# ROTATIONAL–LATERAL STIFFNESS TEST METHOD FOR BEAM–TO–PANEL ASSEMBLIES

## 1. Scope

**1.1** The purpose of this test is to determine 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.

**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).

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

**1.4** The combined stiffness of the assembly determined by this method, K, 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 shall be taken into account by theoretical analysis or by using the alternate test procedure described in Section 10.

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

## 2. Description of Terms

**2.1** *Subassembly* – A subassembly is 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 (Figure 1).

**2.2** *Panel* – The panel used in the subassembly may be made of any structural material, for example: aluminum, reinforced concrete, fiberboard, gypsum board, plastic, plywood, steel, etc. (Figure 1).

**2.3** *Beam* – A beam may have 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 (Figure 1).

* AISI *Specification*, Section C3.1.3.

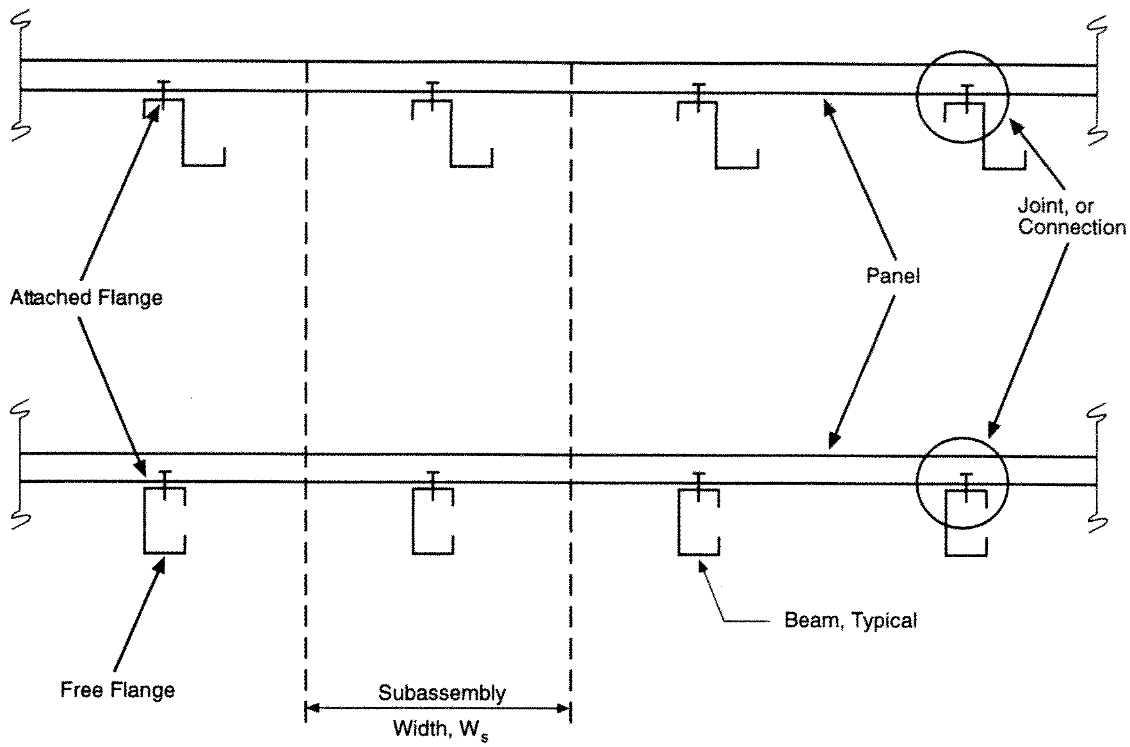



**Figure 1 – Wall, Floor, Ceiling or Roof Assembly**

**2.4** *Joint or Connection* – A joint or connection includes the 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.

**2.5** *Lateral Load* – The total lateral load, P, in kips (kN), is applied to the unattached flange of the beam (Figure 2) in a plane parallel to that of the original panel position.

**2.6** *Lateral Deflection* – The lateral deflection (Figure 2) is the lateral displacement, D, in inches (mm), of the unattached flange due to the lateral load, P.

**2.7** *Rotational–Lateral Stiffness* – The rotational–lateral stiffness, K, is equal to the 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. Thus, the units of K are: kips (kN) of lateral load per inch (mm) of beam length per inch (mm) of deflection, or k/in./in. (kN/mm/mm).

## 3. Materials

**3.1** Components of the test specimen(s) shall be measured, and the component suppliers shall be identified.

**3.2** Physical and material properties of the panel and beam shall be determined according to the latest edition of Specification ASTM E370 or other applicable standards.

## 4. Test Specimens

**4.1** 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,

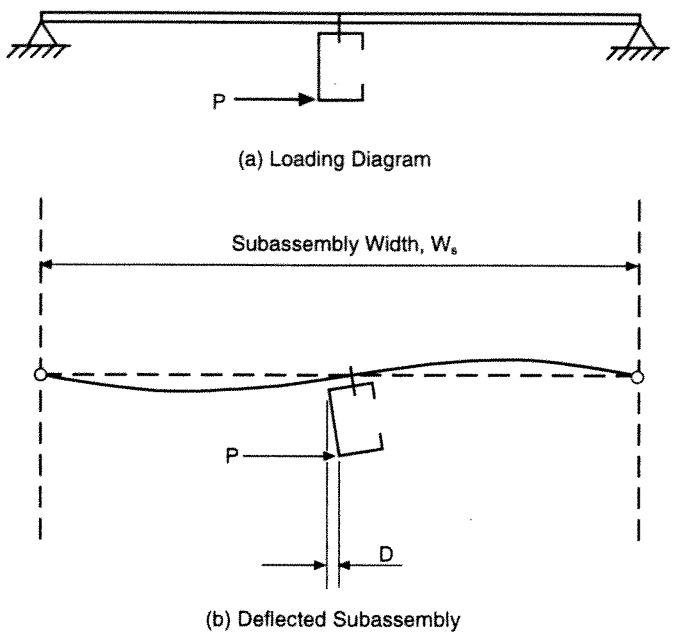



**Figure 2 – Loaded and Deflected Subassembly**

$W_I$, 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 fastener 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.

**4.2** 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).

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

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

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

**4.5** The minimum beam and panel length, $L_B$, of the test specimen shall not be less than the largest of (a) two times the maximum connector spacing, $F_S$, used in actual 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.

**4.6** 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.

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

**4.8** The fabrication and field installation procedures specified for the overall assembly, and the tools used, shall also be used in the specimen construction as much as possible.

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

## 5. Test Setup

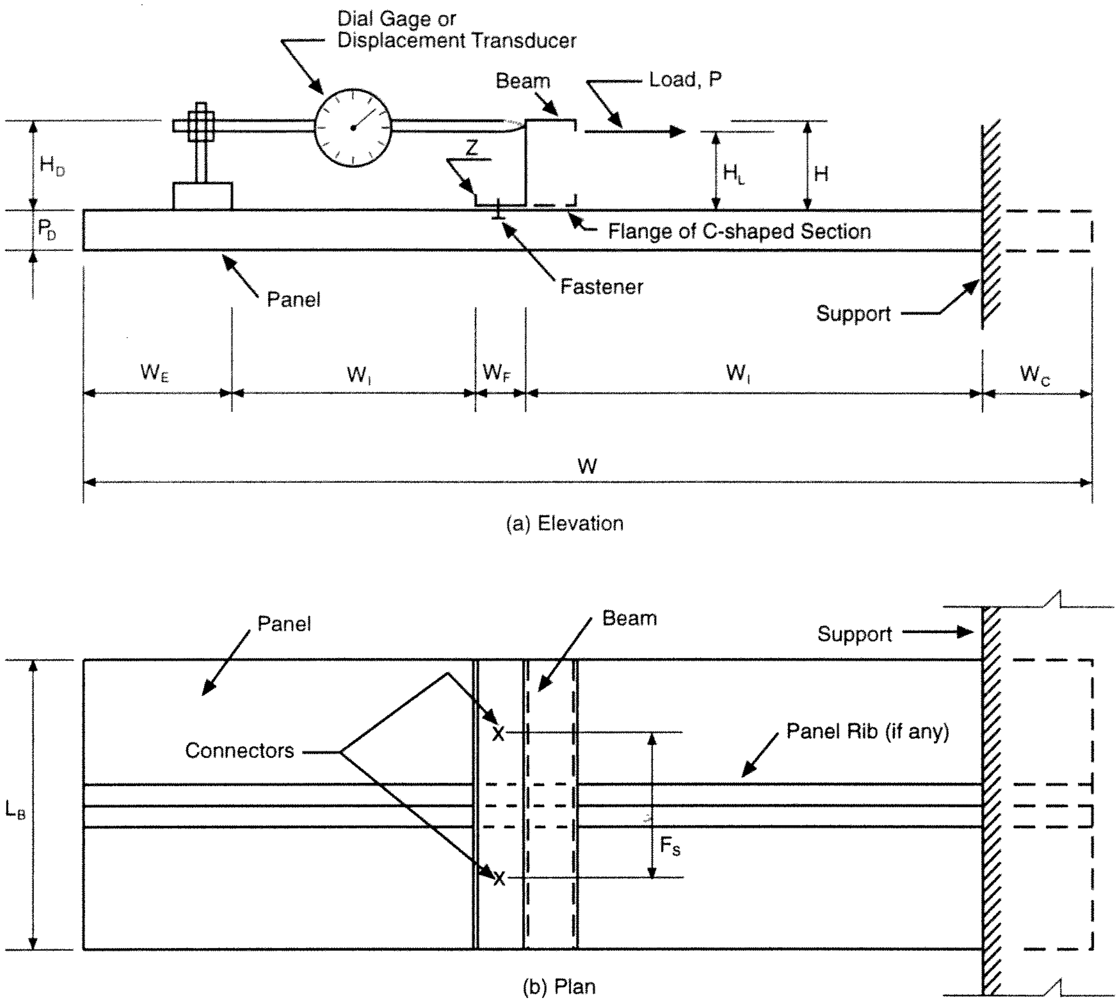



**Figure 3 – Test Specimen and Horizontal Test Setup**

**5.1** The test specimens may be tested in a horizontal or vertical position (Figure 3 and Figure 4, respectively). The zero–load readings of the deflection–measuring device(s) shall be recorded.

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

**5.3** When the test specimen panel is 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 reasonably maintained. For foam–filled sandwich panels, if necessary, the filler material over the distance $W_C$ may be replaced with wood, gypsum, or similar filler materials.

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

**5.5** 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

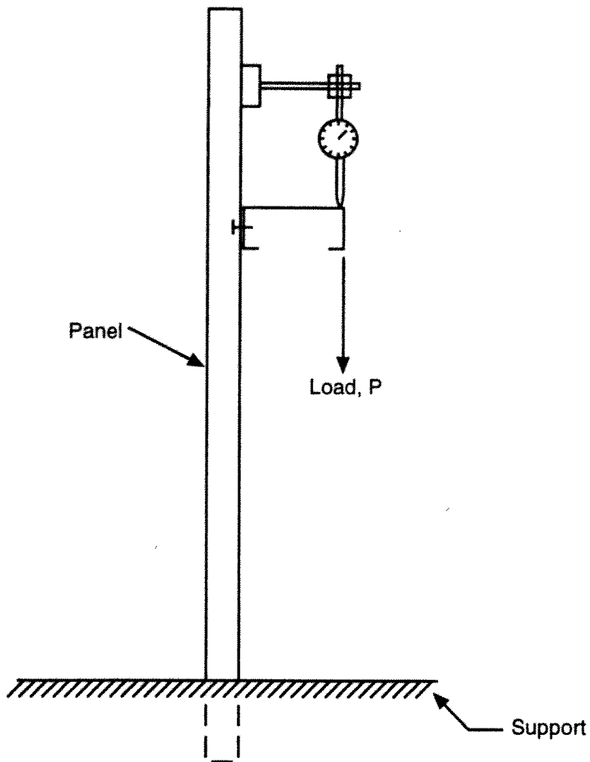



**Figure 4 – Vertical Test Setup**

are to 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.

**5.6** 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.

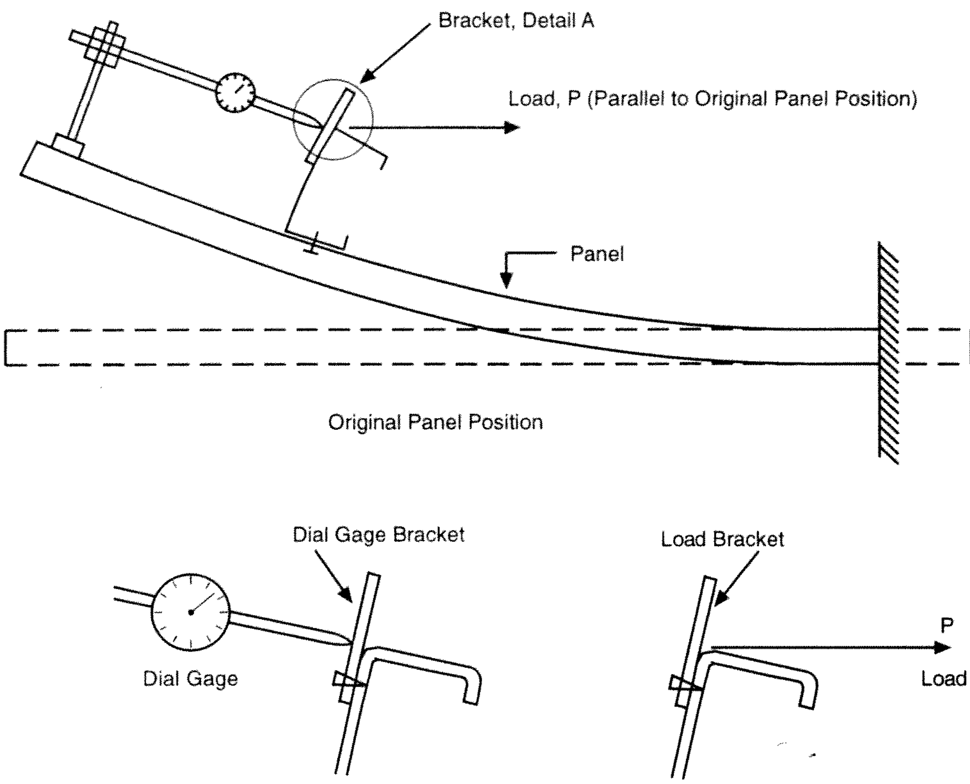
**5.7** The load application shall be accomplished by chain or wire, and the necessary precautions shall be taken to ensure that the direction of the applied load remains essentially parallel to the original plane of the panel (Figure 5).

**5.8** 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 midwidth point, and have graduations at not greater than 0.001 in. (0.0254 mm) intervals.

## 6. Test Procedures

**6.1** The dial–gage height, $H_D$, and load height, $H_L$, as shown in Figure 3, shall be arranged such as to equal as close as possible 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.

**6.2** No preload is to be used. The load shall be applied in a direction which is critical for the intended use of the results.




Detail A

**Figure 5 – Dial Gage and Load Bracket**

**6.3** 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 5 percent of the beam depth.

**6.4** 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 5 minutes before reading the lateral movement.

**6.5** 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.

**6.6** 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 may be terminated earlier.

## 7. Number of Tests

**7.1** 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 may be used.

**7.2** If used as part of a series of at least three tests, one test is 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 strengths, etc.

**7.3** Three tests are required for any specific condition of welded or adhesively–bonded specimens, or for specimens using non–metallic materials.

**7.4** 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 must be tested. One test of every thickness may be used in accordance with Section 7.2.

**7.5** When the rotational–lateral stiffness for a range of screw spacings is to be determined, the minimum number of specimens shall be as follows: 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. 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. One test of every screw spacing may be used in accordance with Section 7.2.

**7.6** Where the rotational–lateral stiffness for a range of other panel parameters – such as yield or ultimate strength, changes in geometry, etc. – are to be determined, a number of tests similar to the requirements under Sections 7.2 through 7.5 shall be performed.

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

## 8. Test Evaluation Procedure

**8.1** Typical load–displacement curves (P vs. D) obtained from the tests are 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 8.2, shall be used for the test evaluation procedure.*

**8.2** The test stiffness, $K_t$, at any load level is determined by

$$K_t = P/D/L_B \qquad (2)$$

**8.3** The nominal test stiffness, $K_N$, shall be determined by

$$K_N = P_N/D_N/L_B \qquad (3)$$

where $P_N$ and $D_N$ shall be determined for a point, N, such that either $P_N$ shall be equal to 0.8 times the ultimate load, $P_u$, for load–displacement curves as shown in Figure 6(a), or the displacement $D_N$ shall be equal to 0.8 times the ultimate displacement, $D_u$, for load–displacement curves as shown in Figure 6(b), or by a tangent drawn from the origin to the P–D curve as shown in Figure 6(c), resulting in $P_N \leq 0.8P_u$ and $D_N \leq 0.8D_u$.

* The test stiffness, $K_t$, includes the stiffness effects of the beam, $K_e$, and the beam–to–panel connection, $K_b$, but excludes the bending stiffness of the panel, $K_c$, and follows the relationship $K_t = (1/K_a+1/K_b)^{-1}$.

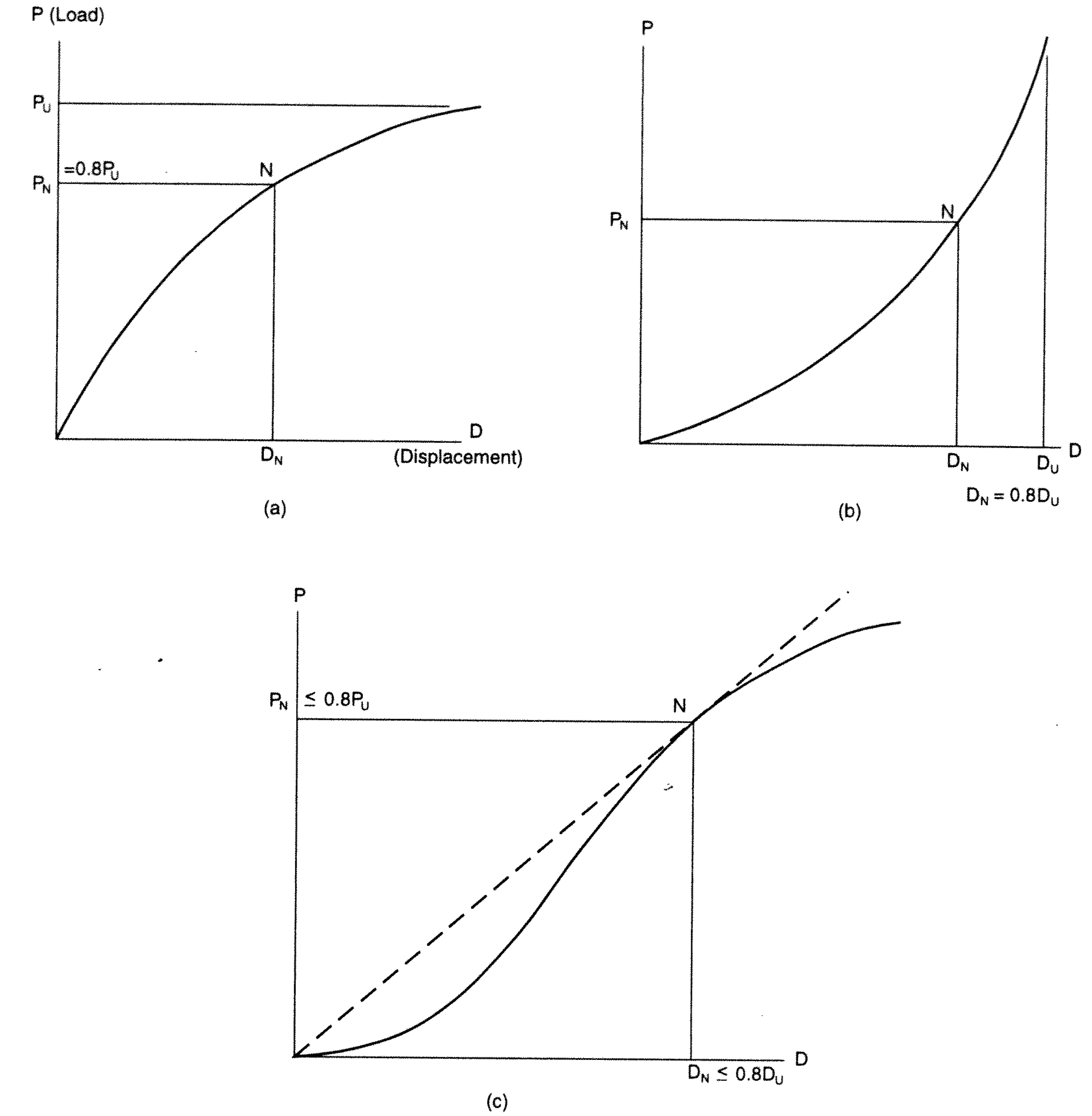



**Figure 6 – Typical Load Displacement Curves**

**8.4** When the design engineer specifies in advance a desired maximum lateral displacement limit of $D_{NL}$, the test may be discontinued when $D_{NL}$ is reached, and $K_N$ may be determined from $P_N$ at $D_{NL}$, as long as the limits under Section 8.3 are observed and $D_{NL}$ is not exceeded in actual design applications.

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

**8.6** 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 actual design applications, unless such an analysis shows that these contributions are insignificant. Alternately, the panel stiffness may be included by using the alternate test method under Section 10.

**8.7** For subassemblies such as shown in Figure 2, the applied lateral test loads cause

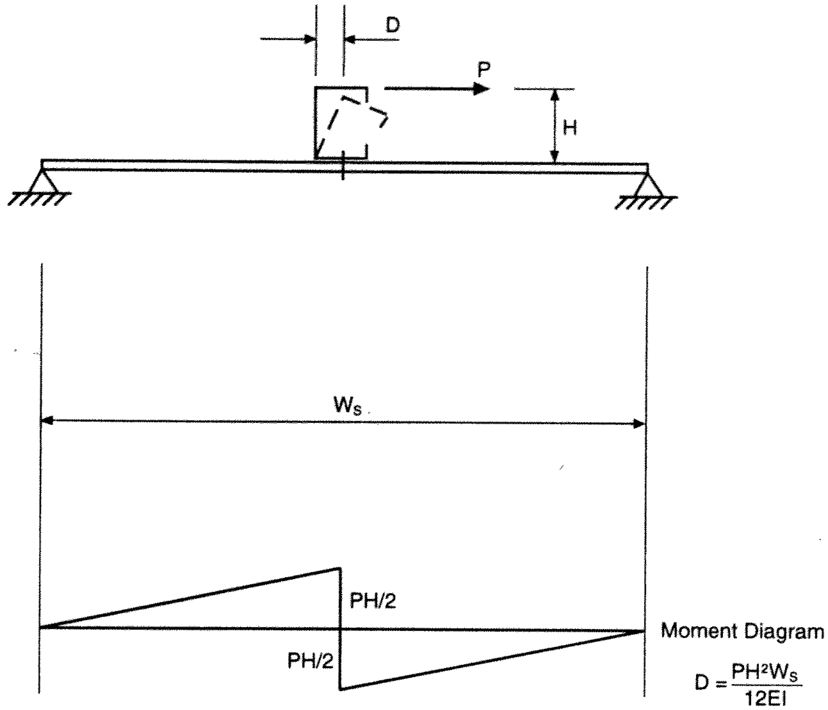



**Figure 7 – Bending Moment Diagram with an Interior Beam**

a bending moment distribution in the panel similar to that shown in Figure 7, and a lateral displacement of the unattached flange of the beam, $D_c$, equal to

$$D_c = PH_L^2W_s/(12EI) \quad (4)$$

where $W_s$ is the width of the subassembly (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.)
The panel stiffness is equal to

$$K_c = 1/D_c \quad (5)$$

**8.8** The overall rotational–lateral stiffness of the assembly shall be determined as

$$K = (1/K_t + 1/K_c)^{-1} \quad (6)$$

**8.9** When tests covering ranges of parameters (thickness, yield strengths, screws spacings, etc.) are conducted according to Section 7, a linear interpolation may be used to determine intermediate K values.

## 9. Test Report

**9.1** 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 actual physical properties of each component, and the sources of supply. Differences between the actual and the nominal dimensions and material properties shall be noted in the report.

**9.2** In addition, 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.

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

**9.4** 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.

## 10. Alternate Rotational–Lateral Stiffness Test*

**10.1** To include the panel–stiffness contribution in the test, rather than by linear–elastic analysis, the design engineer may request a test specimen and setup as shown in Figure 8 and Figure 9, respectively.

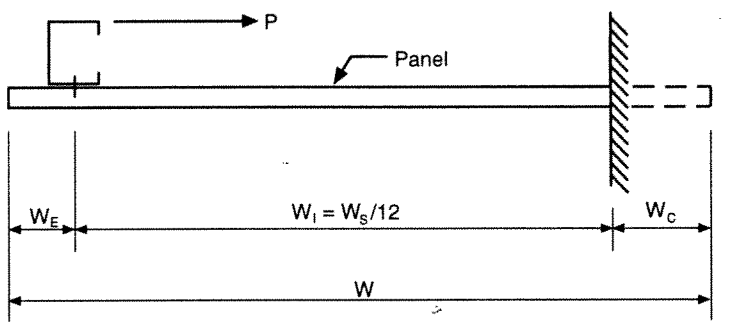



**Figure 8 – Panel Width for Alternate Test**

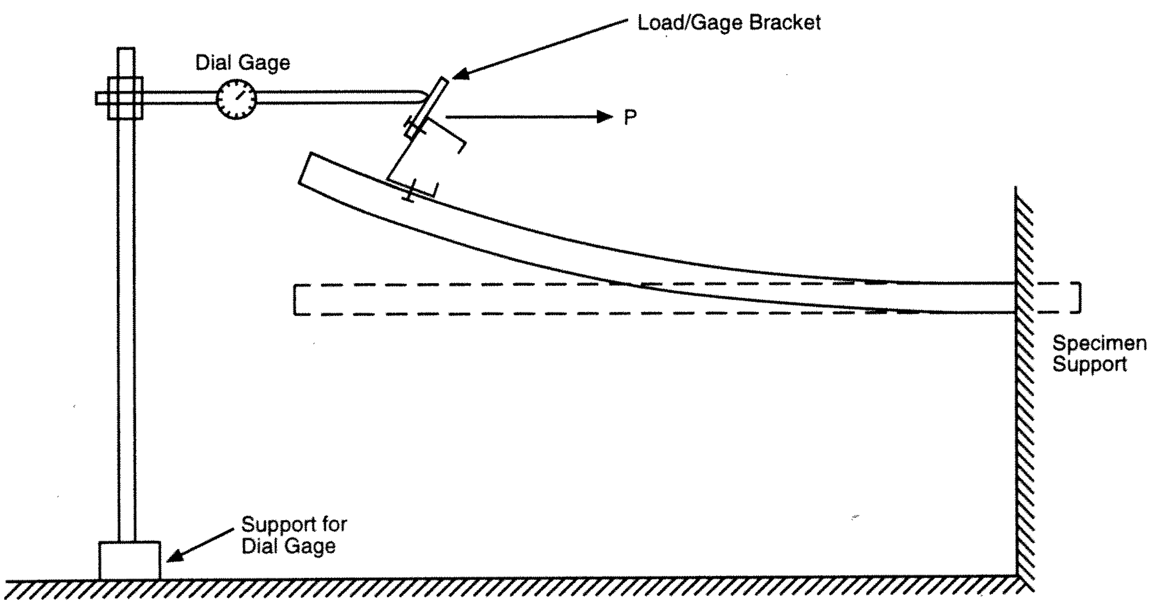



**Figure 9 – Test Setup for Alternate Test**

**10.2** The test specimens shall be as described under Section 4 except as follows.

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

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

$$W = W_E + W_I + W_C \qquad (7)$$

**10.2.2** 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.

**10.2.3** 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.

**10.2.4**. For other subassembly conditions, $W_I$ shall be determined to represent the actual conditions.

**10.3** The test–setup shall be as described under Section 5 except as follows.

**10.3.1** The clamped support as shown in Figures 8 and 9 shall be sufficiently rigid to minimize the rotation and translation of the test specimen at the support.

**10.3.2** 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.

**10.4** Test procedures shall be the same as described under Section 6.

**10.5** The number of tests shall be determined as described in Section 7.

**10.6** The test–evaluation procedure shall follow the underlying principles used to develop Section 8. 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. No further adjustments are needed.

**10.7** 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 actual field conditions, unless such an analysis shows that these displacements and their effect on K are insignificant.