

AISI Test Procedures for Cold-Formed Steel Structural Members and Connections

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Abstract

Over time the American Iron and Steel Institute (AISI) has developed a series of test procedures for determining the strength, stiffness and properties of cold-formed steel members and connections. These test procedures provide both an alternative for designing cold-formed steel members and structures and effective tools for research and development. Since 2001, four new test procedures have been developed and four previously published test procedures have been updated. For the convenience in document referencing, a new clarifying numbering system was established for all the AISI test procedures. In addition, all the published AISI test procedures have been approved by the American National Standards Institute (ANSI) as American National Standards (ANS).

This paper provides an overview for the new developed test procedures and summarizes the changes made to the previously published ones.

Introduction

The *North American Specification for the Design of Cold-Formed Steel Structural Members* (NASPEC) permits the use of test results to determine the strength and stiffness of cold-formed steel members and connections when their composition or configuration is such that calculation of strength and/or stiffness cannot be made using the provisions of the NASPEC. The AISI test procedures provide means for determining design data in these situations. Standardizing test

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procedures also establish a common ground for researchers and manufacturers to share test results and ensure test quality.

In the 2002 edition of the *AISI Cold-Formed Steel Design Manual* (AISI 2002), an identifying numbering system was established as “AISI TS” followed by a sequence number and the year when the test procedure was published or updated. For all of the published test procedures prior to 2002, the year “2002” is assigned. A list of the current AISI test procedures, along with the corresponding identifying numbers, is found in Appendix 1.

Since 2001, four new test procedures, AISI TS-9 to AISI TS-12, were developed, and the existing test procedures, AISI TS-5 to AISI TS-8, were updated.

Summary of the Changes and Overview of the New Test Procedures

1. Updates of AISI TS-5, Test Methods for Mechanically Fastened Cold-Formed Steel Connections.

AISI TS-5 provides a series of methods for determining the strength and deformation of mechanically fastened connections for cold-formed steel building components. In the test procedure, the percentage difference between the maximum load and mean maximum load for requiring additional tests has been revised from 10 percent to 15 percent. This change is to bring this requirement into compliance with *Specification* Section F1.1, which allows for a 15 percent deviation.

2. Updates of TS-6, Standard Procedures for Panel and Anchor Structural Tests:

This test procedure extends and provides methodology for interpreting results of tests performed according to ASTM E1592, Standard Test Method for Structural Performance of Sheet Metal Roof and Siding Systems by Uniform Static Air Pressure Difference. In 2001, ASTM E1592 was updated with one of the major changes: the elimination of the option to test the boundary condition with both ends open. Reports from manufacturers using test results with the open-open end condition indicated that such tests formed the basis of adequate designs. As a result, AISI TS-6 was revised in 2004 to include the open-open end condition, in addition to the other end conditions in ASTM E1592-01. A table is added to the test procedure, which provides the minimum number of equal spans for both ends restraint, one end restraint and both ends open.

3. *Updates of AISI TS-7, Cantilever Test Method for Cold-Formed Steel Diaphragm*

This test procedure provides a cantilever test method for determining the shear strength and shear stiffness of a cold-formed steel diaphragm. Editorial changes were made to Figure 1 in the test procedure to better illustrate the simply supported boundary conditions of the deformed shape.

4. *Updates of AISI TS-8, Base Test Method for Purlins Supporting a Standing Seam Roof System*

Two approaches can be used to determine the strength of purlins supporting standing seam roof systems. One is to disregard the contribution of the lateral support provided by the roof system, and design the purlins considering only discrete lateral brace restraint. The second approach is to determine the strength with consideration of the contribution of the lateral bracing support from the standing seam roof system. The Base Test Method determines the degree of lateral support that the standing seam roof can provide by determining the strength reduction as compared to the strength of the fully braced purlin. The following changes and additions have been made to the test procedure:

- a. If the test is performed with the purlin flanges opposed, they must be field installed with their flanges opposed as well.
- b. A new figure was added, which shows how an intermediate brace that does not impede the vertical deflection during the test can be installed on the test specimen.
- c. Rational procedures are permitted to reduce the number of Base Tests when an inventory consists of different clip types; a specific purlin depth and profile having different flange widths; and identical panel profiles except purlin thickness. The change is based on the research work performed by Trout and Murray (2000).
- d. In a Base Test with purlins facing in the same direction and with the top flanges of the purlins not restrained, the term $2P_L(d/B)$ can only be added to the failure load, w_{ts} , when the downhill purlin is the first to fail, where P_L =required anchorage force; d =depth of purlin; and B =purlin spacing.

5. *New Test Procedure AISI TS-9, Standard Test Method for Determining the Web Crippling Strength of Cold-Formed Steel Beams*

The web crippling strength obtained from tests is related not only to the section profile and the loading condition, but also to specimen length, lateral restraints and configuration of the test setup. It is therefore important to have a standard

test procedure, such as TS-9, for web crippling tests to ensure comparable test results. This performance test method establishes procedures for conducting tests to determine the web crippling strength of cold-formed steel flexural members for conditions of Interior-One-Flange Loading (IOF), End-One-Flange Loading (EOF), Interior-Two-Flange Loading (ITF) and End-Two-Flange Loading (ETF). Illustrations for these loading conditions are provided in Figure 1. The test method is applicable to single-web, multiple-web and built-up web sections as shown in Figure 2. The test procedure provides guidance on how to setup the test specimen, perform the test, evaluate the test results, and finally prepare the test report.

6. *New Test Procedure AISI TS-10, Test Method for Distortional Buckling of Cold-Formed Steel Hat Shaped Columns*

Cold-formed steel hat section members are susceptible to distortional buckling. This test method establishes procedures for determining the distortional buckling strength for hat section members subjected to compression. To ensure the distortional buckling occurs, the specimen length, L , must be determined either analytically or experimentally. For the analytical approach, the distortional buckling half wavelength can be obtained using the finite strip method (AISI 2006) or other numerical methods. The test specimen length, L , must be at least four times the half wavelength, and must be tested between the flat ends. If the distortional buckling is not observed experimentally, the specimen length must be adjusted to achieve the distortional buckling mode, i.e., an array of tests of differing specimen lengths must be performed until the distortional buckling mode is observed or it is shown that the distortional buckling mode is not a controlling limit state. In addition to how to properly select the test specimen length, the test procedure also provides guidance on specimen preparation, column test procedure, determination of the strength based on test results, preparation of test report, and required test precisions.

7. *New Test Procedure AISI TS-11, Method for Flexural Testing Cold-Formed Steel Hat Shaped Beams*

This test procedure provides a method to experimentally determine the nominal strength of cold-formed hat section members. As illustrated by Figure 3, the test setup, it is critical to select the appropriate length, b , such that the interested buckling mode will be in control. The test procedure recommends that for local buckling, length “ b ” must be taken as at least three times the maximum flat dimension of the section; for overall buckling, length “ b ” must be based on the maximum in-place unbraced length of the actual member; and for distortional buckling, length “ b ” is to be determined either analytically or experimentally.

For the analytical approach, length “b” must be at least the distortional buckling half wavelength. If the distortional buckling mode is not observed, the test specimen length must be adjusted to achieve the distortional buckling. For the experiment approach, an array of tests of differing lengths must be performed until distortional buckling is observed. In addition, the test procedure also provides requirements for conducting the test, and what test data is to be included in the report.

8. *New Test Procedure AISI TS-12, Test Procedure for Determining a Strength Value for a Roof Panel-To-Purlin-To-Anchorage Device Connection*

Metal building roof systems need to be anchored to rafters due to tendency of sliding caused by down-slope components of gravity and external loads, as well as overturning caused by the eccentricity of down-slope components and resistance as illustrated in Figure 4. Because of many different types and methods of steel roof construction, it is not practical to develop a generic method to predict the strength of the roof panel-to-purlin-to-anchorage device connections. The interaction of the three components to an anchorage location is a complex phenomenon and highly indeterminate and a test is the only feasible way to determine the strength of the connections in the load path. This test method provides designers with a means of establishing a lower bound on the strength of the roof panel-to-purlin-to-anchorage connections. The test procedure is applicable to either through-fastened or standing seam, multi-span, multi-purlin line roof systems. To obtain the lower bound strength, a test setup capable of supporting simulated gravity loading is required. No fewer than three tests must be conducted for each roof panel-to-purlin-to-anchorage device system. The setup may consist of any number of purlin lines and any number of purlin spans, but all purlin flanges must face in the same direction. The anchorage system must be located along an external purlin line and may consist of any of the anchorage combinations specified in Section D3.2.1 of the *North American Specification for the Design of Cold-Formed Steel Structural Members* (2001, 2004). The lower bound strength of each roof panel-to-purlin-to-anchorage device connection used in the test is determined by calculating the anchorage force, P_L , at that location using the provisions in Section D3.2.1 of the NASPEC. The lesser of the load corresponding to a measured deflection of ½ in. (13 mm) at the top of the anchorage device or the maximum applied load in the test is used for this calculation. The following example illustrates how the lower bound strength is obtained based on test results of a standing seam roof panel-to-purlin-to-anchorage connection system.

Example for Determining the Lower Bound Strength of Roof Panel-to-Purlin-to-Anchorage Device:

A test setup with three continuous 25 ft spans, four Z-purlin lines, anchorage device connections at the rafters along one purlin line was loaded to failure using a vacuum test chamber to determine a lower bound strength for the standing seam roof panel-to-purlin-to-anchorage device connections. The AISI Test Procedure TS-12-05 is to be used to determine the ASD and LRFD lower bound strengths. The 8Z2.25x0.70 purlins failed at a load of 175 lb/ft. (2.55 kN/m). The deflection at the top of the anchorage devices did not exceed ½ in. (13 mm). The lower bound strength of the anchorage devices, P_{Ln} , are determined using the *North American Specification* Eq. D.3.2.1-5:

$$P_{Ln} = C_{tr} \left[\frac{0.053b^{1.85}L^{0.13}}{n_p^{0.95}d^{1.07}t^{0.94}} \cos \theta - \sin \theta \right] W$$

For the given example,

C_{tr} = 0.63 for end support devices and 0.87 for interior support devices;

d (depth of section) = 8 in. (203 mm);

b (flange width) = 2.25 in. (57.2 mm);

t (thickness) = 0.07 in. (1.78 mm);

L (span length) = 300 in. (7620 mm);

n_p (number of parallel purlin lines) = 4;

θ (angle between vertical and plane of web of Z-section) = 0 degree; and

W (total test load supported by purlin lines between adjacent supports =
175x25x4 = 17,500 lbs (77.84 kN).

Substituting the above values into the equation for P_L , the anchorage forces are 1939 lbs (8.62 kN) at the end supports and 2678 lbs (11.9 kN) for the interior supports. The ASD ($\Omega=1.67$) allowable design strengths for the standing seam panel-to-purlin-anchorage device connections are computed to be 1160 lbs (5.16 kN) at the end supports and 1600 lbs (7.10 kN) for the interior supports. For LRFD ($\phi = 0.9$), the design strengths for the standing seam panel-to-purlin-anchorage device connections are 1745 lbs (7.76 kN) at the end supports and 2400 lbs (10.7kN) for the interior supports.

Conclusion

Since the publication of the AISI test procedures in the 2002 Cold-Formed Steel Design Manual, some changes and additions have been made. This paper summarized these revisions to the previously published test procedures and provided an overview of the four new test procedures. The revised and the newly developed test procedures can be ordered through the AISI website at (www.steel.org).

References

American Iron and Steel Institute (2006), *Direct Strength Method Design Guide*, Washington, DC.

American Iron and Steel Institute (2004), *Supplement 2004 to the North American Specification for the Design of Cold-Formed Steel Structural Members*, 2001 Edition, Washington, DC.

American Iron and Steel Institute (2002), *AISI Cold-Formed Steel Design Manual*, 2002 Edition, Washington, DC.

American Iron and Steel Institute (2001), *North American Specification for the Design of Cold-Formed Steel Structural Members*, 2001 Edition, Washington DC, 2001.

American Iron and Steel Institute (1996), *Specification for the Design of Cold-Formed Steel Structural Members*, 1996 Edition, Washington DC.

Trout, A. M. and T. M. Murray (2000), "Reduced Number of Base Tests," Research Report CE/VPI-ST00/17 submitted to Metal Building Manufacturers Association, Department of Civil & Environmental Engineering, Virginia Tech, Blacksburg, VA.

Appendix 1 AISI Test Procedures

Designation	Title
AISI TS-1-02	Rotational-Lateral Stiffness Test Method for Beam-to-Panel Assemblies
AISI TS-2-02	Stub-Column Test Method for Effective Area of Cold-Formed Steel Column
AISI TS-3-02	Standard Method for Determination of Uniform and Local Ductility
AISI TS-4-02	Standard Test Methods for Determining the Tensile and Shear Strength of Screws
AISI TS-5-02	Test Methods for Mechanically Fastened Cold-Formed Steel Connections
AISI TS-6-02	Standard Procedures for Panel and Anchor Structural Tests
AISI TS-7-02	Cantilever Method for Cold-Formed Steel Diaphragm
AISI TS-8-04	Base Test Method for Purlins Supporting a Standing Seam Roof System
AISI TS-9-05	Standard Test Method for Determining the Web Crippling Strength of Cold-Formed Steel Beams
AISI TS-10-05	Test Method for Distortional Buckling of Cold-Formed Steel Hat Shaped Columns
AISI TS-11-05	Method for Flexural Testing Cold-Formed Steel Hat Shaped Beams
AISI TS-12-05	Test Procedure for Determining a Strength Value for a Roof Panel-To-Purlin-To-Anchorage Device Connection

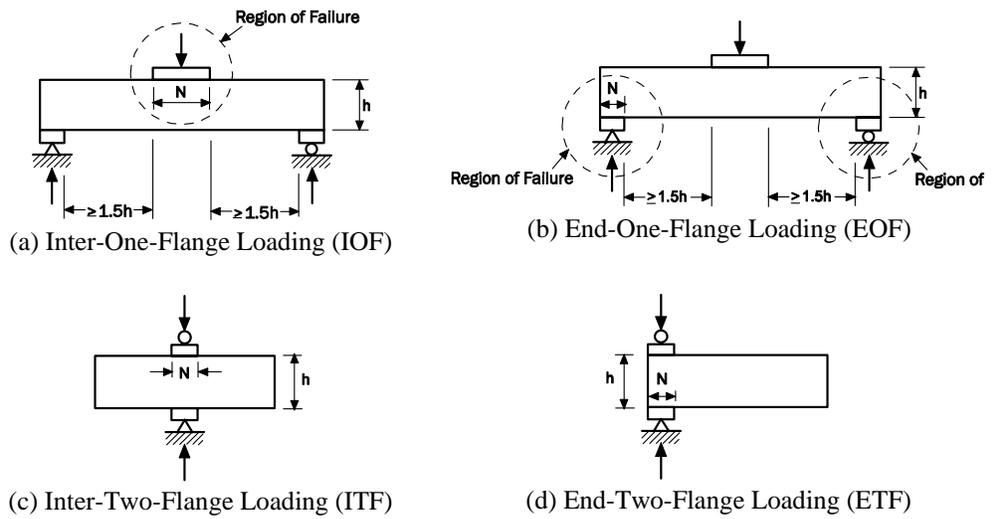


Figure 1 Loading Conditions

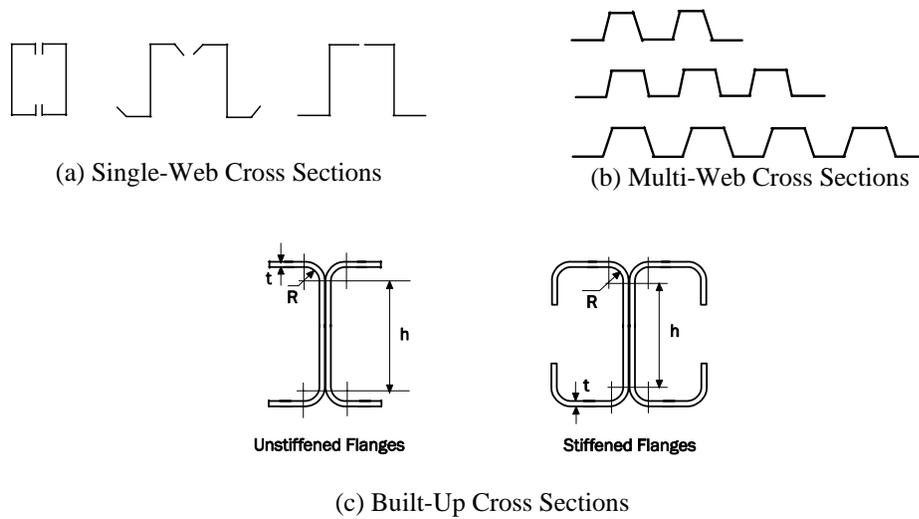


Figure 2 Cold-Formed Steel Cross Sections

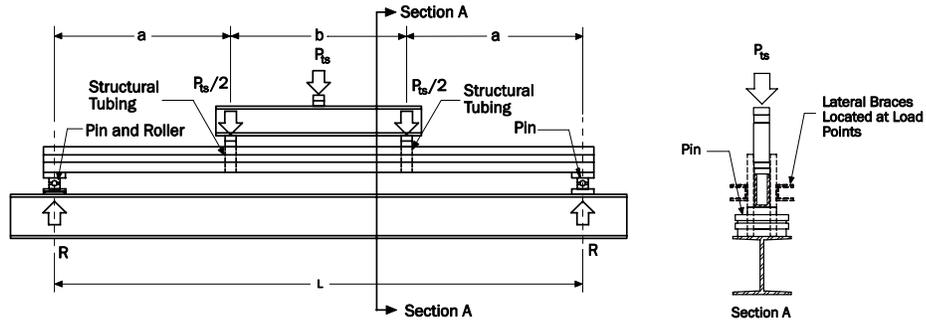


Figure 3 Simply Supported Beam Test

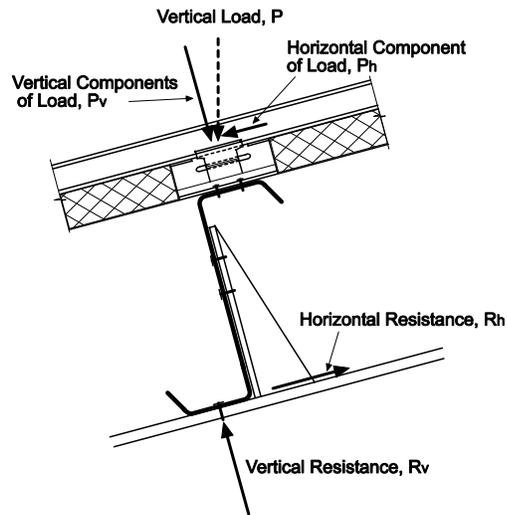


Figure 4 Force and Resistance on Panel-to-Purlin-to-Anchorage Connection