AMERICAN NATIONAL STANDARDS INSTITUTE/ STEEL DECK INSTITUTE

ANSI/SDI AISI S901-2017 (R2024)

Test Standard for Determining the Rotational-Lateral Stiffness of Beam-to-Panel Assemblies

Approved American National Standard

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First Printing, December 2024

PREFACE

(This Preface is not part of the ANSI/SDI AISI S901-2017 (R2024), *Test Standard for Determining the Rotational-Lateral Stiffness of Beam-to-Panel Assemblies*, but is included for informational purposes only.)

This Standard is a reaffirmation of ANSI/AISI S901-2017.

This Standard has been developed as a consensus document for the design of cold-formed steel members and structures. The intention is to provide criteria for routine use and not to provide specific criteria for infrequently encountered problems, which occur in the full range of structural design. The Symbols and Appendices to this Standard are an integral part of the Standard. A non-mandatory Commentary has been prepared to provide background for the Standard provisions and the user is encouraged to consult it. Additionally, non-mandatory User Notes may be interspersed throughout the Standard to provide concise and practical guidance in the application of the provisions. The user is cautioned that professional judgment must be exercised when data or recommendations in the Standard are applied, as described more fully in the disclaimer notice preceding this Preface.

AISI S901-17

American Iron and Steel Institute

AISI STANDARD

Test Standard for Determining the Rotational-Lateral Stiffness of Beam-to-Panel Assemblies

2017 Edition

Approved by
the AISI Committee on Specifications for the Design of
Cold-Formed Steel Structural Members

The material contained herein has been developed by the American Iron and Steel Institute (AISI) 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 will 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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PREFACE

The American Iron and Steel Institute Committee on Specifications developed this Standard to provide test methods for determining the rotational-lateral stiffness of beam-to-*panel* assemblies.

The Committee acknowledges and is grateful for the contribution of the numerous engineers, researchers, producers and others who have contributed to the body of knowledge on this subject.

User Notes are non-mandatory and copyrightable portions of this Standard.

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AISI S901-17
TEST STANDARD FOR DETERMINING THE ROTATIONAL-LATERAL STIFFNESS OF BEAM-TO-PANEL ASSEMBLIES

1. Scope

1.1 The purpose of this Standard is to determine the rotational-lateral stiffness of *beam*-to-*panel* assemblies.

1.2 This Standard applies to structural *subassemblies* consisting of *panel*, *beam*, and joint components, or of the joint between a wall, floor, ceiling, or roof *panel* and the supporting *beam* (purlin, girt, joist, stud, etc.).

1.3 This Standard is also used to establish a limit of the displacements for avoiding joint failure.

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), Washington, DC:

S100-16, *North American Specification for the Design of Cold-Formed Steel Structural Members*

b. ASTM International (ASTM), West Conshohocken, PA:

A370-16, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*

E6-15, *Standard Terminology Relating to Methods of Mechanical Testing*

IEEE/ASTM SI10-10, *American National Standard for Metric Practice*

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.

Subassembly. A representative portion of a larger structural assembly consisting of a wall, floor, ceiling, or roof *panel* with one *beam* connected to the *panel* either continuously or at regular intervals. See Figure 1.

Panel. *Panel* used in the *subassembly*, which is made of any structural material. See Figure 1.

Beam. A beam that has either an open or closed cross-section. One flange of the beam is connected to the *panel*, and is called the "attached" flange. The other is the "unattached" flange. See Figure 1.

Joint or Connection. A local area around a mechanical fastener, weld, or adhesively bonded area that connects the *beam* with the *panel*. The local area also includes filler material such as insulation located between the *panel* and the *beam* flange.

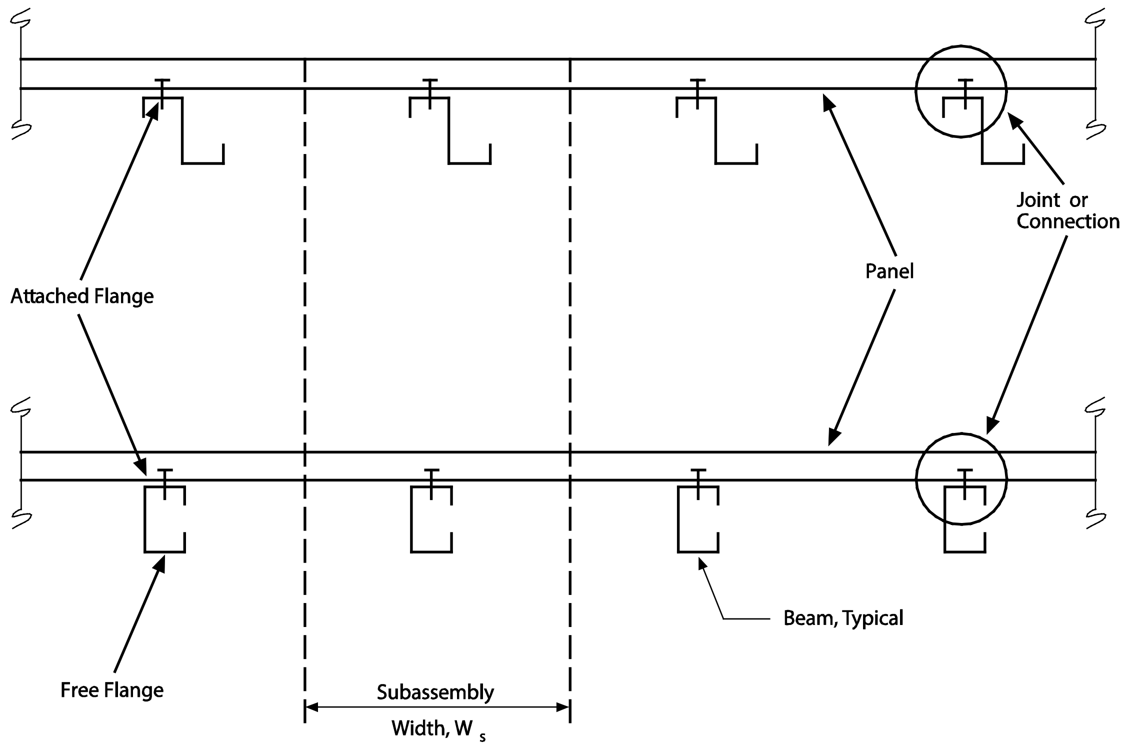

Figure 1 - Wall, Floor, Ceiling or Roof Assembly

Lateral Load. Total load, P, in kips (kN), applied to the unattached flange of the *beam* in a plane parallel to that of the original *panel* position. See Figure 2.

Lateral Deflection. Lateral displacement, D, in inches (mm), of the unattached flange due to the *lateral load*, P. See Figure 2.

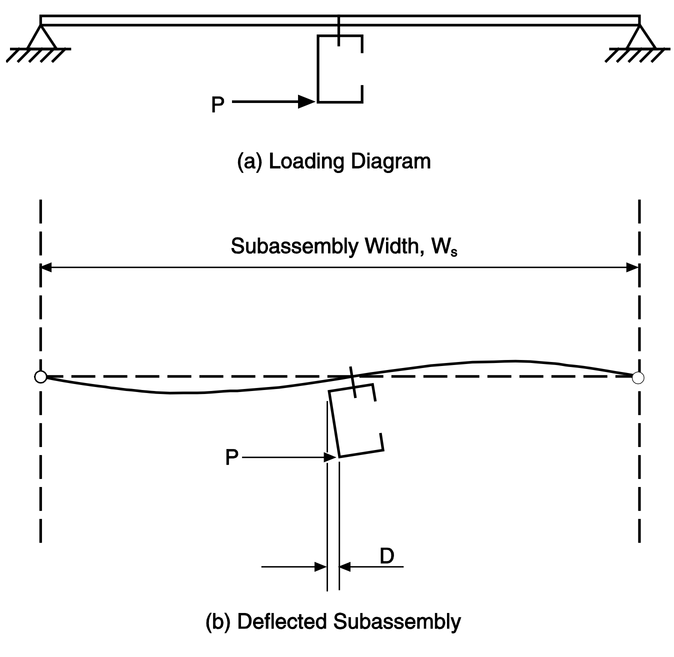

Figure 2 - Loaded and Deflected Subassembly

Rotational-Lateral Stiffness. Total *lateral load* applied on the unattached flange of the test *beam*, divided by the length dimension of the *beam*, L_B (Figure 3b), and divided by the *lateral deflection* of the unattached flange of the *beam* at that load level.

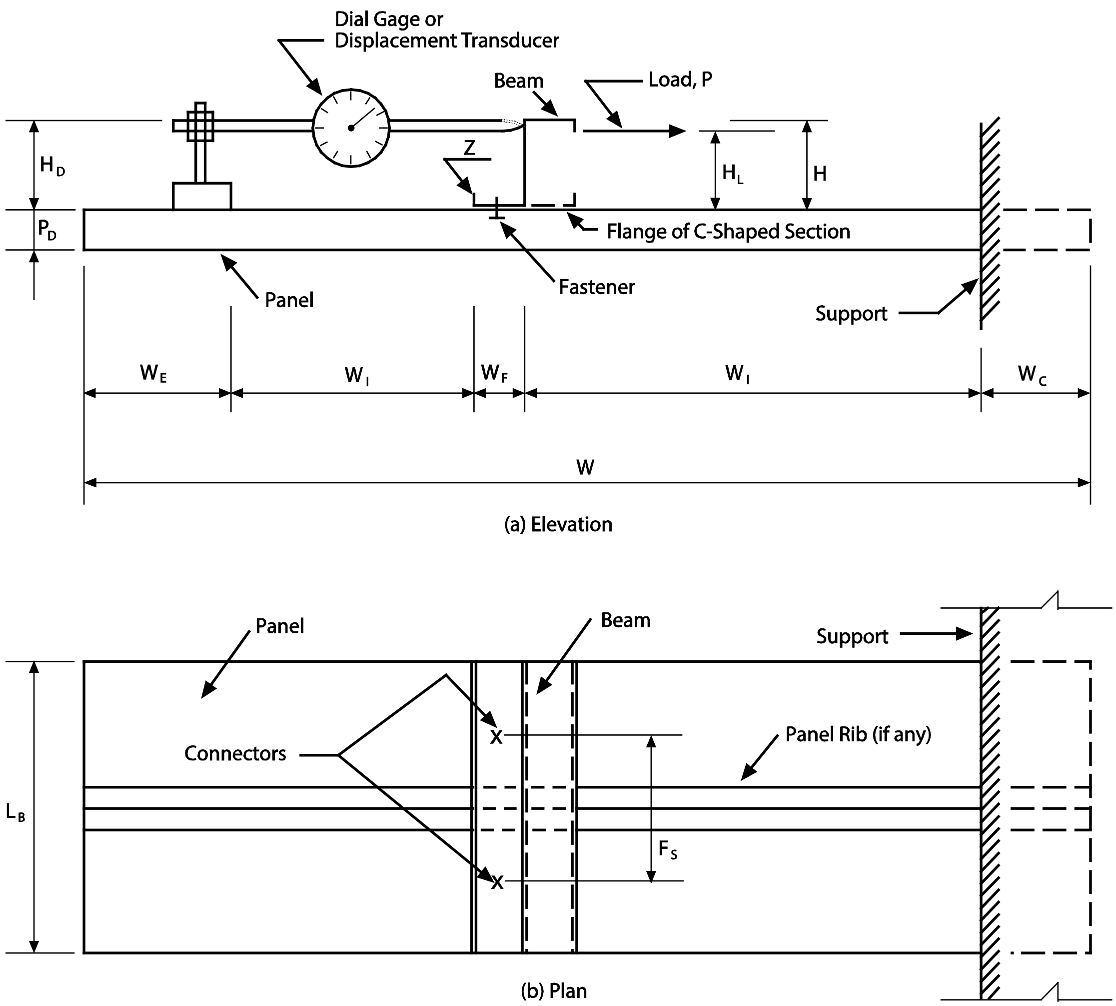

Figure 3 - Test Specimen and Horizontal Test Setup

4. Symbols

D = Lateral displacement

D_c = Lateral displacement of unattached flange of the *beam*

D_N = Displacement at point N on the load-displacement curve

D_{NL} = Desired maximum lateral displacement limit

D_u = Displacement corresponding to ultimate load, P_u, or ultimate displacement

E = Modulus of elasticity

F_S = Connector spacing along flange of *beam*. See Figure 3b.

H = Overall *beam* height. See Figure 3a.

H_D = Deflection-measuring device height measured from the top of the test *panel*. See Figure 3a.

H_L = Height where load is applied. See Figure 3a.

I = Effective moment of inertia of *panel* cross-section

K = *Rotational-lateral stiffness*

K_a = *Beam* stiffness

K_b = Stiffness of *beam*-to-*panel connection*

K_c = Bending stiffness of *panel*

K_N = Nominal test stiffness

K_t = Test stiffness

L_B = Length dimension of *beam*. See Figure 3b.

N = Designation of a special point on load-displacement curve which is used to determine the nominal test stiffness

P = Total *lateral load* applied to unattached flange

P_D = Overall *panel* depth. See Figure 3a.

P_N = Load at point N on the load-displacement curve

P_u = Ultimate load

W = Overall *panel* width. See Figure 3a.

W_C = *Panel* embedded distance in the support. See Figure 3a.

W_E = End dimension of test *panel*. See Figure 3a.

W_F = Overall width of attached *beam*. See Figure 3a.

W_I = Clear distance between deflection-measuring device support and specimen support. See Figure 3a.

W_s = Width of *subassembly*. See Figure 1.

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 SI10.

6. Measurement Precision

6.1 Loads shall be recorded to a precision of ±1 percent of the full range of the measuring device.

User Note:

The capacity (range) of the load-measuring device should be appropriate to the expected maximum tested load. The use of a measuring device with a calibrated capacity greatly exceeding the anticipated load is inappropriate. A target ratio of the load-measuring device capacity to specimen strength of no greater than three is recommended.

The tests should be conducted on a testing machine that complies with the requirements of ASTM E4-16, *Standard Practices for Force Verification of Testing Machines*.

6.2 Deflections shall be recorded to a precision of 0.001 in. (0.025 mm).

7. Materials

7.1 Components of the test specimen(s) shall be measured for test analysis and records, and the component suppliers shall be identified.

7.2 Physical and material properties of the *panel* and *beam* shall be determined in accordance with AISI S100, ASTM A370, or other applicable standards.

8. Test Specimen

8.1 The overall *panel* width, W (Figure 3), of the specimen shall be such that the deflection-measuring device support and the specimen support are each separated from the *beam* by a distance, W_I, not less than the largest of the following distances: (a) 1.5 times the overall *panel* depth P_D, (b) the overall width of the attached *beam* flange, W_F, and (c) the connector spacing along the flange of the *beam*, F_S. For ribbed *panels*, W_I shall also exceed two times the width of the attached flat of the *panel*.

8.2 The clamped width of the specimen, W_C, shall be at least equal to two times the *panel* depth, but not less than 2 in. (50.8 mm).

8.3 The end dimension, W_E, shall be long enough to attach a deflection-measuring device or an extensometer to the end of the *panel*.

8.4 The minimum overall *panel* width shall be equal to:

$$W = W_E + 2W_I + W_F + W_C \tag{1}$$

8.5 The minimum *beam* and *panel* length, L_B, of the test specimen shall not be less than the larger of: (a) two times the maximum connector spacing, F_S, used in field installations, or (b) the nominal coverage width of the *panel*. The specimen shall contain at least two fasteners in each line of *connections* along the *beam*.

8.6 Each specimen shall be assembled under the supervision of a representative of the testing laboratory, either at the manufacturer's facilities or at the testing laboratory.

8.7 Each specimen shall be assembled from new material (i.e., materials not used in previous test specimens) and in accordance with manufacturer's specifications.

8.8 The fabrication and field installation procedures specified for the overall assembly, and the tools used, shall also be used in the specimen construction.

8.9 Drilled or punched pilot holes in the *panels* or *beams* shall be the same as those used in field installations.

9. Test Setup

9.1 The test specimens are permitted to be tested in a horizontal or vertical position. See Figure 3 and Figure 4, respectively. The zero-load readings of the deflection-measuring device(s) shall be recorded.

9.2 The clamped end of the *panel* shall be the only support of the test specimen.

9.3 Where the test specimen includes a hollow-core, corrugated, or trapezoidal *panel*, voids of the clamped regions shall be filled with filler materials such as wood, gypsum, or similar filler materials to ensure that the clamped overall depth of the *panel* is maintained.

For foam-filled sandwich *panels*, if necessary, the filler material over the distance, W_C, is permitted to be replaced with wood, gypsum, or similar filler materials.

9.4 Loads applied to the unattached flange shall be introduced at the extreme fiber of the *beam*, or at the intersection of the outer faces of the unattached flange and the web.

9.5 If the *beam* does not have a flat face perpendicular to the *panel* at the locations where the load is to be applied and the lateral displacement is to be measured, brackets shall be mechanically attached to the *beam* web to provide a flat surface. Figure 5 shows a typical application of a load bracket or deflection-measuring device bracket. The attachment of either bracket shall be accomplished such that the bracket does not stiffen the *beam* or reduce its distortion.

9.6 The total *lateral load* applied, P, shall be distributed over several locations, if necessary, to reduce variations in the *lateral deflection* along the length of the unattached flange.

9.7 The load application shall be accomplished by chain or wire. The direction of the applied load shall remain parallel to the original plane of the *panel*. See Figure 5.

9.8 One or more deflection-measuring device shall be used to measure the lateral displacements during loading. The gages shall be arranged symmetrically about the mid-width point, and have graduations at not greater than 0.001 in. (0.0254 mm) intervals.

10. Test Procedure

10.1 The deflection-measuring device height, H_D, and load height, H_L, as shown in Figure 3, shall be adjusted such that they are equal to or as close as possible to the overall *beam* depth, H. Prior to loading the test specimen, the dimensions, H_D and H_L, and the dial-gage readings shall be recorded.

10.2 No preload shall be used. The load shall be applied in a direction that is for the intended use of the system.

10.3 The applied load shall be increased in five or more equal increments to the maximum expected value, in order to produce deflection increments of not more than five (5) percent of the *beam* depth.

10.4 If the specimen includes fiberglass insulation or other non-metallic elements in the *joint* between *panel* and *beam*, the load shall be held at each increment for five (5) minutes before reading the lateral movement.

10.5 After each load increment is added, and the deflection has stabilized, the load and lateral movement of the unattached flange shall be measured and recorded.

10.6 A test shall be terminated at failure (fastener pullout, fastener failure, *panel* buckling, *panel* failure, *beam* failure, etc.) and the mode of failure recorded, unless the design engineer has determined that the application of the *rotational-lateral stiffness*, K, occurs at lower load or displacement levels and that the test is permitted to be terminated earlier.

11. Number of Tests

11.1 The minimum number of tests for one set of parameters shall be three. For parametric studies using multiple values of one or more parameters, a smaller number of tests are permitted to be used.

11.2 If used as part of a series of at least three tests, one test is permitted to be sufficient for a specific condition of an all-metallic mechanically fastened specimen using the same basic components, but using unique geometrical or physical-property differences such as fastener spacings, different *beam* or *panel* yield stresses, etc.

11.3 Three tests shall be required for any specific condition of welded or adhesively bonded specimens, or for specimens using non-metallic materials.

11.4 When the *rotational-lateral stiffness* for three or more *panel* or *beam* thicknesses with otherwise identical parameters is to be determined, at least two specimens each with the minimum and the maximum thickness shall be tested. For a ratio of maximum-to-minimum thicknesses greater than 2.5, additional specimens with intermediate thicknesses shall be tested. One test of every thickness is permitted to be used in accordance with Section 11.2.

11.5 When the *rotational-lateral stiffness* for a range of screw spacings is to be determined, the minimum number of specimens shall be in accordance with this section. One test of every screw spacing is permitted to be used in accordance with Section 11.2.

11.5.1 For a ratio of maximum-to-minimum screw spacings equal to or less than 2, at least two specimens each with the minimum and the maximum screw spacing shall be tested.

11.5.2 For a range of five or more different screw spacings, or for a ratio of maximum-to-minimum screw spacings greater than 2, additional specimens with intermediate spacings must be tested.

11.6 Where the *rotational-lateral stiffness* for a range of other *panel* parameters (i.e., yield stress or ultimate strength, changes in geometry, etc.) are to be determined, a number of tests similar to the requirements under Sections 11.2 through 11.5 shall be performed.

11.7 For unsymmetric or staggered fastener arrays and/or *beams* unsymmetric about a plane parallel to the web, duplicate tests are permitted to be required by the design engineer using new specimens with the *beam* orientation, or the force direction, reversed.

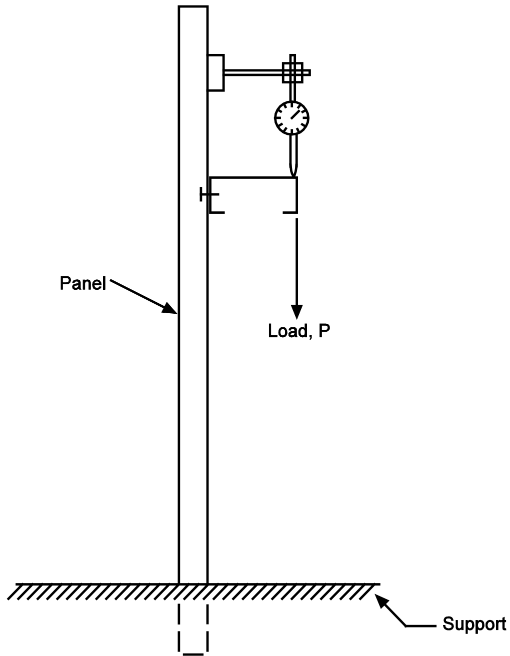

Figure 4 - Vertical Test Setup

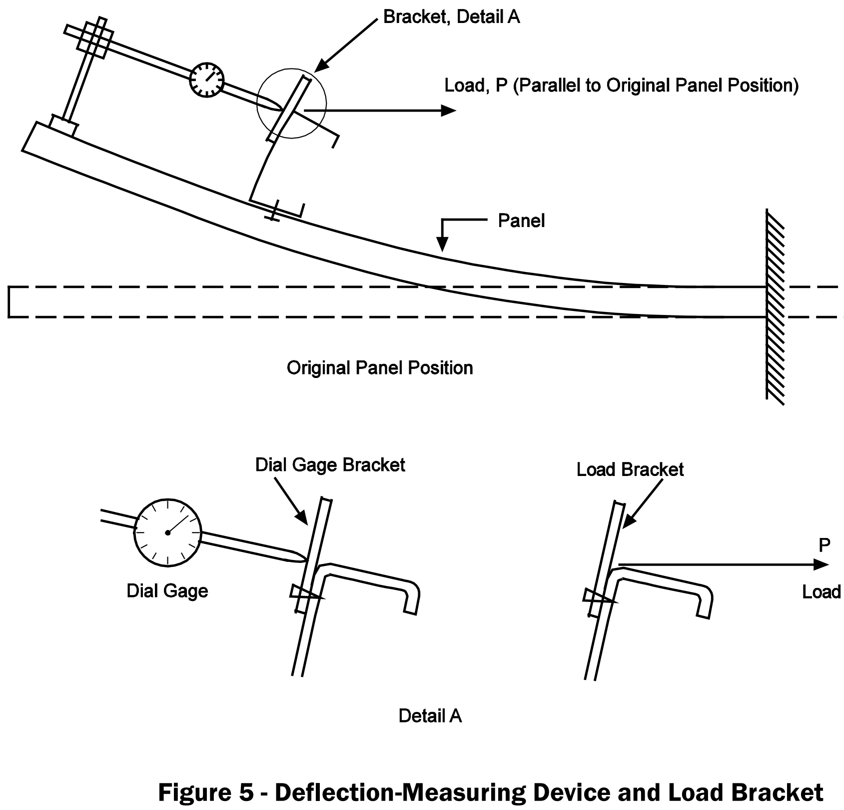

Figure 5 - Deflection-Measuring Device and Load Bracket

12. Test Evaluation

12.1 Typical load-displacement curves (P vs. D) obtained from the tests shall be graphed such as shown in Figure 6. For multiple tests of one set of test parameters, the curve resulting in the lowest value of K_t, as defined in Section 12.2, shall be used for the test evaluation procedure.

12.2 The test stiffness, K_t, at any load level shall be determined as follows:

$$K_t = (P/D)/L_B \tag{2}$$

12.3 The nominal test stiffness, K_N, shall be determined as follows:

$$K_N = (P_N/D_N)/L_B \tag{3}$$

where P_N and D_N are defined by (a) through (c) based on the shape of the load-displacement (P-D) curve:

(a) When the load reaches the ultimate load, P_u, prior to displacement reaching its ultimate, D_u, as shown in Figure 6(a):

$$P_N = 0.8P_u \tag{4}$$

D_N = Displacement at P_N

(b) When displacement reaches the ultimate displacement, D_u, prior to the load reaching its ultimate load, P_u, as shown in Figure 6(b):

$$D_N = 0.8D_u \tag{5}$$

P_N = Load at D_N

(c) When a P-D curve changes from bending upward to bending downward, as shown in Figure 6(c), a tangent is drawn from the origin to the P-D curve at point N, such that

$$D_N \leq 0.8D_u \tag{6}$$

$$P_N \leq 0.8P_u \tag{7}$$

12.4 When the design engineer specifies in advance a desired maximum lateral displacement limit of D_{NL}, the test is permitted to be discontinued when D_{NL} is reached, and K_N is permitted to be determined from P_N at D_{NL}, as long as the limits under Section 12.3 are observed and D_{NL} is not exceeded in design applications.

12.5 Where either H_D or H_L is not equal to the overall *beam* height, H, K_t and K_N shall be corrected by the factor H_DH_L/H^2.

12.6 In addition, K_t and K_N shall be adjusted by the stiffness contributions of the *panel*, K_c, derived from the linear-elastic displacement analysis representing the design applications, unless such an analysis shows that these contributions are insignificant. Alternatively, the *panel* stiffness shall be included by using the alternative test method under Section 14.

12.7 For *subassemblies* such as shown in Figure 2, where the applied lateral test loads cause a bending moment distribution in the *panel* similar to that shown in Figure 7, a lateral displacement, D_c, of the unattached flange of the *beam* shall be determined as follows:

$$D_c = \frac{PH_L^2 W_s}{12EI} \tag{8}$$

where W_s is the width of the *subassembly* as shown in Figure 2 and Figure 7, E is the modulus of elasticity of the *panel* material, and I is the effective moment of inertia of the *panel* cross-section (obtained from deflection determination calculations for cold-formed metal deck *panels*).

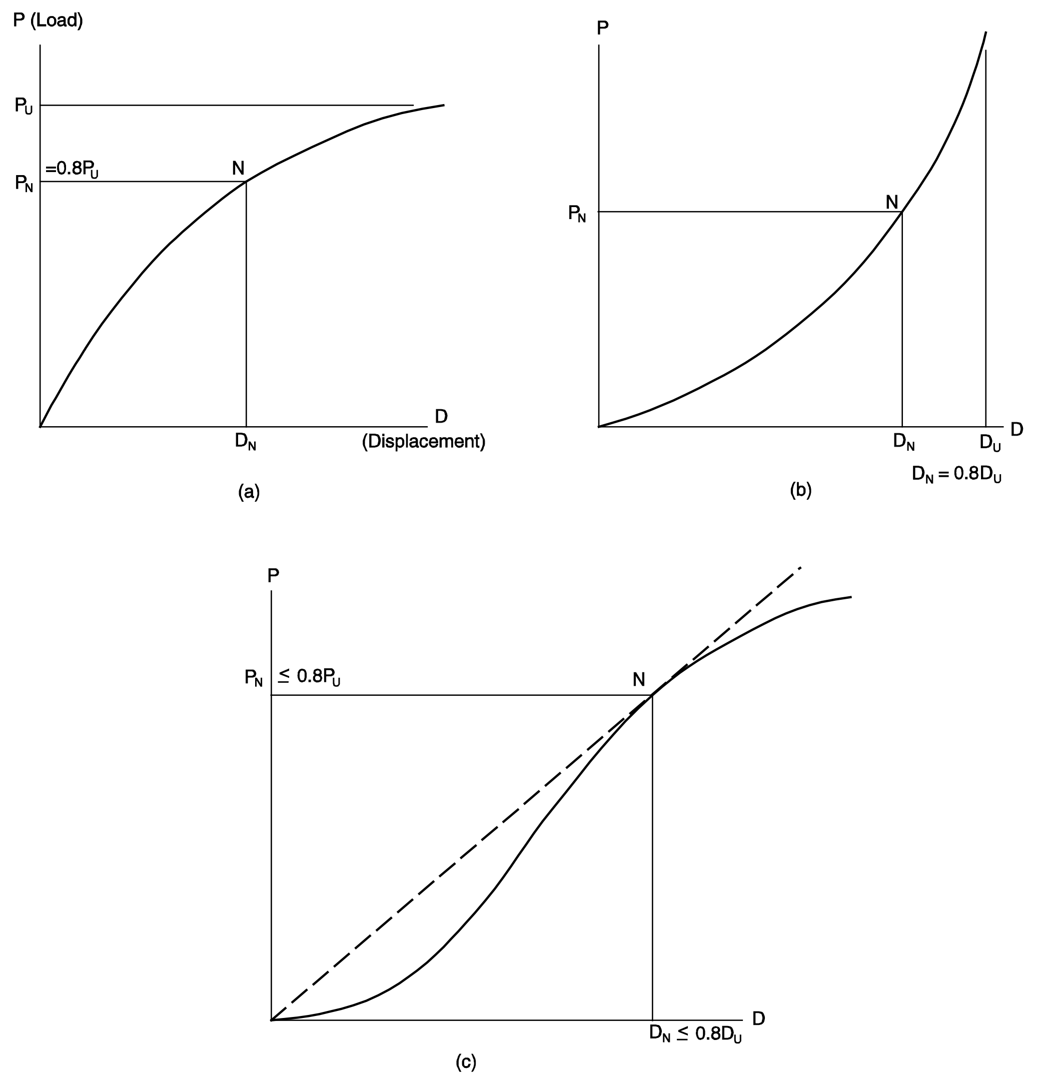

Figure 6 - Typical Load Displacement Curves

The *panel* stiffness shall be determined as follows:

$$K_c = 1/D_c \tag{9}$$

12.8 The overall *rotational-lateral stiffness* of the assembly shall be determined as follows:

$$K = \left(\frac{1}{K_t} + \frac{1}{K_c}\right)^{-1} \tag{10}$$

12.9 When tests covering ranges of parameters (thickness, yield stresses, screw spacings, etc.) are conducted according to Section 11, a linear interpolation is permitted to be used to determine intermediate K values.

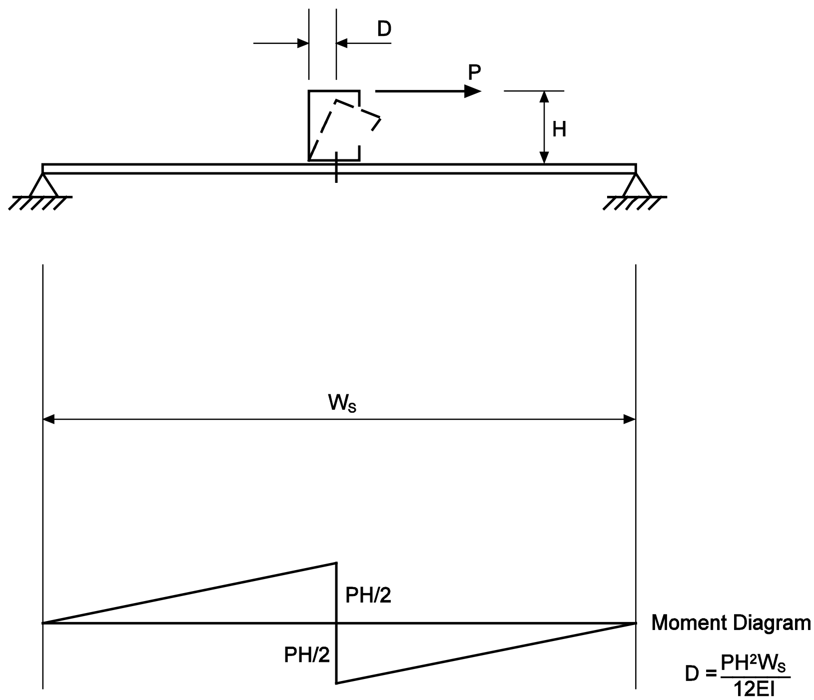

Figure 7 – Bending Moment Diagram With an Interior Beam

13. Test Report

13.1 The test report shall consist of a description of all specimen components, including drawings defining the actual and nominal geometry, material specifications, material properties, test results describing the physical properties of each component, and the supply sources. Differences between the actual and the nominal dimensions and material properties shall be noted in the report.

13.2 The test report shall contain a sketch or photograph of the test setup, the latest calibration date and accuracy of the equipment used, the signature of the person responsible for the tests, and a tabulation of all raw and evaluated test data.

13.3 All graphs resulting from the test evaluation procedure shall be included in the test report.

13.4 A summary statement, or tabulation, shall be included in the summary of the report to define the actual and nominal *rotational-lateral stiffness* derived from the tests conducted, including all limitations.

14. Alternative Rotational-Lateral Stiffness Test

This alternative *rotational-lateral stiffness* test provided in Section 14 is permitted to be used in place of the basic tests, as provided in Sections 8 through 12.

> **User Note:**
> This alternative method is conservative as compared to the basic methods which analytically account for the stiffness of the *panel*.

14.1 To include the *panel*-stiffness contribution in the test, rather than by linear-elastic analysis, the design engineer is permitted to request a test specimen and setup as shown in Figure 8 and Figure 9, respectively.

14.2 The test specimens shall be as described under Section 8 except as permitted in Section 14.2.1 through Section 14.2.4.

14.2.1 The minimum overall *panel* width of the specimen, W (Figure 8), shall be equal to

$$W = W_E + W_I + W_C \tag{11}$$

14.2.2 The minimum end dimension, W_E, shall equal the width of the attached *beam* flange plus 4 in. (102 mm) to allow the development of local deformation patterns around the fasteners as they would develop in a real structure.

14.2.3 For specimens representing interior-*beam subassemblies*, as shown in Figures 1 and 2, the dimension W_I of the test specimen (Figure 8) shall be equal to $^1/_{12}$ of the *subassembly* width, W_S (Figures 1 and 2), to assure that the overall *rotational-lateral stiffness* contribution of the test-specimen *panel* is the same as that of the *subassembly*.

14.2.4 For other *subassembly* conditions, W_I shall be based upon the field conditions.

14.3 The test-setup shall be as described under Section 9 except as permitted in Section 14.3.1 and Section 14.3.2.

14.3.1 The clamped support shown in Figures 8 and 9 shall minimize the rotation and translation of the test specimen at the support.

14.3.2 The lateral-displacement measuring device shall be located on a support fixed relative to the clamped support of the test *panel*, as shown in Figure 9.

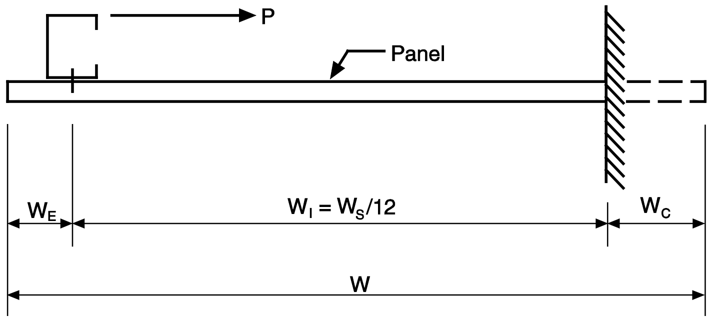

Figure 8 - Panel Width for Alternative Test

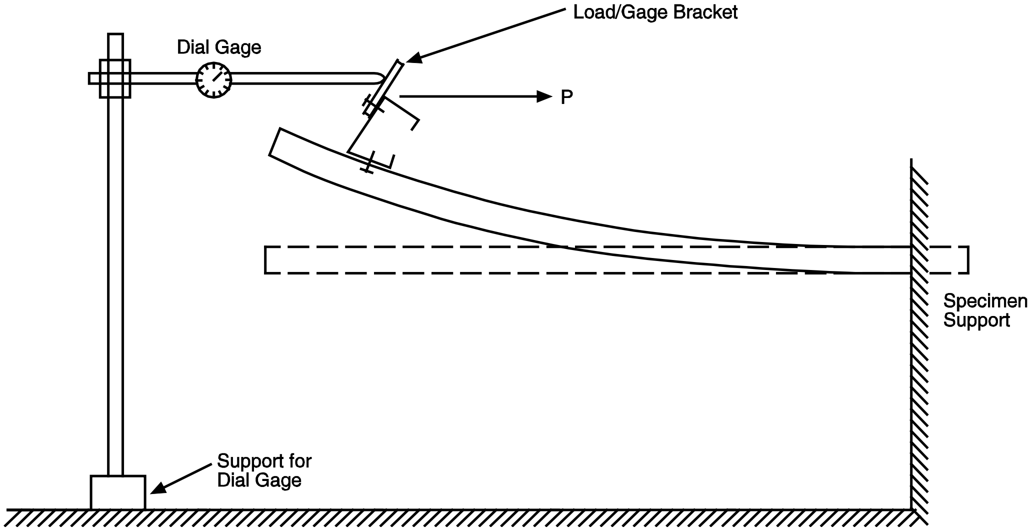

Figure 9 - Test Setup for Alternative Test

14.4 Test procedures shall be the same as described under Section 10.

14.5 The number of tests shall be determined as described in Section 11.

14.6 The test-evaluation procedure shall follow the underlying principles used to develop stiffness as described in Section 12. The test stiffness at any load level shall be determined according to Equation 2 and the nominal test stiffness shall be determined according to Equation 3.

14.7 For other interior-*beam* spacings, for exterior-*beam* conditions, or for other geometrical conditions, the measured displacements shall be adjusted by a linear-elastic analysis to represent the field conditions, unless such an analysis shows that these displacements and their effect on K are insignificant.

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AISI S901-17-C
COMMENTARY ON TEST STANDARD FOR DETERMINING THE ROTATIONAL-LATERAL STIFFNESS OF BEAM-TO-PANEL ASSEMBLIES

This test method is used primarily in determining the strength of *beams* connected to *panels* as part of a structural assembly. The unattached "free" flange of the *beam* is restrained from lateral displacements and twisting by the bending stiffness of the *beam* elements, the *connection* between the "attached" flange of the *beam* and the *panel*, and the bending stiffness of the *panel*.

The combined stiffness, K, of the assembly determined by this test method consists of: (a) the lateral stiffness of the *beam*, K_a, which is a function of the geometry of the *beam* and geometric details of the *beam*-to-*panel connection*, (b) the local stiffness of the joint components in the immediate vicinity of the *connection*, K_b, which is affected by the type of fasteners, the fastener spacing used, and the geometry of the elements connected, and (c) the bending stiffness of the *panel*, K_c, which is a function of the moment of inertia of the *panel*, the *beam* spacing, and the *beam* location (edge vs. interior). The latter stiffness should be taken into account by theoretical analysis or by using the alternative test described in Standard Section 14.

For specific geometric conditions, the design engineer is permitted to require duplicate testing using a new specimen with the *beam* orientation, or the force direction, reversed.

Another related test standard for the determination of the rotational restraint (k_ϕ) supplied by sheathing fastened to cold-formed steel members is AISI S918; where the sheathing can provide beneficial rotational restraint to the member (stud, joist, etc.) in order to provide restraint against distortional and lateral torsional buckling. See Schafer et al. (2008, 2010); and Gao and Moen (2013) for more discussions. AISI S918 provides both fastener and sheathing rotational stiffness utilized in the AISI standards (S100-16 Appendix 2), and may be replaced by the experimental values developed in AISI S918.

The test stiffness in Section 12.1, K_t, includes the stiffness effects of the *beam*, K_a, and the *beam*-to-*panel connection*, K_b, but excludes the bending stiffness of the *panel*, K_c, and is presented by the following relationship:

$$K_t = (1/K_a+1/K_b)^{-1} \quad \text{(C-1-1)}$$

In very thin steel members, a plastic hinge may form in the *beam* flange at the juncture of the web to the flange. The web plastic deformation may be ignored in stiffness calculations.

The assembly deformations may need some limitations to prevent a large angle between the load and the steel member. The angle is sometimes large and the resultant of the force should be considered. Moreover, a large angle may cause tension in the fasteners, which may not be desirable in real applications.

Reference

AISI S918-17 (2017), *Test Standard for Determination of Fastener-Sheathing Rotational Stiffness*, American Iron and Steel Institute, 2017.

Gao, T. and C. D. Moen (2013) "Flexural Strength Experiments on Exterior Metal Building Wall Assemblies With Rigid Insulation." *Journal of Constructional Steel Research*, 81, 104–113.

Schafer, B.W., Sangree, R.H., Guan, Y. (2008). "Rotational Restraint of Distortional Buckling in Cold-Formed Steel Systems." International Conference on Thin-walled Structures. Brisbane, Australia, 18- 20 June 2008. 461-468.

Schafer, B. W., L. C. M. Vieira Jr., R. H. Sangree, and Y. Guan (2010), "Rotational Restraint and Distortional Buckling in Cold-Formed Steel Framing Systems," Revista Sul-Americana de Engenharia Estrutural (South American Journal of Structural Engineering), Special Issue on Cold-Formed Steel Structures, 7 (1) 71-90.