International Specialty Conference on Cold-Formed Steel Structures

(1988) - 9th International Specialty Conference on Cold-Formed Steel Structures

Nov 8th, 12:00 AM

Test Procedures for the Design of Cold-formed Steel Structural Members, Connections, and Assemblies

K. H. Klippstein

Ninth International Specialty Conference on Cold-Formed Steel Structures
St. Louis, Missouri, U.S.A., November 8-9, 1988

TEST PROCEDURES FOR THE DESIGN OF COLD-FORMED STEEL STRUCTURAL MEMBERS, CONNECTIONS, AND ASSEMBLIES

by

Karl H. Klippstein, P.E.*

SUMMARY

The 1986 Cold-Formed Steel Design Manual published by the American Iron and Steel Institute (AISI) contains a new Part VII, entitled "Test Procedures."

Currently, Part VII of the AISI manual describes two tests, entitled: (1) Rotational-Lateral Stiffness Test Method for Beam-to-Panel Assemblies, and (2) Stub Column Test Method for Effective Area of Cold-Formed Steel Columns.

The described procedures represent the first step towards utilizing more uniform test methods, which eventually will become American Society for Testing and Materials (ASTM) standards, and lead to more uniform theoretical results.

Additional test procedures are in preparation, such as Mechanically Fastened Cold-Formed Steel Connections; Shear Diaphragm Tests of Roof, Floor, and Wall Panels; and Shear Tests of 2-by-2-Foot Small-Scale Specimens.

Eventually, these new test guidelines will allow for improved and more realistic cold-formed-steel design provisions.

----

* Research Associate Professor, Department of Civil Engineering, University of Pittsburgh, 936 Benedum Hall, Pittsburgh, PA 15261.

INTRODUCTION

For many years, the AISI Advisory Group on the "SPECIFICATION FOR THE DESIGN OF COLD-FORMED STEEL STRUCTURAL STEEL STRUCTURAL MEMBERS," has been concerned about the acceptance of cold-formed steel products based on tests. The current (1986) AISI edition of the specifications, and especially Section F entitled "Tests For Special Cases," defines very clearly when and if tests are appropriate, necessary, and applicable.

Tests for special cases may be made by an independent laboratory, or by a laboratory of a manufacturer. Hopefully, such tests are properly documented and reported such that they may be used to substantiate or improve existing specification provisions, or to develop new specification provisions, and ultimately to assist other members of the industry in the aim of using uniform design rules in the spirit of fair competition.

Section F1 of the current specifications specifically deals with tests for determining structural performance where the composition or configuration of elements, assemblies, connections, or details of cold-formed steel structural members are such that the calculation of their safe load-carrying capacity or deflection cannot be made in accordance of the provisions of the specifications. Detailed rules are given as to the number of tests to be performed, and how to evaluate them.

However, as stated in Section F2 of the specifications, the procedures outlined in Section F1 are not applicable to confirmation tests on specimens whose capacities can be computed according to the specification or its specific references.

Section F3 of the specifications deals with tests for determining mechanical properties for full sections, flat elements of formed sections, and virgin steel.

In view of the varied and ever-increasing applications of cold-formed steel products, it is anticipated that more detailed test procedures are necessary to account for the many geometric configurations and load conditions not yet covered by the specifications.

A step in this direction is made by the addition of Part VII of the AISI Cold-Formed Steel Design Manual. Hopefully, the tests described in Part VII will eventually be adopted by ASTM as standard test procedures, which would then be referenced in the main body of the AISI specifications under Section F.

The test procedures currently contained in Part VII of the AISI manual are described below.

ROTATIONAL-LATERAL STIFFNESS TEST METHOD FOR BEAM-TO-PANEL ASSEMBLIES

The purpose of this test is to determine the rotational-lateral stiffness of the connection between a beam (such as a purlin, girt, floor joist, or wall stud) and the attached panel material (such as the metal roof, siding, plywood flooring, or gypsum cladding).

Actually, the combined rotational-lateral stiffness of the entire assembly is assessed by this test, i.e. the lateral stiffness of the beam, Ka; the local stiffness around the fasteners connecting the beam with the panel, Kb; and the bending stiffness of the panel material, Kc. The overall stiffness of the assembly, K, determined by this method is:

$$K = (1/Ka + 1/Kb + 1/Kc)^{-1}$$

This stiffness will eventually be used to determine the lateral buckling strength of the compression flange of beams whose tension flange is attached to some panel material, and whose compression flange may rotate and laterally move, except as restrained by its connection to the tensile portion of the beam, the fasteners connecting the tension flange to the panel, and the panel stiffness. The terminology used in the Test Procedure in Part VII is different from the terminology used above, but the end result is the same.

Applications for the results of this test will include the strength determination of the unattached flange of single-span purlins, girts, and curtainwall studs exposed to negative wind pressure, and of multispan continuous purlins, girts, studs, and joists in the negative moment region.

Typically, a subassembly of width Ws, as shown in Figure 1, would be tested, with a beam consisting of a Z- or C-shaped cross section, a panel, and the typical connectors. The subassembly is meant to represent a loaded and deflected test condition as shown in Figure 2. To accomplish this task, a load is applied as shown in Figure 3, and a dial gage is used to determine the lateral deflection of the beam relative to the panel. This test setup will provide for determining Ka and Kb.

The tests can be performed in a vertical setup as shown in Figure 4, or in a horizontal setup as shown in Figure 5. Test procedures, number of tests, and test evaluation procedures are clearly defined in Part VII of the AISI manual.

The test evaluation procedure depends upon the shape of the load-displacement curves shown in Figure 6, with the aim of using a nominal load, Pn, which is equal to 0.8 times the ultimate load, Pu, or which causes a nominal deflection, Dn, equal to 0.8 times the ultimate deflection, Du.

STUB-COLUMN TEST METHOD FOR EFFECTIVE AREA OF COLD-FORMED STEEL COLUMNS

One of the most important tests to be performed for perforated columns used by the rack-manufacturing and wall-stud industries is the stub-column test, which determines the effective area (in the 1980 AISI specifications represented by the Q factor times the gross cross section), Aeff. This test primarily considers the effects of local buckling and residual stresses of columns that have holes or hole patterns in the flat and/or curved elements of the cross section. Any hole pattern not covered by the main body of the AISI specifications must be tested.

The overall effective area of a column with perforated elements is the mean of two different portions: (a) the effective area of the full cross section between perforations, and (b) the effective area of the perforated cross section. Obviously, the length and width of the perforations, and the spacing between perforations, have vital effects on the overall performance of the column, but the test will automatically take care of all of these effects, except that adjustments must be made for any differences in the actual thickness or yield strength, as they most likely are different from the minimum values specified.

The length of the stub column must meet certain requirements partially depicted in Figure 7, which shows hypothetical perforation patterns and suggested stub column lengths, L. The criteria used for the determination of L is a function of the stub column width, W, the pitch length of the repetitive pattern, Lp, and the radius of gyration about the minor axis, ry. To avoid overall column-buckling effects, the stub-column length may not exceed twenty times the minimum radius of gyration, unless governed by W or Lp, in which case the overall buckling effects must be accounted for in the final evaluation of the test. Details of the evaluation process are given in the test procedure.

A typical stub-column-test setup is shown in Figure 8. Vertical alignment of the stub column within the test apparatus, the use of plane steel endplates and grout layers at the top and bottom of the stub column to assure uniform introduction of the axial load, and speed of testing, are of vital importance to an acceptable test.

Details on the number of tests to be conducted, the precision of the measurements to be used, the calculations necessary to determine the effective area of a tested section, and the information to be included in the test report, are given in the described test procedures.

FORTHCOMING TEST PROCEDURES

Aside from the test procedures published and described above, additional test procedures are being prepared for future publication. A test procedure on mechanical connections is in its final stage of being published. Also, a test procedure on diaphragms (roofs, floors, and walls) has been drafted and will soon be published. Other test procedures such as for full-scale column testing and small wall-diaphragm specimens are under way.

Most important, however, is the development of the probabilistic evaluation of test results, which is going to be discussed in the next presentation by Dr. Pekoz, Cornell University, and Dr. Hall, University of Illinois. The results of that presentation will be used extensively in future evaluations of test results.

SUMMARY

Because the utilization and application of light-gage cold-formed steel products are so far ahead of the necessary specification provisions that would cover the design of these products, it is of vital importance to develop test procedures that ensure a uniform evaluation of the performance, strength, and safety of these products.

The test procedures published in Part VII of the 1986 AISI Manual are a first step in a direction that meets these needs. More test procedures are being drafted and will be issued along with future amendments and revisions of the specifications.

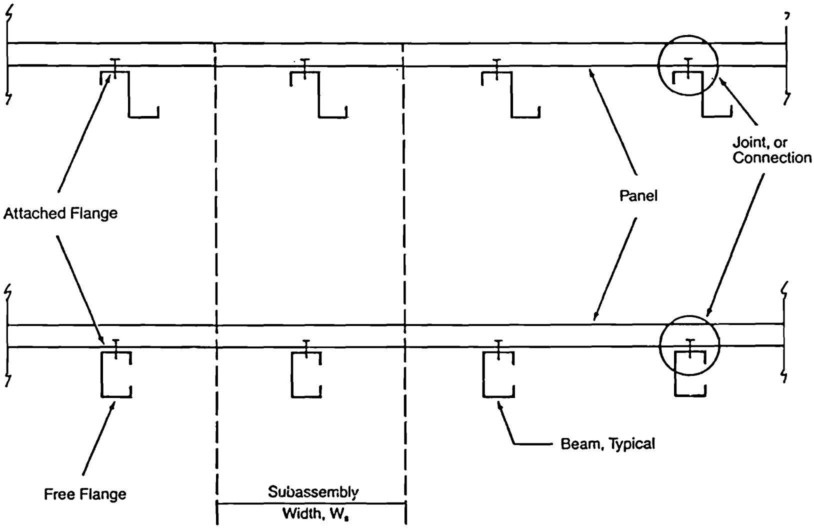


Figure 1 Wall, Floor, Ceiling, or Roof Assembly

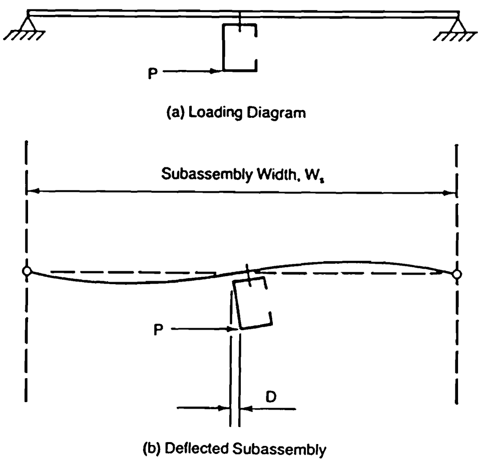
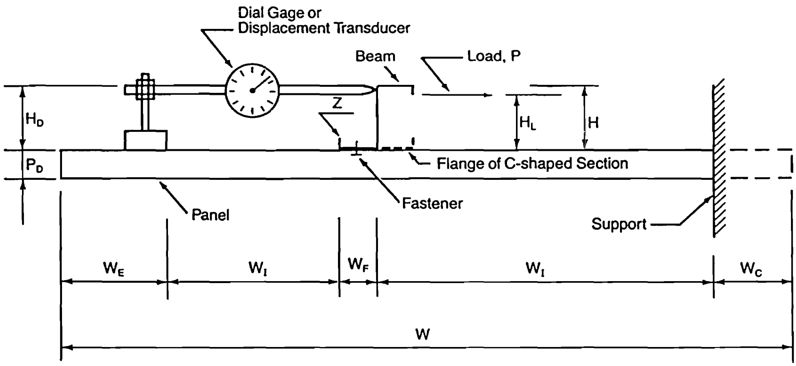
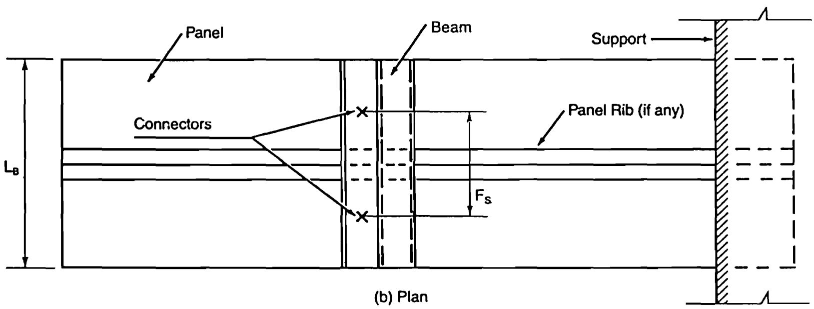


Figure 2 Loaded and Deflected Subassembly



-(a) Elevation



(b) Plan

Figure 3 Test Specimen and Horizontal Test Setup

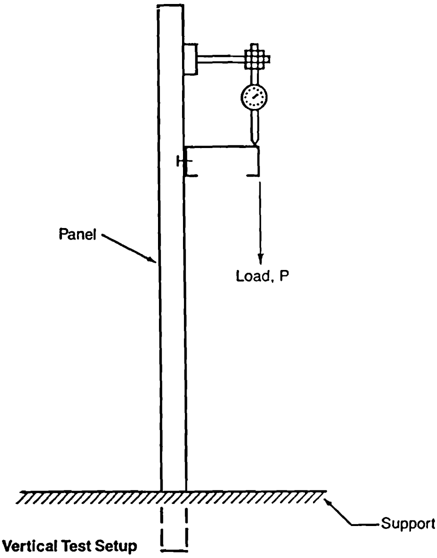


Figure 4 Vertical Test Setup

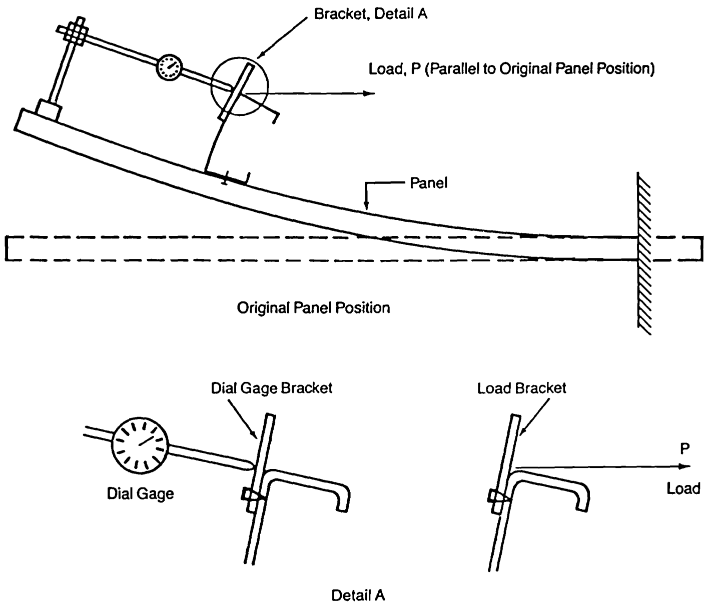


Figure 5 Dial Gage and Load Bracket

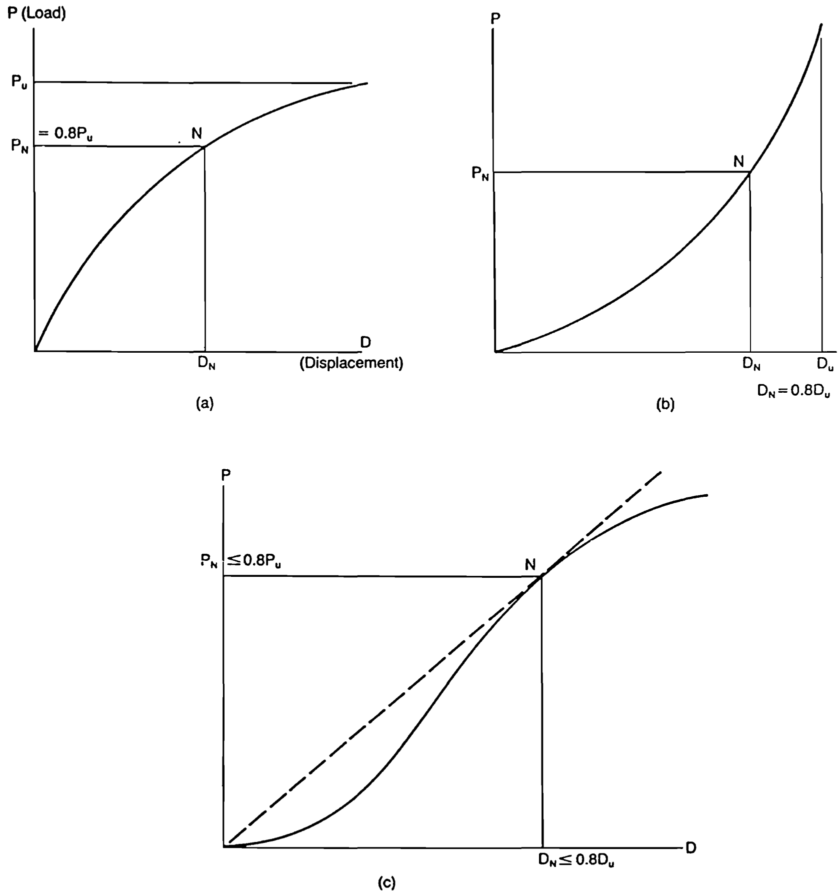


Figure 6 Typical Load-displacement Curves

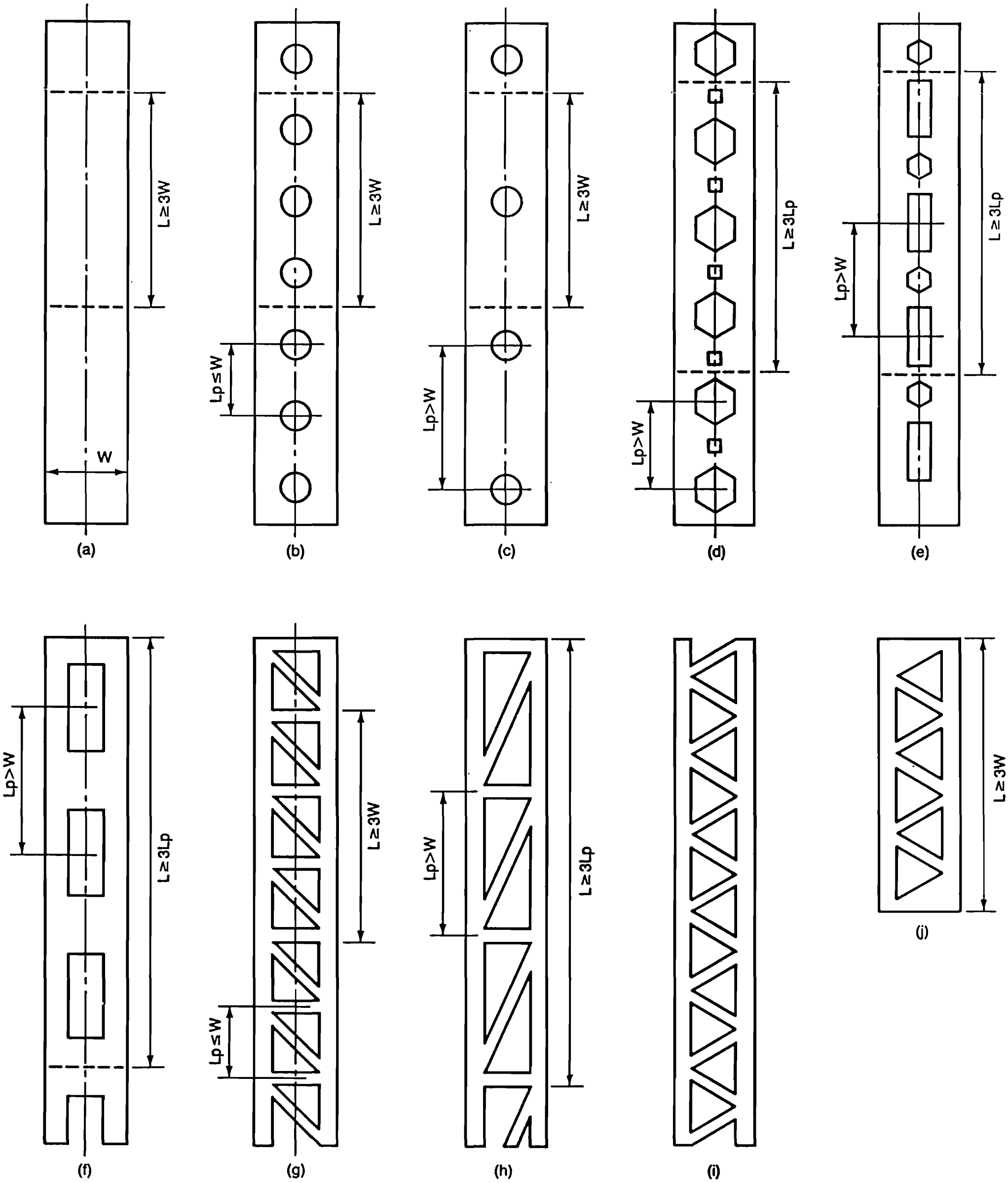


Figure 7 Hypothetical Perforation Patterns And Suggested Stub Column Lengths

NOTES: (1) Perforations shown are in a flat portion of a member with width W
(2) L = Length of Stub Column.
(3) L_p = Pitch Length of Perforation Pattern

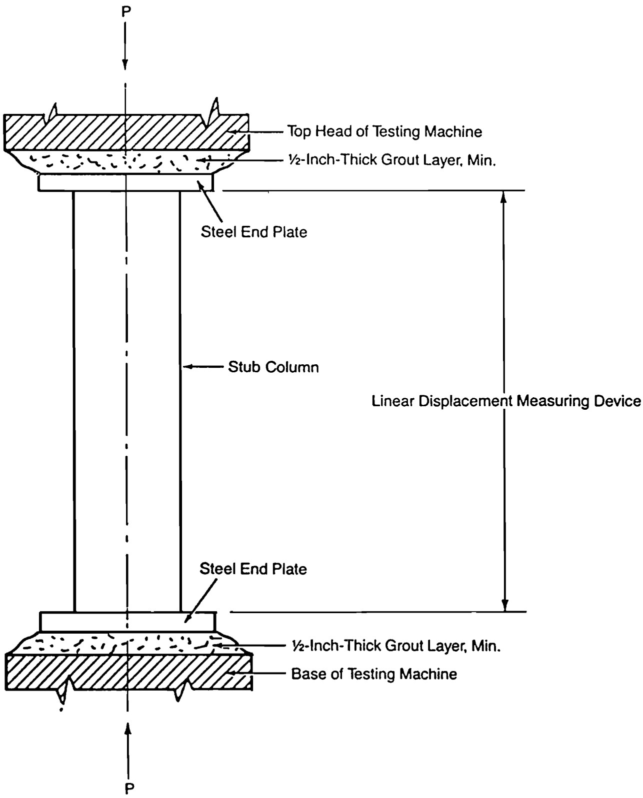


Figure 8 Test Setup