Engineer's Notebook

aids for the structural engineer's toolbox

Built-Up Cold-Formed Steel Compression Member Design

By Roger LaBoube, Ph.D., P.E.

Built-up cold-formed steel compression members are commonly used as shear wall chord members, and at openings of doors and windows (stud packs) to resist the additional load transferred from an opening header. The provisions in *North American Specification for the Design of Cold-Formed Steel Structural Members*, AISI S100 Section D1.2 are limited to concentrically loaded compression members composed of two shapes joined together at discrete points along the axis of the member. Thus, the AISI S100 provisions are limited to either an I-shaped cross section or a box-shaped cross section.

Today there are various assumptions employed when designing the stud packs. An often employed assumption by inexperienced cold-formed steel design engineers is that each stud in a stud pack has the same tributary area as a typical wall stud. What this assumption consists of is adding studs to the stud pack equal to the number of studs displaced by an opening. Thus, the stud pack is not engineered but, in fact, is simply assembled to provide an equal number of studs as if the opening did not occur. This assumption can be both uneconomical and can result in poor framing designs as illustrated by *Figure 1*.

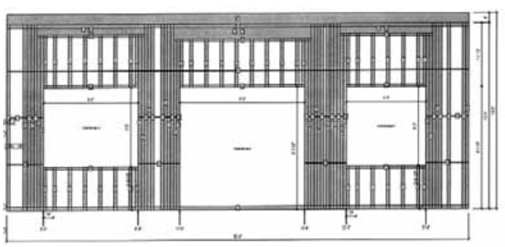

Figure 1.

Another questionable assumption made by inexperienced cold-formed steel design engineers is that the axial load is shared equally to each individual member of the stud pack, and each member's strength is based on the behavior as a discrete member. Making this assumption can lead to a suspect load path or an uneconomical, design as any synergy of the individual stud pack members is not accounted for in the design.

The following discussion introduces design concepts and practical considerations for built-up member design, for which AISI S100 and AISI framing standards, AISI S211 *North American Standard for Cold-Formed Steel Framing – Wall Stud Design* have specific design provisions.

Design Methodology

Built-up compression members interconnected at discrete points have a reduced shear rigidity which reduces the buckling stress of the member. To reflect the reduced shear rigidity, AISI S100 Section D1.2 requires the use of a modified slenderness ratio, $(KL/r)_m$ as follows:

where

$$\left(\frac{KL}{r}\right)_m = \sqrt{\left(\frac{KL}{r}\right)_o^2 + \left(\frac{a}{r_i}\right)^2}$$

$(KL/r)_o$ = Overall slenderness ratio of entire section about built-up member axis

a = Intermediate fastener or spot weld spacing

r_i = Minimum radius of gyration of *full unreduced cross-sectional area* of an individual shape (single C-section) in a built-up member

Note, the modified slenderness ratio is only applied to the buckling axis that requires the interconnecting fasteners to transfer shear. For an I-shaped section, this means the $(KL/r)_y$ axis is the slenderness ratio to be modified. The $(KL/r)_x$ axis is not modified.

When applying the modified slenderness ratio, the following additional the fastener *strength* [*resistance*] and spacing shall be satisfied:

1) The intermediate fastener or spot weld spacing, a, is limited such that a/r_i does not exceed one-half the governing slenderness ratio of the built-up member.
2) The ends of a built-up compression member are connected by a weld having a length not less than the maximum width of the member, or by connectors spaced longitudinally not more than 4 diameters apart for a distance equal to 1.5 times the maximum width of the member.
3) The intermediate fastener(s) or weld(s) at any longitudinal member tie location are capable of transmitting *required strength* [factored forces] in any direction of 2.5 percent of the *available axial strength* [*factored resistance*] of the built-up member.

AISI S211 requires that if the above criteria are not met, the design strength of the built-up member shall be taken as the sum of the individual members of the built-up section.

AISI S100 Section D1.2 imposes stringent connection requirements for the ends of built-up members (requirement 2 above). However, based on research, the following provision has been adopted for the next edition of the AISI framing standards which will combine the current framing standards into one document, *North American Standard for Cold-Formed Steel Structural Framing* AISI S240:

> Exception: Where a built-up axial load bearing section comprised of two studs oriented back-to-back forming an I-shaped cross-section is properly seated in a track in accordance with the requirements of Section C3.4.3, and the top and bottom end bearing detail of the studs consists of full support by steel or concrete

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components with adequate strength and stiffness to preclude differential end slip of the built-up studs, the compliance with the end connection provisions of AISI S100 Section D1.2(b) is not required.

The current framing standards are a free download from **www.aisistandards.org**.

Example Problem

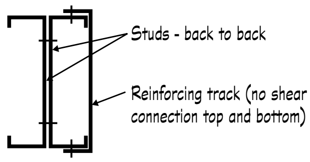

Figure 2.

A typical 9-foot jamb stud as shown consisting of two 600S162-54 (50 ksi) sections interconnected by two self-drilling screws 24 inches on center in the web (*Figure 2*). The track section is not considered to be a structural member to resist axial loads, but is needed to create a closure for the opening at the door or window. Weak axis bracing (in the plane of the wall) is provided at 4-foot intervals.

$L_x = 9$ ft, $L_y = L_t = 4$ ft

Properties:
Single 600S162-54, $r_y = 0.5699$ inch

Double 600S162-54, $r_x = 2.2677$ inches, $r_y = 0.7042$, a = 24 inches (center to center spacing of web fasteners)

KL/r for the y-axis,

$$\left(\frac{KL}{r}\right)_m = \sqrt{\left(\frac{KL}{r}\right)_o^2 + \left(\frac{a}{r_i}\right)^2}$$

$= [(48/0.7042)^2 + (24/0.5699)^2]^{0.5} = 80.12$

KL/r for the x-axis,

$(KL/r)_x = (9 \times 12)/2.2677 = 47.63$

The y-axis slenderness ratio controls the axial capacity.

$$F_e = \frac{\pi^2 E}{(KL/r)^2} = 45.35 \text{ ksi}$$

$$\lambda_c = \sqrt{\frac{F_y}{F_e}} = 1.05$$

For $\lambda_c \leq 1.5$

$F_n\ (0.658^{\lambda_c^2})F_y = 31.52$ ksi

The effective area, A_e, is computed at $f = F_n$, $A_e = 0.7010$ square inches

$P_n = F_n A_e = 31.52$ ksi x 0.7010 in^2 = 24.93 kips

Available Strength, $P_a = P_n/\Omega = 24.93$ kips/1.80 = 13.85 kips

A design consideration is the spacing of the web connectors which will influence both load capacity and economics as summarized:

"a" (inches)	"Pa" (kips)
24	13.85
18	14.50
12	14.99

The design engineer should carefully consider if the increased load will provide the most economical design solution because of the added labor expense of providing screws at a closer spacing.

When creating built-up sections, orientation of the individual members should be considered. For example, if two 600S162-54 (50 ksi) sections were oriented in a box configuration (*Figure 3*), with the toe-to-toe welds spaced 24 inches on center, the available strength, P_a, is 16.92 kips vs 13.85 kips for the I-section configuration. Furthermore, the I-section configuration requires the additional track section for the jamb closure.

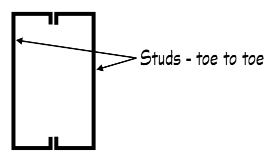

Figure 3.

Check the following additional the fastener and spacing requirements:

1) The intermediate fastener or spot weld spacing, a, is limited such that a/ri does not exceed one-half the governing slenderness ratio of the built-up member.
   $a/r_i = 24/0.5699 = 42.11$
   $0.5(KL/r) = 0.5\ (80.12) = 40.06$
   Although the a/r_i is 5% larger than one-half the governing slenderness ratio of the built-up member, the 24-inch spacing is deemed to be acceptable. This criteria is to ensure that the individual member will not buckle prior to overall buckling of the built-up member. The additional track section, as well as sheathing attached to both flanges of the individual member, will enhance its buckling strength.
2) The ends of a built-up compression member are connected by a weld having a length not less than the maximum width of the member, or by connectors spaced longitudinally not more than 4 diameters apart for a distance equal to 1.5 times the maximum width of the member. The built-up member will be properly seated in track sections top and bottom, thus by utilizing the provision of AISI S240, additional fasteners are not required.
3) The intermediate fastener(s) or weld(s) at any longitudinal member tie location are capable of transmitting *required strength* [factored forces] in any direction of 2.5 percent of the *available axial strength* [*factored resistance*] of the built-up member.
   Using No. 12 self-drilling screws, the nominal shear capacity of a screw is 1.29 kips. The available strength of a screw is 1.29 kips/3.0 = 0.86 kips per screw. Where 3.0 is the safety factor.
   2.5% x 13.85 kips = 0.35 kips < 0.86 kips, Okay!

Practical Considerations

Specific design methodology for two members interconnected is presented here, but in many cases more than two members are used to create a stud pack. The following are design thoughts offered by several experienced cold-formed steel design engineers:

- The design varies from job-to-job based on the contractor preference and politics (e.g. on some union jobs, the cold-formed steel contractor can't install HSS thicker than ⅛-inch – iron worker vs carpenter unions).
- Where we see a pair of 97-mil, S200 or bigger studs, our firm starts thinking HSS. The cost of buying two (2) heavy studs and then welding them together seldom makes sense when compared to buying a tube.
- Our firm is not a big fan of triple or more built-ups both due to cost and, in the case of jamb stud packs, the notion that equal load-sharing is questionable for the studs away from the opening.
- Our firm limits studs to a maximum of three (3) in a stud pack because of concern that equal load sharing does not occur as well as the economics of fabricating the stud pack. Our firm uses a light-weight welded I-section whenever three (3) studs are not adequate. Also, we do not change the thickness of the stud in the panel to create a stud pack. If the panel consisted of 6-inch 54 mil studs, we limited the stud pack to three 6-inch 54 mil studs; we did not up the thickness of the column studs.

Giving consideration to load path and fabrication costs can help cold-formed steel design engineers to develop the most efficient cold-formed steel wall framing assembly.▪