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TECHNICAL NOTE

On Cold-Formed Steel Construction

CFSEI COLD-FORMED STEEL ENGINEERS INSTITUTE

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BASIC C-SHAPED WALL STUD BEHAVIOR

Summary: Although cold-formed steel framing shares some limit states with hot-rolled steel, cold-formed steel framing and specifically C-Shaped studs exhibit unique behaviors when subjected to various loading conditions. This Tech Note gives an overview of those unique behaviors that need to be considered when designing C-Shaped cold-formed steel members.

Cold-formed steel (CFS) wall studs experience limit states similar to hot-rolled steel beam and column members; however, the thickness and singly-symmetric shape may create different controlling strength limit states. Unlike thicker doubly-symmetrical hot-rolled steel shapes, CFS wall studs have larger slenderness ratios and may experience local buckling (web, flange, or stiffening lip) or global buckling of the member (Kl/r). This Tech Note reviews the most prevalent limit states of C-Shape wall studs and provides resources for further understanding of each limit state. This is an overview and does not discuss the limit state of combined flexural and axial loaded stud members nor the implications of sheathing braced design vs. all-steel design. Refer to AISI S240, Section B3 and AISI S100, Sections E, F, and G for complete requirements.

(Note: AISI S240-15, *North American Standard for Cold-Formed Steel Structural Framing, 2015 Edition* references AISI S100-12, *North American Specification for the Design of Cold-Formed Steel Structural Members, 2012 Edition*. Since AISI S100-16, *North American Specification for the Design of Cold-Formed Steel Structural Members, 2016 Edition* has been adopted by IBC 2018, this Tech Note references AISI S240-15 and AISI S100-16.)

Typical CFS Curtain-Wall Design Limit States:

Curtain-wall studs typically refer to wall studs that resist exterior wind loading, but do not carry superimposed axial loads from floors, roofs, or other primary structure elements. Curtain-wall studs must resist shear, bending, web crippling and meet deflection limitations. They must also resist some axial loading but are primarily designed as flexural members. Axial loading from the wall assembly self-weight is often negligible relative to its axial strength with light to moderate cladding weight like a metal panel or EIFS finish. If heavy finishes (large stone or brick) are used, the design must consider combined bending and axial interaction when analyzing the curtain-wall studs.

The following strength limit states apply to curtain-wall studs *[AISI S240, Section B3.2]:*

1. **Shear *[AISI S240, Section B3.2.3]***
   Wall stud available shear strength is often much higher than required shear strength. Other limit states will almost always control over shear alone, but shear and bending interactions can control multi-span members or those with cantilevers.

2. **Yielding *[AISI S240, Section B1.2.2.3]***
   Yielding may occur first when the studs are braced to prevent the global buckling limit state. If a typical wall is braced by sheathing or by discrete braces at 4’-0” OC, a stud may fail by this limit state prior to global buckling.

3. **Local Buckling**
   [No specific AISI S240 reference exists because local buckling is addressed by using the effective section modulus in the flexural strength calculations.] The web or flange can locally buckle as partially stiffened or unstiffened plate elements (Figure 1). The interaction of this buckling with global buckling can control the capacity.

4. **Distortional Buckling [1,2]** ***[AISI S240, Section B3.2.2.2]***
   The lip stiffener may not prevent the flange and adjoining web corner from becoming unstable (Figure 1). AISI S100 has design provisions that can be used to predict this limit state. This buckling mode may be reached prior to the yielding or lateral-torsional buckling limit states when the flange/web juncture is adequately restrained. AISI allows distortional buckling checks to consider additional restraint from attached sheathing [G101-08].

5. **Lateral-Torsional Buckling (Global)** ***[AISI S240, Section B3.2.2.1]***
   The singly-symmetric shape deflects with respect to its major axis and rotates about its shear center and may become unstable (Figure 1).

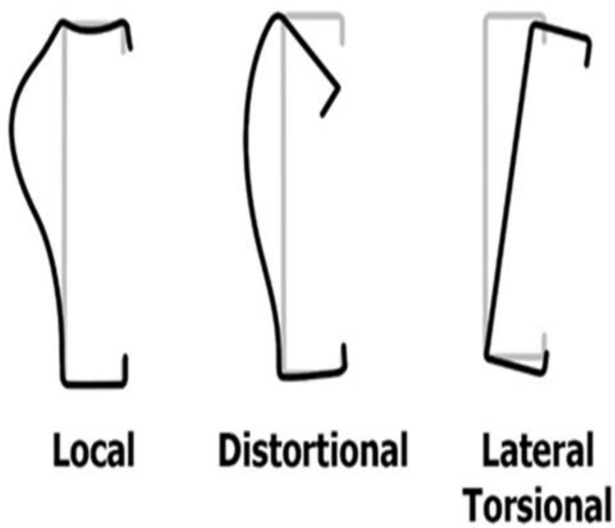

Figure 1: CFS Buckling Modes (Major Axis Bending)

6. **Web Crippling** ***(Figures 2-3) [AISI S240, Section B3.2.5]***
   This limit can be seen at point loads, supports, or any point loaded location on the stud. It is often mitigated by utilizing clips, web stiffeners, or other connection methods to reinforce the location where web crippling may control. The various loading conditions and failure modes can be seen in Figures 2 and 3 below. Web crippling must also be checked for combined bending and web crippling.

Figure 2: Interior-One-Flange Load Web Crippling

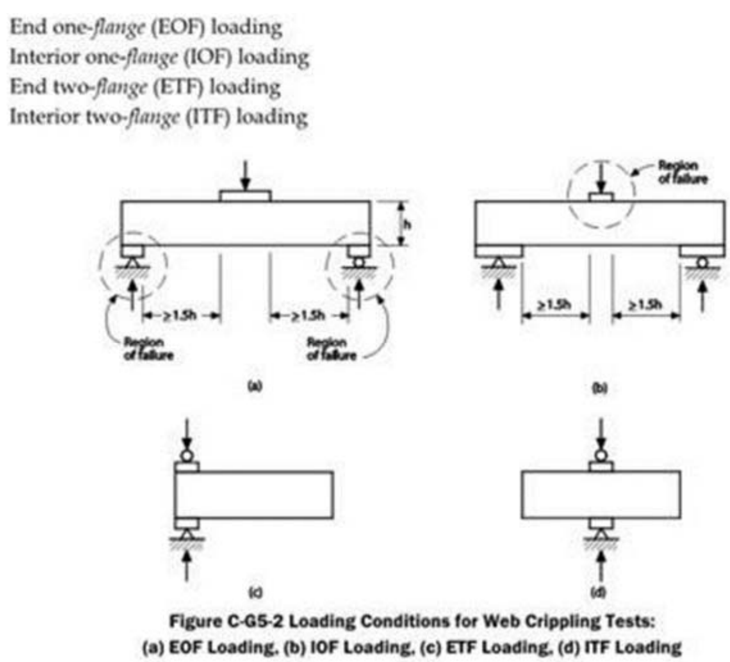

Figure 3: Loading Conditions for Web Crippling Tests
(AISI S100-16, Figure C-G5-2)

Typical CFS Bearing Wall Design Limit States *[AISI S240, Section B3.2.1]:*

Axial load bearing studs typically resist superimposed gravity loads from the primary structure. This is often encountered when CFS walls must support a floor or roof above including all dead and live loads. Exterior load bearing studs must be designed for a combination of axial and wind load resistance. Interior studs do not receive exterior wind loads, but must resist a minimum 5 psf differential pressure along the wall in combination with all gravity loading conditions.

Unlike non-bearing exterior wall studs, bearing wall studs are more often controlled by strength limit states over deflection limits, so designing in LRFD may lead to some economy in certain circumstances. It is important to remember that deflection can still control bearing wall studs. An example would be a wall supporting roof loads in a high wind region; the roof loading may be low enough relative to the lateral wind loading that the stud deflection controls.

In addition to the limit states noted above, the following limit states will typically be considered in an axial load bearing wall design.

1. **Global Buckling *[AISI S240, Section B3.2.1.1] (Figure 4)***
   Bracing of studs may prevent the weak axis and torsional-buckling from controlling the design so the strong axis buckling resistance can be better utilized. This includes flexural and flexural-torsional buckling.

2. **Local Buckling**
   [No specific AISI S240 reference exists because local buckling is addressed by using the <u>effective</u> area in the axial strength calculations.] Wall stud strength is often controlled by flexural or flexural-torsional buckling due to their slenderness ratio, but this buckling limit state interacts with local buckling to lower the member capacity.

Figure 4: Flexural Buckling About the Minor Axis

3. **Distortional Buckling *[AISI S240, Section B3.2.1.2] (Figure 5)***
   The stud flanges rotate about their flange-web junction. Similar bracing methods used for flexural-distortional buckling also restrain axial distortional buckling. AISI S100 has equations for the prediction of the strength.

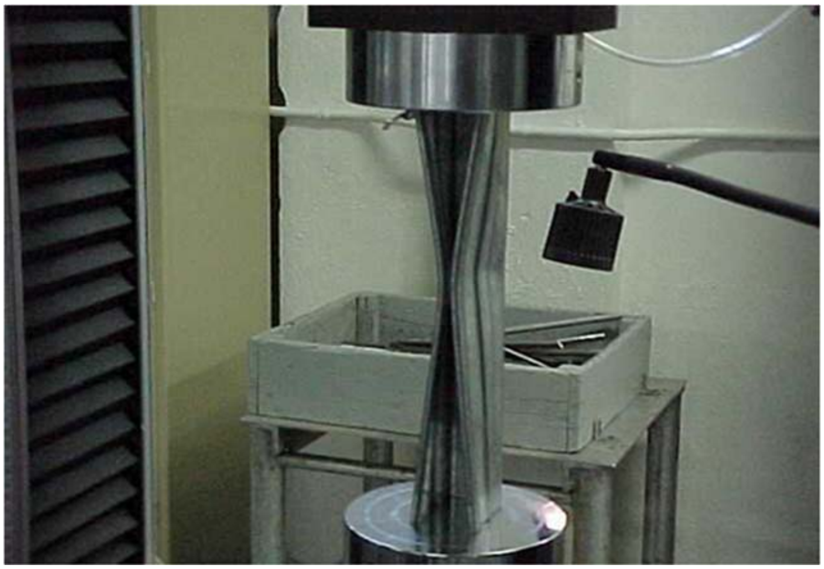

Figure 5: Distortional Buckling of Compression Member

Note: AISI S100 requires potential reduced capacity be checked due to local buckling interacting with yielding and global buckling for members in flexure and in compression (See AISI S100, Section F3 for flexural and AISI S100, Section E3 for compression).

REFERENCES

<u>Design Aids:</u>

For wall stud design examples, CFSEI and AISI have developed the following:

- Tech Note W102-12: *Introduction to Curtain Wall Design Using Cold-Formed Steel*
- AISI D110-16, *Cold-Formed Steel Framing Design Guide - 2016 Edition*
- AISI D112-13, *Brick Veneer Cold-Formed Steel Framing Design Guide, 2013 Edition*
- AISI D113-19, *Cold-Formed Steel Shear Wall Design Guide, 2019 Edition*

<u>Code References:</u>

- AISI S240-15, *North American Standard for Cold-Formed Steel Structural Framing, 2015 Edition*
- AISI S100-16, *North American Specification for the Design of Cold-Formed Steel Structural Members, 2016 Edition*

Other CFSEI Resources:

- Tech Note G101-08: *Design Aids and Examples for Distortional Buckling (Formerly G100-9)*
- Tech Note G103-11a: *Tabulated Local and Distortional Elastic Buckling Solutions for Standard Shapes*
- Tech Note G104-14: *Welded Box-Beam Flexure Design*
- Tech Note TN-559: *Design Considerations for Flexural and Lateral-Torsional Bracing*
- CFSEI Framing Design Webinars (https://cfseiondemand.com/online-courses/)

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