\pm 0.0005$ in. (0.01 mm) for sheet base metal thicknesses, $\pm 0.05$ in. (1 mm) for sheet profile dimensions, and $\pm 0.005$ in. (0.1 mm) for fastener dimensions.

8.1.3 Fasteners shall be placed within $\pm 0.05$ in. (1 mm) of their specified location and affixed in accordance with the manufacturer’s recommendations or the site practice.
Special note shall be taken of the following, if applicable: (1) the diameter of pre-drilled holes, (2) the torque and depth control for threaded fasteners, and (3) the installation tools and cartridge types used for power-actuated fasteners.

8.2 Lap-Joint Shear Tests

8.2.1 Shear test deformations shall be obtained from extensometer readings across the lap joint to the accuracy as specified in Section 6.3.
(b) Setup 2

(c) Setup 3

Figure 1 – Standard Lap-Joint Shear Test, units – in. (mm)
8.2.2 The standard shear test specimen shall be a single-lap joint using two flat steel components connected with two (2) fasteners. See Figure 1(a). The test specimen setup shown in Figure 1(b) is permitted if the sheet steel components are connected to a connection plate or base steel in a field lap-joint connection. Test Setup 3, as illustrated in Figure 1(c), shall be used for applications with an edge dimension, d, greater than or equal to d and less than 2d, and where the fastener spacing, e₂, is greater than or equal to 3d. All geometrical proportions of the specimen shall be as given in Table 1, except for tests investigating special edge or spacing conditions, dimensions e₁, p, and w are permitted to be modified.

8.2.2.1 The test fixture for the standard shear test shall provide for central loading across the lap joint. See Figures 1(a) and 1(b). When the machine grips are adjustable or when the thickness of either strap is less than 1/16 in. (approximately 2 mm), packing shims shall not be required for central loading.

8.2.2.2 The extensometer gage length, \( \ell_g \) in Table 1, shall be short enough to eliminate the influence of stretch in the specimen straps on the extensometer readings.

8.2.2.3 Test setups as shown in Figures 1(a) and 1(b) are permitted for determination of strength and flexibility of structural and stitch sidetap connectors used in diaphragms when those connectors are in the bottom trough and not at elevated sidetaps.

<table>
<thead>
<tr>
<th>Fastener Diameter d, in. (mm)</th>
<th>Specimen Dimensions in., (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fastener Diameter d, in. (mm)</td>
<td>Specimen Dimensions in., (mm)</td>
</tr>
<tr>
<td>w</td>
<td>Lₕ</td>
</tr>
<tr>
<td>---</td>
<td>---</td>
</tr>
<tr>
<td>( \leq 1/4 ) (6.5)</td>
<td>2-3/8 (60)</td>
</tr>
<tr>
<td>&gt;1/4 (6.5)</td>
<td>10d (10d)</td>
</tr>
<tr>
<td>Tolerance</td>
<td>±1/16 (±2)</td>
</tr>
</tbody>
</table>

8.2.3 The alternative shear test specimen Setup 1 shall be a simulated diaphragm-action connection with central loading applied in the plane in which the overlapping elements are joined by the fasteners. See Figure 2(a). This specimen shall be used to determine the strength and flexibility of the diaphragm connection. Geometric proportions of the specimen shall be as given in Table 2, unless the field proportions of a diaphragm are to be tested.

8.2.4 The alternative shear-test specimen Setup 2 shall be a simulated diaphragm-action connection with central loading applied in a plane different from that in which the overlapping elements are joined by the fasteners. See Figure 2(b). This specimen shall be used to determine the strength and flexibility of the diaphragm connection, especially for crest-connected overlapping elements of diaphragms. Geometric proportions of the
specimen shall be as given in Table 2, unless the proportions of a diaphragm are to be
tested. Guides shall be machined and polished, then greased.

(a) Setup 1

(b) Setup 2

Figure 2 - Alternative Lap-Joint Shear Test, units - in. (mm)

User Note:
Extensometer has not been shown in Figure 2(b), Setup 2, for the clarity of the presentation. One end of the extensometer should be mounted on the top sheet and the other end mounted on the bottom sheet of the test specimen to be consistent with the setup as illustrated in Figure 2(a). Mounting should not resist shear and slip at the connection faying surface.
<table>
<thead>
<tr>
<th>Fastener Diameter d, in. (mm)</th>
<th>Specimen Dimensions, in. (mm)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>w</td>
<td>e₄</td>
</tr>
<tr>
<td>≤ 1/4 (6.5)</td>
<td>3-5/8 (92.5)</td>
<td>3/8 (10)</td>
</tr>
<tr>
<td>&gt; 1/4 (6.5)</td>
<td>3-1/4 + e₂ (82.5 + e₂)</td>
<td>1.5d (1.5d)</td>
</tr>
<tr>
<td>Tolerance</td>
<td>±1/16 (±2)</td>
<td>±1/32 (±1)</td>
</tr>
</tbody>
</table>

8.2.4.1 The alternative test fixture shall be designed such that the base plate is securely attached to a level foundation beam (or slab) and loaded in a horizontal plane using a hydraulic ram or an equivalent system. See Figure 2(b). Lubricating material shall be used to reduce the friction between guide and grips.

8.2.5 Structural and stitch sidelap connector flexibility shall be determined by measuring the displacement of the connection corresponding to 40% of the ultimate lap-joint shear capacity on the load-displacement curve (0.4Pu). Tests shall be conducted with minimum and maximum base steel thickness of the supporting member in accordance with connector application limits. Tests shall be conducted with all sheet steel and base steel thickness combinations for which the connection is intended. Test specimen strength and flexibility shall be determined in accordance with Sections 10.5 and 10.6 respectively.

8.3 Tension Tests

8.3.1 The following failure modes shall be identified when loading induces tension in the shanks of fasteners that connect steel as thin as 0.0149 in. (0.38 mm) to structural support members:
   a. pull-over
   b. pull-out
   c. gross distortion.

8.3.2 The standard tension-test specimen for pull-over strength or for pull-out strength shall be specially formed from flat sheet stock used to produce the sheet steel product under consideration. See Figure 3(a) or 3(b). The specimen geometry shall serve as a generic model for profiled sheet steel. The connection support member thickness for the pull-over test shall be at least 1/8 in. (3 mm) in order to resist fastener pull-out with a minimal amount of symmetrical deformation from the test loads. Support members for standard pull-over tests shall be in accordance with Table 3. For pull-out tests, the field total sheet steel thickness connected to the support shall be permitted to be simulated by adding pieces of packing. See Figure 3(b).

8.3.2.1 The standard tension-test fixture shall be designed for clamping of the test specimen and central loading along the axis of the fastener. See Figure 4.

8.3.2.2 The alternative tension-test fixture with a hook shall be permitted for
tension pull-out specimens. Test fixture dimensions shall be in accordance with ASTM E1190. See Figure 5.

8.3.2.3 The influence of asymmetrical deformation of the sheet steel support members on pull-over strength shall be permitted to be tested with the generic standard test specimen by using the modified standard tension-test fixture. See Figure 6. Where the supporting member rotates, such as C- or Z-shaped purlins or girts between lateral supports in metal buildings, the prying tension shall be considered.

Table 3
Standardized Support Members for Tension Pull-Over Tests

<table>
<thead>
<tr>
<th>Thickness of Support Material, in. (mm)</th>
<th>t ≥ 1/4 (6.5)</th>
<th>t &lt; 1/4 (6.5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type of Support to be Used in Practice</td>
<td>All Types</td>
<td>Hot-Rolled Sections, Cold-Formed Sections, Hollow Sections, and Sheet Steel</td>
</tr>
<tr>
<td>Standardized Support to be Used in the Tests</td>
<td>Hot-Rolled Flat Steel: 2-3/8 x t (60 x t)</td>
<td>Hot-Rolled Angle: 1-5/8 x 1-5/8 x t (40 x 40 x t)</td>
</tr>
</tbody>
</table>

Figure 3 – Standard Test Specimens

(a) Standard Pull-Over Test Specimen
units – in. (mm)

(b) Standard Pull-Out Test Specimen
units – in. (mm)
Figure 4 – Standard Tension Test Fixture

Figure 5 - Alternative Tension-Test Fixture with Hook, units – in. (mm)
User Note:
The test fixture dimension X as specified in Figure 5 should be the minimum edge distance in Table 1 in ASTM E1190. The corresponding information is extracted as follows:

<table>
<thead>
<tr>
<th>Shank Diameter in. (mm)</th>
<th>Minimum Edge Distance in Steel in. (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.100 to 0.156 (2.5 to 4.0)</td>
<td>0.5 (12)</td>
</tr>
<tr>
<td>0.157 to 0.199 (4.1 to 5.0)</td>
<td>0.5 (12)</td>
</tr>
<tr>
<td>0.200 to 0.250 (5.1 to 6.5)</td>
<td>1.0 (25)</td>
</tr>
</tbody>
</table>

Note: Shank diameter is the same as the fastener nominal diameter, d.

![Figure 6 - Modified Standard Tension – Test Fixture for Influence of Flexible Support Members, units – in. (mm)](image)

8.3.3 A specific standard tension-test specimen for pull-over strength of a profiled sheet, with width and length dimensions of 8 in. by 8 in. (200 mm by 200 mm), shall be cut from the sheet steel under consideration and drilled for four 1/2 in. (13 mm) diameter bolts located 6 in. (150 mm) apart. See Figure 7. The specimen shall be cut and drilled so that the location of the test fastener on the sheet profile corresponds to the location where the prototype has flexural tensile stresses in the region of the fastener, which will augment the tensile stresses caused by the fastener pull-over test.

8.3.3.1 The test fixture for a specific standard tension test shall consist of a stiff base plate assembly with four tapped holes located to match the holes in the test specimen. See Figure 7. The test specimen shall be clamped to the base with four 1/2 in. (12 mm) diameter bolts with 1-1/8 in. (29 mm) diameter by 3/32 in. (2.5 mm) thick washers under the bolt heads. Central loading shall be provided by a loading arm that is pin-connected to the symmetric loading channel to which the sheet steel is fastened. The loading channel shall be permitted to be fabricated from the member used in the field connection or specially fabricated in accordance with the test objectives.

8.3.3.2 A modification to the test fixture shall be required to resist excessive
deformation in thin flexible profiled sheet steel with relatively wide flat-widths. See Figure 8. Excessive deformation shall be prevented by stiffening angles attached to the base plate assembly. The angles shall be located a distance apart equal to the flat-width of test sheet steel.

Figure 7 - Specific Standard Tension – Test Specimen and Fixture, units – in. (mm)
8.3.4 The alternative tension-test specimen with a trapezoidal cross-section shall be permitted to be utilized whenever detailed information about the sheet steel deformation is required, or where the prototype has flexural tension at the fastener. See Figures 9(a) and 9(b). The specimen shall consist of a segment of the test sheet steel with a centrally located test fastener that connects to a loading channel similar to that used for the standard tension test. The length of the specimen, \( L \), shall be such that the flexural tension is at design value, and \( L \) is at least 12 times the flat-width of the corrugations, \( b \).

The width of the specimen shall be two (2) corrugations for trough fastening and three (3) corrugations for crest fastening. Transverse stiffening straps approximately 3/4 in. (20 mm) wide by 1/16 in. (2 mm) thick shall be fastened across the specimen width to ensure that the sheet profile is maintained during loading. The straps shall be located approximately \( L_a/4 \) from the mid-length of the specimen.

8.3.4.1 The test fixture shall provide for simple end supports of the test specimen. For tensile loading of a single fastener at mid-span, a loading channel shall be used. See Figure 9(c). The test specimen and the test fixture shall provide the following proportions:

1) Span \( L_a \) equal to or greater than \( 6b \), and less than \( 3M_u/P \), to prevent premature
bending failure of the test sheet,
2) Specimen sheet steel support width, a, less than $L_a/6$, and
3) Transverse stiffening straps are located at a distance $L_a/4$ from the mid-span.

**8.3.5** Where sheet steel is fastened to the support by a clip, as shown in Figure 9(d), or by a fastener near the edge of the underneath sheet so as to hide the fastener head, as shown in Figure 9(e), the test specimen shall be such that the panel lap is at the center of the width. All other specimen dimensions shall meet the requirements of Section 8.3.4. The test fixture requirements at stiffeners and sheet steel supports shall be the same as in Section 8.3.4.1.

![Diagram](image-url)

**Figure 9 - Alternative Tension - Test Specimen and Fixture**

**8.3.6** A large-scale tension test capable of full-scale prototype testing of sheet steel connections shall be permitted to be conducted. See Figure 10. The test panel shall
contain two beams (purlins or girts, or similar). The test panel shall be uniformly loaded over its surface by regulating the air pressure inside the chamber below the panel.

![Diagram of Large-Scale Tension Test]

**Figure 10 – Large-Scale Tension Test**

9. **Test Procedures**

9.1 **General**

9.1.1 The speed of testing shall not be greater than that at which the relative displacement readings can be accurately taken. End grips of the testing machine shall be in alignment with the axis of the specimen test fixtures during loading.

9.1.2 When manual controlled tests are performed without computerized crosshead rate control and without a computer-based data acquisition system, loading shall be applied in load increments of approximately one-fifth of the estimated maximum load. When the maximum estimated load is approached, smaller increments shall be used. Each load increment shall be maintained for at least one minute (or until it has stabilized) before proceeding with the next increment. Loading shall continue until the load cannot be maintained, or until one or more fasteners have failed.

9.1.3 When a computerized test system is used with crosshead rate control capacity and data acquisition capability, the speed of testing as determined by the rate of separation of the testing-machine heads shall be 0.10 in. (approximately 3 mm) per minute or the rate caused by a loading rate of 500 pounds (2 kN) per minute.

9.2 **Shear Tests**

9.2.1 The speed of testing shall conform to Section 9.1.2 or 9.1.3, depending on the type of test system in use. For structural and stitch sidelap diaphragm connectors, once the ultimate lap shear capacity of the test specimen has been reached, the deformation or slip measurements corresponding to 40% of the ultimate lap shear capacity shall be measured on the load-displacement curve.
9.2.2 The failure mode(s) shall be identified and recorded in accordance with the following classifications:

Type I - End failure, or longitudinal shearing of the sheet along two approximately parallel lines (Figure 11(a)).
Type II - Bearing tearing, or piling up of the thinner, or of both (equal thickness), sheet material in front of the fastener (Figure 11(b)).
Type III - Tension failure of one sheet in the net section (Figure 11(c)).
Type IV - Shearing of the fastener (Figure 11(d)).
Type V - Tilting and pull-out of fastener, including sheet pull-over (Figure 11(e)).

Figure 11 shows only one (1) fastener, but the model shall also be applicable for two (2) or more fasteners.
9.3 Tension Tests

9.3.1 The speed of testing shall conform to Section 9.1.1 or 9.1.2, depending on the type of test system in use.

9.3.2 When deformation measurements are necessary, they shall be recorded at each loading increment and at the maximum load. If permanent-set measurements are necessary, a small preload (approximately 10 percent of the anticipated maximum load) shall be permitted to be used. After each loading increment, the load shall be reduced to the preload and the permanent set shall be recorded.

10. Calculations

Calculations to evaluate the test results and to determine the characteristic connection strength shall be made in accordance with Section F1 of AISI S100.

For diaphragm design, the strength and the stiffness/flexibility shall be calculated in accordance with 10.1 to 10.6.

10.1 Structural connector shear strength, Qf, stitch sidelap connector shear strength, Qs and structural connector pull-over strength, Pnov shall be determined in accordance with F1.1 of AISI S100.

10.2 When tests include a range of variables, it shall be permitted to calibrate an equation for calculating the strengths of Qf, Qs, and Pnov. The calibration shall be in accordance with F1.1 of AISI S100.

10.3 Safety factor (Ω) determined shall be less than or equal to and the resistance factor (ϕ) determined shall be greater than or equal to those presented in AISI S100 Table D5. Otherwise, full-scale testing of the diaphragm system shall be required.

10.4 When tests include a range of variables, it shall be permitted to calibrate an equation for calculating the structural connector flexibility, Sf, and stitch sidelap connector flexibility, Ss. Calibration of the equation or the characteristic flexibility per fastener shall be permitted. The coefficient of variation (Vp) of the test results shall be less than those of the full-scale diaphragm system stiffness tests used to confirm an analytical design.

10.5 Using standard shear test (Figure 1), test specimen strength shall be determined as:

\[
Q_f = \frac{P_u}{C} \quad (1)
\]

where

\[
Q_f, Q_s = \text{Structural or stitch sidelap connector strength for sheet steel to base steel or sheet steel to sheet steel in diaphragms, respectively}
\]

\[
P_u = \text{Maximum connection strength}
\]

\[
C = 2 \text{ for Test Setups 1 and 2 as illustrated in Figures 1(a) and 1(b)}
\]

\[
C = 4 \text{ for Test Setup 3 as illustrated in Figure 1(c)}
\]

10.6 Using standard shear test (Figure 1), test specimen flexibility shall be determined as:

\[
S_f = \frac{\Delta g}{(\alpha)(0.4Q_f)} \quad (2a)
\]

\[
S_s = \frac{\Delta g}{(\alpha)(0.4Q_s)} \quad (2b)
\]
where
\[ S_f = \text{Structural connector flexibility for sheet to base steel in diaphragm} \]
\[ S_s = \text{Stitch connector flexibility for sheet to sheet steel in diaphragm} \]
\[ \Delta g = \text{Total elongation of extensometer gage length } \ell_g \text{ at 40 percent of } P_u \]
\[ \alpha = \text{Coefficient to convert the measured deflection } \Delta g \text{ to individual deflection at fastener} \]
\[ = 1 \text{ for Test Setups 1 and 3 as illustrated in Figures 1(a) and 1(c)} \]
\[ = 2 \text{ for Test Setup 2 as illustrated in Figure 1(b)} \]
\[ Q_f = \text{Structural connector strength for sheet to base steel in diaphragm} \]
\[ Q_s = \text{Stitch connector strength for sheet to sheet steel in diaphragm} \]

11. Test Report

11.1 The objectives of the test series shall be stated at the outset of the report so that the necessary test results, such as the maximum load per fastener, the flexibility of the connection, and the failure mode, are identified.

11.2 The type of tests, the testing organization, and the dates on which the tests were conducted shall be included in the documentation.

11.3 The test unit shall be fully documented, including:

1) The measured dimensions of each specimen,

2) Identification data for the fasteners and accessories such as washers. Fastener data shall include the name of the manufacturer, designation or type, dimensions, number of threads (including unthreaded length or imperfect threads below head), and the major and minor diameters in the threaded region.

3) The details of fastener application including pre-drilling, tightening torque, and any unique tools used in the operation, and

4) The results of the sheet-type tension tests including yield stress, tensile strength, and elongation to failure. The location and orientation of the sheet-tension coupons shall also be given.

For pull-out tests, additional data shall indicate the drill-point diameter and length of flutes if self-drilling screws are used. Otherwise, the diameter of the pilot drill used shall be stated. Washers or washer-head data shall include diameter, thickness, configuration, and material. Sealing washers shall additionally define the type, material, and dimensions of the sealant.

11.4 The test set-up shall be fully described including the testing machine, the specimen end grips or supports, and the devices used to measure deformation.

11.5 The test procedure shall be fully documented, including the rate of loading and the load increments.

11.6 In accordance with the test objectives stated by the responsible engineer, the report shall include a complete documentation of all applicable test results for each specimen such as the load-deformation curve, the maximum load, and the mode of failure. The report shall also include the necessary calculations for the characteristic connection strength per fastener and the connection flexibility for the test unit. Calculations for reduction of the test strength (corresponding to the specified minimum yield stress of the steel sheet product) shall also be included when applicable.
Commentary on AISI S905-08 w/S1-11

Test Methods for Mechanically Fastened Cold-Formed Steel Connections

The continued introduction of new and different mechanical fasteners increases the need for standardized tests for cold-formed steel connections. Standard test specimens, fixtures, and procedures facilitate the exchange of information vital to understanding the behavior of a variety of fasteners with diverse properties by providing a basis for comparing strength and deformation measurements. This test standard provides shear and tension performance test procedures for determining the strength and deformation of mechanically fastened connections of cold-formed steel members, including diaphragm applications. Connections involving gypsum wallboard, wood and Oriented Strand Board (OSB) are outside the scope of this test method. These test methods provide the requirements for evaluating mechanically fastened connections for cold-formed steel members in buildings designed according to AISI S100 (2010) and related building codes. These performance test procedures are based extensively on test methods used successfully in the past (References 2 to 4).

The failure modes that can be identified by this test procedure include: end shearing failure (Figure 11(a)); bearing, tearing and piling up (Figure 11(b)); tension failure on net section (Figure 11(c)); shearing of fastener (Figure 11(d)); and tension failure of fastener through tilting, pull-over and pull-out (Figure 11(e)). It is critical to properly identify the failure modes during the tests. Practically, certain failure modes may prohibit the use of a connection regardless of its strength.

Standard and alternative test setups of specimens and fixtures are provided in Standard Section 8 for lap-joint shear and tension tests. Test procedures and data recording are generally not affected by the modified specimens and fixtures used for alternate tests, but these alternate tests represent the state-of-the-art with respect to mechanical fastener testing.

The standard tension-test fixture described in Standard Section 8.3.2.1 is designed for the convenience of clamping the test specimen and centering the load along the axis of the fastener.

The dimensions of the asymmetrical support member as shown in Figure 6 of the Standard simulate mechanical fastenings to cold-formed C-Sections, Z-Sections and angles. References 5 and 10 provide information on how prying tension is considered.

For the full-scale prototype test as shown in Figure 10 of the Standard, failure can occur in the panel connections to the beams. Only the nominal tension forces, which do not include the prying forces caused by the rotations of the C- and Z-shaped purlins or girts, can be computed from the known value of the load acting on the panel surface at failure. A description of prying forces is given in Reference 10. The arrangement illustrated in Figure 9 is fully described in References 3, 5, 6, and 7. The beam span and the purlin spacing should match those of the prototype of Reference 10 within ±20 percent in order to properly simulate the effects of prying action.

Calculations to evaluate the test results and to determine the characteristic connection strength should be made in accordance with F1 of AISI S100 (2010). The test result evaluation described in the Standard is based on procedures provided in References 8 and 9.
Standard Equations (2a) and (2b) for determining the test specimen flexibility are developed based on Reference 11.

The determination of the individual fastener lap-joint shear strength is independent of which test setup is used. The Test Setups 1 and 2 in Figure 1 with two and four fasteners are essentially the same. The two fastener setup (shown in Figure 1(a)) has one base steel component and one sheet steel component. The four fastener setup (shown in Figure 1(b)) uses two base steel components with one sheet steel component bridging across both base steel components. These two different test setups are the same from a load distribution standpoint, with the four fastener test specimen offering fabrication and test specimen efficiency. The individual fastener lap-joint shear strength is the total connection strength divided by two in either case. Test Setup 3 (as shown in Figure 1(c)) was added to cover the geometric condition of an application having a small edge dimension. This test setup permits the edge dimension to be less than the one provided in Table 1, but the total width of the specimen is still required to satisfy the dimension given in Table 1. Edge dimension of $2d$ is set to assist the user in determining when Test Setup 3 is to be used. Test Setup 3 should not be used for determining the design strength of interior fasteners.

The determination of the individual fastener lap-joint shear flexibility, however, is dependent on which test setup is used.

In 2011, Section 7.1 was revised to be consistent with AISI S100 Section F1.1(a) with respect to the required number of test specimens.

References

5. LaBoube, R.A.; Golovin, M.; Montague, D.J.; Perry, D.C.; and Wilson, L.L., “Behavior of Continuous Span Purlin Systems,” Proceedings of the Ninth International Specialty Conference on Cold-Formed Steel Structures, St. Louis, MO, November, 1988, University of Missouri-Rolla.
8. Pekoz, T., and Hall, B., “Probabilistic Evaluation of Test Results,” *Proceedings of the Ninth International Specialty Conference on Cold-Formed Steel Structures*, St. Louis, MO, November, 1988, University of Missouri-Rolla.


