01 May 2014

Rotational-Lateral Stiffness Test Method for Beam-to-Panel Assemblies, 2013 Edition

American Iron and Steel Institute

AISI S901-13

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AISI STANDARD

Rotational-Lateral Stiffness Test Method for Beam-to-Panel Assemblies

2013 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.

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1st Printing – May 2014

Produced by American Iron and Steel Institute

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 S901-13

Rotational-Lateral Stiffness Test Method for Beam-to-Panel Assemblies

1. Scope

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

1.2 This test method 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 test method is also used to establish a limit of the displacements for avoiding joint failure.

Commentary:
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 procedure described in Standard Section 13.

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.

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:

S100-12, *North American Specification for the Design of Cold-Formed Steel Structural Members*

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

A370-12a, *Standard Test Methods and Definitions for Mechanical Testing of Steel Products*
E6-09be1, *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 (i.e., aluminum, reinforced concrete, fiberboard, gypsum board, plastic, plywood, steel, etc.). 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.

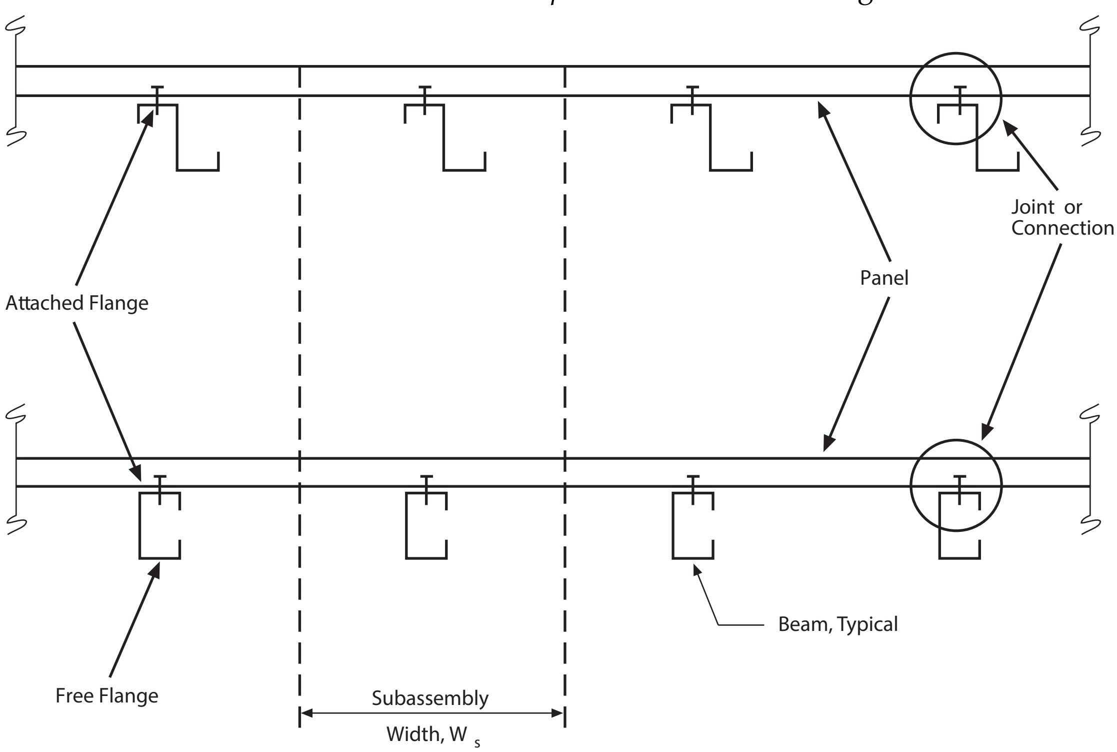

Figure 1 - Wall, Floor, Ceiling or Roof Assembly

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.

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.

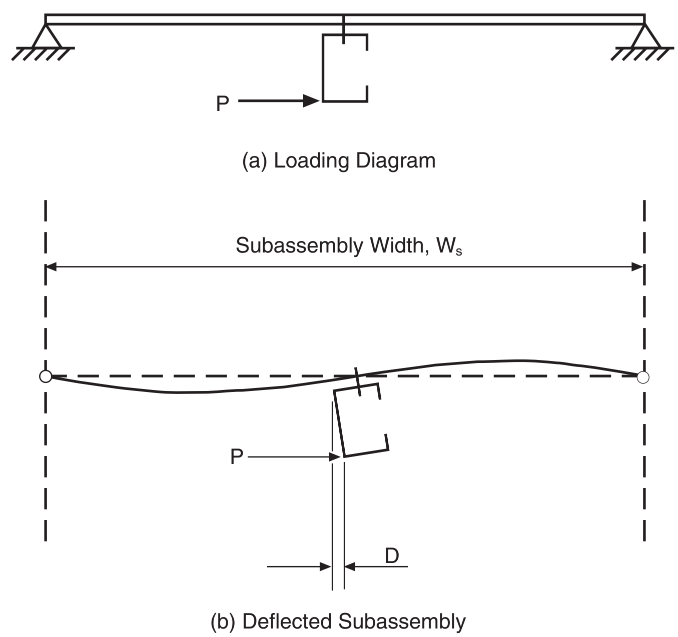

Figure 2 - Loaded and Deflected Subassembly

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 = Dial-gage 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 dial-gage 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. Materials

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

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

7. Test Specimen

7.1 The overall *panel* width, W (Figure 3), of the specimen shall be such that the dial-gage 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*.

7.2 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).

7.3 The end dimension, W_E, shall be long enough to attach a dial gage or an extensometer to the end of the *panel*.

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

$$W = W_E + 2W_I + W_F + W_C \quad (1)$$

7.5 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.

7.6 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.

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

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

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

8. Test Setup

8.1 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.

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

8.3 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.

8.4 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.

8.5 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 and/or dial gage bracket. The attachment of either bracket shall be accomplished such that the bracket does not stiffen the beam or reduce its distortion.

8.6 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.

8.7 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.

8.8 One or more dial gages or displacement transducers 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.

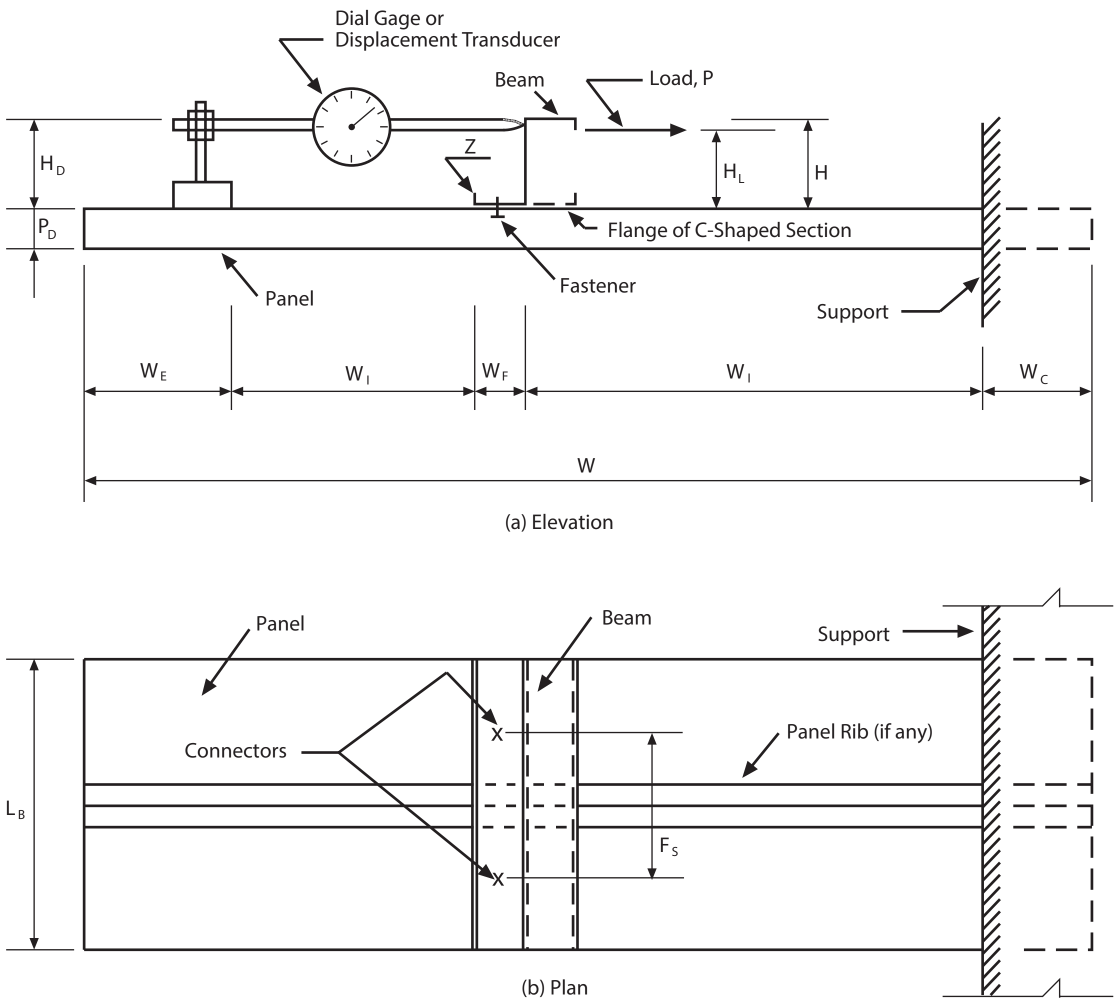

Figure 3 - Test Specimen and Horizontal Test Setup

9. Test Procedure

9.1 The dial-gage 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.

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

9.3 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.

9.4 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.

9.5 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.

9.6 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.

10. Number of Tests

10.1 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 is permitted to be used.

10.2 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.

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

10.4 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 10.2.

10.5 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 10.2.

10.5.1 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.

10.5.2 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.

10.6 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 10.2 through 10.5 shall be performed.

10.7 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.

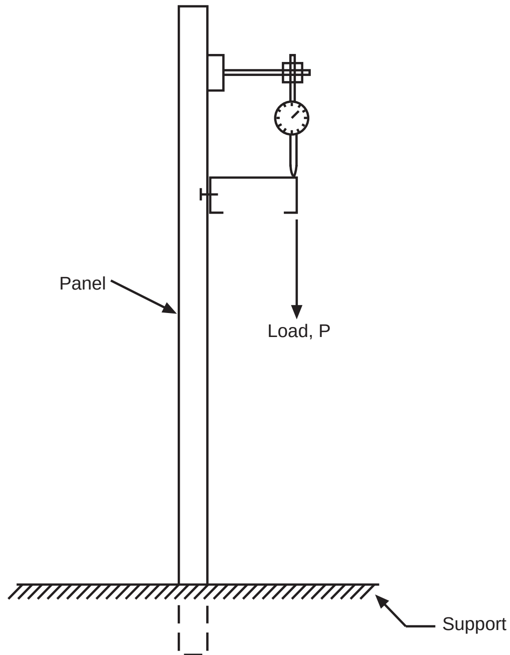

Figure 4 - Vertical Test Setup

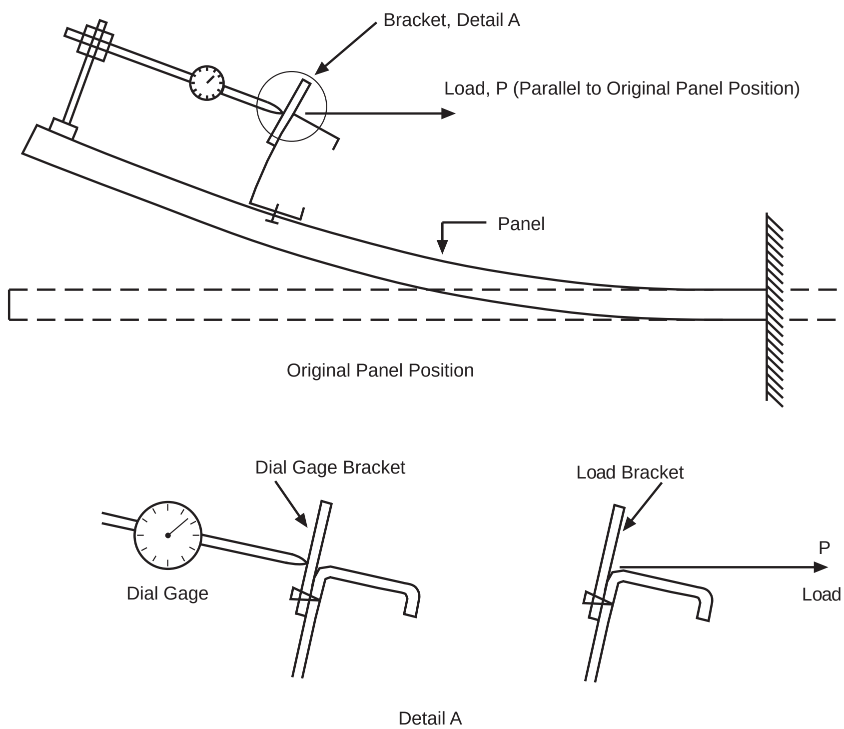

Figure 5 - Dial Gage and Load Bracket

11. Test Evaluation

11.1 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 11.2, shall be used for the test evaluation procedure.

Commentary:
The test stiffness, 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 follows the relationship as follows:

$K_t = (1/K_a+1/K_b)^{-1}$

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

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

11.3 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

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

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

11.4 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 11.3 are observed and D_{NL} is not exceeded in design applications.

11.5 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.

11.6 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. Alternately, the *panel* stiffness shall be included by using the alternative test method under Section 13.

11.7 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*).

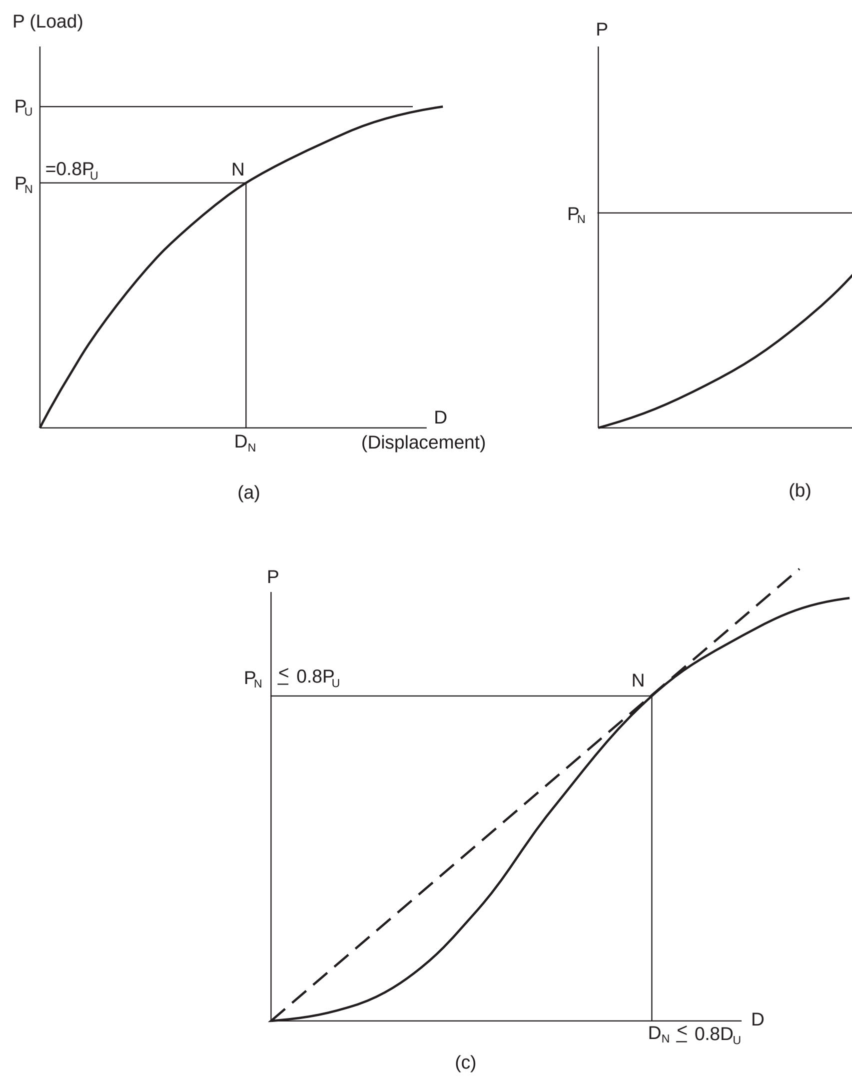

Figure 6 - Typical Load Displacement Curves

The *panel* stiffness shall be determined as follows:

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

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

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

11.9 When tests covering ranges of parameters (thickness, yield stresses, screw spacings, etc.) are conducted according to Section 10, a linear interpolation is permitted to be used to determine intermediate K values.

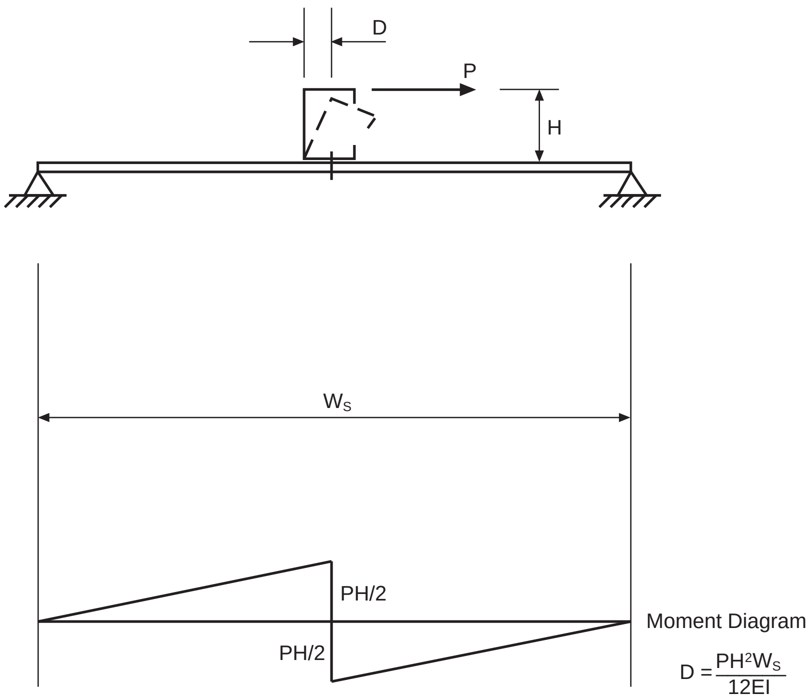

Figure 7 – Bending Moment Diagram With an Interior Beam

12. Test Report

12.1 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.

12.2 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.

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

12.4 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.

13. Alternative Rotational-Lateral Stiffness Test*

This alternative rotational-lateral stiffness test method provided in Section 13 is permitted to be used in place of the basic test methods, as provided in Sections 7 through 11.

13.1 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.

13.2 The test specimens shall be as described under Section 7 except as permitted in Section 13.2.1 through Section 13.2.4.

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

$$W = W_E + W_I + W_C \qquad (11)$$

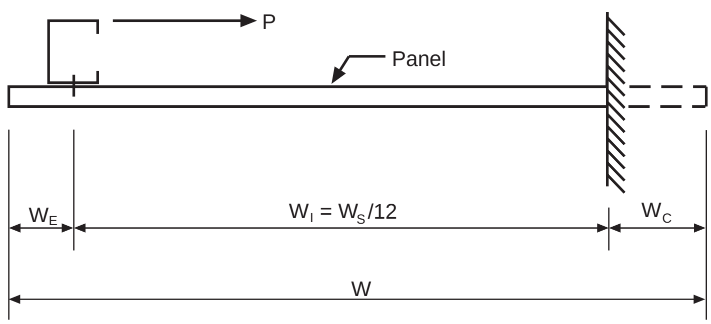

Figure 8 - Panel Width for Alternative Test

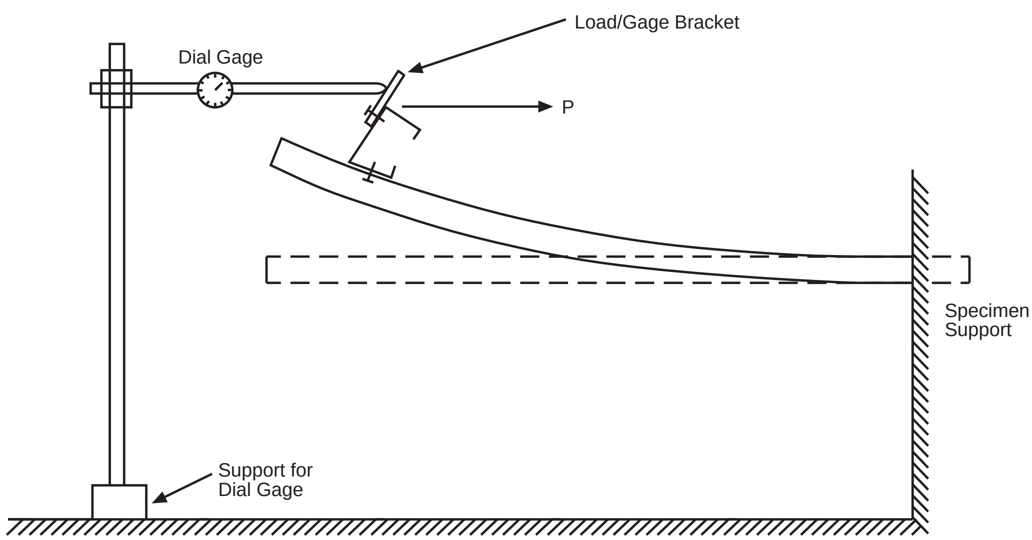

Figure 9 - Test Setup for Alternative Test

* This method is conservative as compared to the basic methods which analytically account for the stiffness of the *panel*.

analysis to represent the field conditions, unless such an analysis shows that these displacements and their effect on K are insignificant.

American Iron and Steel Institute

25 Massachusetts Avenue NW
Suite 800
Washington, DC 20001
www.steel.org

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