Using Cold-Formed Steel Members

Where Do I Begin?

By Roger A. LaBoube, Ph.D., P.E. and Brian Jaks, P.E.

A definition for cold-formed steel members, as given by both the AISI and AISC design specifications:
"Shapes manufactured by press-braking blanks sheared from sheets, cut lengths of coils or plates, or by roll forming cold- or hot-rolled coils or sheets; both forming operations being performed at ambient room temperature, that is, without manifest addition of heat such as would be required from hot forming."

Figure 1: Typical Framing.

For many years, cold-formed steel products have been used by pre-engineered building manufacturers for roof and wall framing. Although engineers are versed in the use and design of hot-rolled steel members, they are often clueless when it comes to the use and design of cold-formed steel members. However, a mixed structural framing system consisting of hot-rolled main frame members and cold-formed purlins and/or girts can translate into a highly competitive framing solution (*Figure 1*). The intent of this article is to address questions pertaining to the use of cold-formed steel members and to introduce resources that may be useful for the design of cold-formed steel members.

The first step in understanding cold-formed steel design is to not purge your brain of your understanding of hot-rolled steel design. Although hot-rolled members are designed by the *Specification for Structural Steel Buildings* (Specification, 2005) and cold-formed steel members are designed by the *North American Specification for the Design of Cold-Formed Steel Structural Members* (North, 2001), there are significant similarities between hot-rolled steel design and cold-formed steel design.

Why Consider Cold-Formed Steel Members?

Some of the advantages of cold-formed steel include:

1) No shop drawings required.
2) Erection can be performed by a carpenter, not an iron worker (historically steel thicker than 12 gauge has belonged to the ironworker).
3) Light weight.
4) Economy in transportation and shipping.
5) Fast and easy erection.
6) High strength-to-weight ratio.
7) Mass produced.
8) Easily out sourced.

Should I Use a C- or Z-Section?

The most commonly used cross section for a purlin or girt is the Z-section. The Z-section can be easily nested, thus creating a more compact bundle for shipping than can be achieved with the C-section. Also, the Z-section can be easily lapped and nested to achieve the economy of a continuous span purlin or girt. Continuity for the C-section can only be accomplished by connecting two C-sections back-to-back (*Figure 2*).

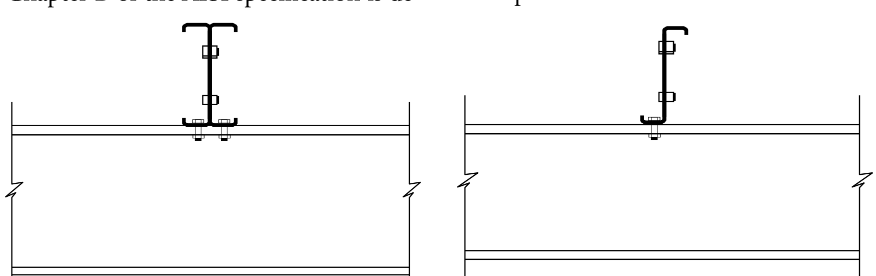
With a solid understanding of hot-rolled member behavior, the transition to cold-formed steel design can be reasonably straightforward. Both the girt and the purlin are flexural members, and therefore their design requirements for bending and shear are similar for both hot-rolled and cold-formed steel members. For a member that experiences local buckling, i.e. slender compression element, the design requirements for bending (M = S F) are based on yielding of the outer fibers, or lateral-torsional buckling. The difference between the American Insitute for Steel Construction (AISC) provisions and the American Iron and Steel Institute (AISI) provisions rest with the manner in which the two specifications consider local buckling. To reflect the local buckling influence, the nominal moment capacity in AISC is based on a reduced stress approach, whereas AISI uses a reduced area, $M_n = S_{xe}F_y$, where S_{xe} is the effective section modulus computed for the reduced area. Chapter B of the AISI specification is devoted almost solely to the evaluation of this effective area. Interestingly, the effective area concept in the AISI specification is similar to the effective area concept used by AISC in Section E7.2.

Although the equation formats differ, the web shear provisions in both the AISC and AISI specifications are virtually the same.

Local concentrated load effects are addressed by AISC in Section J10 for web local yielding or web crippling. Although the AISI equation in Section C3.4 for web crippling differs from the AISC equations, in concept both specifications consider the potential for the same limit states of web local yielding or web crippling beneath concentrated loads. Local concentrated load affects often govern the design for a cold-formed steel member because of the member's larger slenderness ratio, h/t.

Because of the slender webs, cold-formed steel members must also be evaluated for combinations of bending and shear, but plate girders also require such a design check in the AISC specification. Combined bending and web crippling is a design check that is unique to the AISI specification.

Stability bracing is critical to the successful performance of both hot-rolled and cold-formed steel members. However, because the cold-formed steel C- and Z-sections are not doubly-symmetric, the bracing requirements are more important. Both the C- and Z-section require bracing to achieve adequate structural performance.



(a) C-Section *(b) Z-Section*

Figure 2: Member Continuity and Nestability.

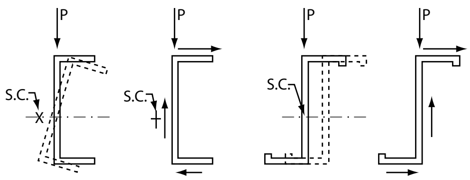


Figure 3: C- versus Z-Section Behavior.

Why Use Cold-Formed Steel Girts?

Whether one chooses a Z-section or a C-section, the cold-formed steel girt facilitates the erection of the wall system. For example, metal wall panels can be quickly and easily attached to the girt by using self-drilling screws.

For positive pressure, the girt is assumed to be laterally braced by the wall panel. For negative or suction loads, bracing (i.e. sag rods) is often not required. Section C3.1.3 of the *North American Specification for the Design of Cold-Formed Steel Structural Members* (North, 2001) provides a design methodology by which the wall panel and the screw connection of the wall panel-to-girt is used as a tension flange brace. The design methodology promulgated by Section C3.1.3 reduces the yield moment by using an empirically derived constant. The design methodology of Section C3.1.3 also applies to purlins attached to through-fastened roof panels.

When using cold-formed steel girts, it is important to recognize that these members are typically limited to maximum spans of about 30 feet. Thus, if a larger bay spacing is called for, an additional column may be required.

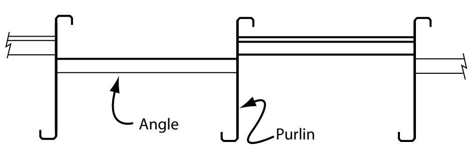


Figure 4: Typical Discrete Brace.

Why Is Purlin Bracing So Important?

When designing the doubly-symmetric W-shape section, bracing is required to prevent premature buckling. However, for the singly-symmetric C-shape, or the point-symmetric Z-shape, braces are required to provide lateral restraint to the cross section. The C-section will twist whereas the Z-section will translate. *Figure 3* shows the internal shear flow and the affect that these shear forces have on the behavior of the section. Thus, the importance of discrete braces as illustrated by *Figure 4*, or continuous bracing provided by roof panels, cannot be overstated.

In addition to discrete or continuous braces to restrain the individual member, the roof system as a whole must be anchored. This anchorage requirement results from the accumulation of the forces that are generated by each purlin, as illustrated by *Figure 5*. The required roof system restraint force, Σ F, that will achieve proper anchorage for the roof system is determined by AISI Section D3.2.1.

New design equations for determination of the required roof system restraint force have been adopted for the 2007 edition of the AISI specification (North, 2007). Also, a design guide is under development that will illustrate the proper application of these new design equations (Seek et al., 2008)

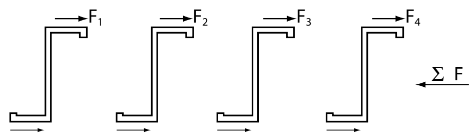


Figure 5: Accumulation of Forces.

Are All Roof Panels Equal?

Although the primary function of a steel roof panel is to provide enclosure for the building, they differ significantly in their structural performance. There are two general families of steel panels: the through-fastened roof panel and the standing seam roof panel.

The though-fastened roof panel can provide restraint bracing to the top compression flange of a girt or purlin. The diaphragm strength and stiffness of the cold-formed steel panel can be assessed by either test or calculation. A generally accepted methodology for calculation of panel diaphragm behavior is given by the Metal Construction Association (Luttrell and Mattingly, 2004). AISI TS-7-02 is the recognized test protocol for cold-formed steel diaphragms.

The standing seam panel is a floating roof panel that is generally only attached to the purlin at the roof eave. Because the standing seam panel has neither through fasteners that secure the panel to the supporting purlin nor sheet-to-sheet side-lap fasteners, the panel lacks significant diaphragm strength and stiffness. Thus, purlins supporting standing seam panels must be either designed for discrete bracing or their moment capacity must be defined by test. AISI Section C3.1.4 contains the guidelines for design of purlins having one flange attached to a standing seam panel.

For design, a roof or wall panel is assumed to be a flexural member. Thus, the same design limit states as previously discussed for the C- and Z-section apply: bending, shear, and local concentrated load affects. Although the limit states are the same, the evaluation of these limit states differs for the through-fastened and standing seam panel. Both the gravity load and wind uplift load design strength for the through-fastened panel can be evaluated using the same design equations that would be applied to the purlin or girt. For gravity loads, the standing seam panel can also be evaluated using the same design equations as for the purlin. However, the standing seam panel, because of its unique and often proprietary connections to the either the purlin or seam-to-seam, requires a full-scale test to assess its wind uplift performance as stipulated by AISI Section C3.1.5.

What Are Appropriate Design Loads?

A successful design begins with the appropriate estimate of the applicable design loads. Loads that are of particular interest are roof live load, snow load, and wind load. There are two national building codes developed by the International Building Code (IBC) and the

National Fire and Protections Association. Fortunately, the design loads are very similar in both of these codes because they reference the American Society of Civil Engineers *Minimum Design Loads for Buildings and Other Structures*, ASCE/SEI 7-05. Guidance on the interpretation and application of the IBC loads is provided by the *Metal Building Systems Manual* (2006).

Where Can I Find Design Information?

Design information can be found in several publications and on several websites. The online version of this article conains references and a list of websites. (**www.STRUCTUREmag.org**)

Conclusion

By utilizing a mixed structural framing system consisting of hot-rolled steel main frame members and cold-formed steel purlins and/or girts can translate into a highly competitive framing solution. The proper and appropriate use of both hot-rolled steel and cold-formed steel members can result in a successful building package.▪

Acknowledgements

The authors extend appreciation to Larry Jeffords, Terry Zwick, and Jim Fisher for their input during the preparation of this article. An excellent introduction, and a must read, for incorporating cold-formed steel members into your building projects is *Industrial Buildings Roofs to Anchor Rods* by Dr. J.M. Fisher. Some information contained herein was paraphrased from Dr. Fisher's document.

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