

INTRODUCTION TO CURTAIN WALL DESIGN USING COLD-FORMED STEEL

This Technical Note updates and replaces LGSEA Technical Note 542.

Summary: A curtain wall can be defined as a non vertically loaded exterior wall (aside from self weight) supported by the primary structural frame of the building. When it comes to cold-formed steel framing, this definition can encompass a great many possible assemblies and applications. This Tech Note discusses the various structural elements of a curtain wall system, and introduces the subjects of Design Loads and Framing Analysis.

Disclaimer: Designs cited herein are not intended to preclude the use of other materials, assemblies, structures or designs when these other designs and materials demonstrate equivalent performance for the intended use; CFSEI documents are not intended to exclude the use and implementation of any other design or construction technique.

INTRODUCTION

Since the introduction of metal and glass curtain wall systems in the early 1900s, they have become very popular in the architectural design of modern structures. These light-weight exterior claddings are often framed with cold-formed steel and use various architectural exterior

finishes. Curtain walls are attached to the primary frame of the building structure and are designed to accommodate structural deflections, including those generated by wind and seismic forces, to control environmental infiltration or leakage, and to provide long-term, low-maintenance performance.

SECTION 1: DEFINITIONS:

While not all-encompassing, the following list of basic definitions of various cold-formed steel curtain wall components may be helpful to the designer. Definitions with an asterisk are from AISI S100-07 or AISI S200-07.

A. Components

A.1 Angles

*A.1.1 Clip Angle:** An L-shaped short piece of steel (normally with a 90-degree bend) typically used for connections.

A.1.2. Continuous Angle: A steel angle that makes the transition between a stud curtain wall and the primary frame. The angle is typically of hot rolled thickness (3/16 to 3/8 inch) however thinner materials can be used if the span and load requirements are relatively small.

A.2 Bracing (Bridging)* Structural elements that are installed to provide restraint or support (or both) to other framing members so that the complete assembly forms as a stable structure.

Cold-rolled channel, flat strap, and solid blocking are commonly used for bracing members.

A.3 Diagonal brace (Kicker) A sloping brace used to provide lateral support to a curtain wall assembly. When installed horizontally, this brace is referred to as a strut.

A.4 Embed A hot-rolled steel plate or angle with shear studs or steel rebar attached which is cast into a concrete floor or beam allowing for the attachment of continuous support angles.

A.5 Fasteners Self-drilling screws are the most common fastener type used. For information pertaining to screws refer to the CFSEI Tech Note – F102-11, “Screw Fastener Selection for Cold-Formed Steel Frame Construction.”

A.6 Girt* Horizontal structural member that supports wall panels and is primarily subjected to bending under horizontal loads, such as wind load.

In steel stud spandrel wall construction, a continuous hot-rolled steel section is often designed to clear span between adjacent columns to serve as a support for wind forces acting on the stud wall. Use of a girt may result in the elimination of labor intensive diagonal kickers.

A.7 Slide Clip A connection device which permits deflection of the primary frame to which a stud attaches.

Slide clips or deflection enabling devices, may be proprietary connectors that permit either vertical or vertical and lateral drift.

A.8 Deflection Track* (Slip Track) A track manufactured with extended flanges and used at the top of a wall to provide for vertical movement of the structure independent of the wall stud. For design guidance consult CFSEI Technical Note TN W100-08a, Single Slip Track Design.

A.9 Structural Member (Structural Stud)* A member that resists design loads as required by the applicable building code, except when defined as a non-structural member.

A structural stud is a C-shaped section, generally formed from 33 mil and thicker steel sheet. The stud resists both wind load and dead load (weight of the materials attached to it). Stud spacing is a function of the exterior wall finish system, the applied loading and the structural properties of the stud.

The cross-section geometry for standard member is defined by AISI S201 *North American Standard for Cold-Formed Steel Framing - Product Data* (2007). Flange dimensions typically vary from 1-3/8 to 2 inches. A minimum 1-5/8 inch flange C-shape is most often specified. Studs with narrower flanges can make field installation of masonry ties or sheathing products more difficult.

The minimum yield strength for a structural stud is 33 ksi. Conditions requiring higher yields (i.e. 50 ksi) include installations where the combination dead and wind loads dictate its use. The thickness of the stud is predicated by engineering design, although the following minimum thicknesses are common:

* 33 mil framing components are permissible in in-fill wall applications involving self-drilling screw attachments.

* A minimum 43 mil member is suggested wherever welding of any cold-formed product is desirable.

The brick Institute of America's BIA Tech Note 28B, mandates the use of minimum 43 mil product in any brick veneer/steel stud application.

Out-of-plane deflection often controls the selection of curtain wall framing components; increasing member depths has beneficial results. For example, a 6 inch stud x 43 mil stud (designated as 600S162-43) ($I_x = 2.3 \text{ in}^4$) has approximately 3 times the stiffness of a 3-5/8" x 43 mil

stud (or 362S162-43) ($I_x = 0.71 \text{ inch}^4$). The weight and thus cost differences between the two, however, may not be as significant.

A.10 Track (or Runner)* A framing member consisting of only a web and two flanges. Track web depth measurements are taken to the inside of the flanges.

B. Finish Systems

Finish Systems applied to steel stud frames include:

B.1 Brick Veneer A single wythe of brick that is laterally, and sometimes vertically supported by the steel framing system. Components exclusive of the framing system include: Brick, mortar, water repellent exterior sheathing, masonry wall ties, weep holes, shelf angles, joints and joint sealants, flashing, insulation, air spaces and vapor barriers. Additional design guidance may be found in AISI CF03-1 *Steel Stud Brick Veneer Design Guide*.

B.2 Ceramic Tile Components exclusive of the framing system include: Acrylic latex grout, ceramic tile keyed to assure bonding to the mortar, acrylic latex modified dry set mortar, modified Portland cement mortar, diamond mesh metal lath, water repellent exterior sheathing, joints and joint sealants, insulation, and vapor barriers.

B.3 Exterior Insulation Finish Systems (EIFS) A light-weight energy efficient exterior wall product, which gives the appearance of stucco or precast concrete. Components exclusive of the framing system include: Polymer or polymer modified base and finish coats, with a metal lath or fiber glass reinforcement, expanded or extruded polystyrene or styrofoam insulation, water repellent exterior sheathing, joints and joint sealants, cavity insulation, and vapor barriers.

B.4 Glass Fiber Reinforced Concrete (GFRC) A composite product which is manufactured using a cement/aggregate slurry reinforced throughout with alkali resistant glass fibers.

Methods of manufacture vary but spraying either by hand equipment into a form of the desired shape and size, or mechanically on a production line are most common.

GFRC panels have high impact load resistance, are non-combustible, light weight, and offer a wide range of surface treatments. Because it is formed, a GFRC panel permits free architectural expression. Clip angles and dowels are used to make the transition between the stud frames and the GFRC panel.

B.5 Metal Panel Factory painted profiled/corrugated steel panels, furnished in single sheets or with a core ma-

material composed of isocyanurate insulation, urethane or wafered aluminum. Architectural finishes are available.

B.6 Modified Portland Cement (Stucco) Portland cement, water, sand and a small quantity of lime (Portland cement plaster) used on exterior surfaces. The finish is anchored to the supports with expanded metal lath attached over a water-resistant sheathing product to the stud frames.

Other systems include thin-cast brick, dimensional stone such as granite or limestone, wood siding, etc.

C. Related Elements

C.1 Caulking The sealing of a joint in a curtain wall assembly, (prefabricated panels, brick veneer, etc.) to prevent air and water infiltration.

C.2 Control Joint A joint placed in a construction assembly to form a plane of weakness to prevent random cracking, etc.

C.3 Expansion Joint A joint placed strategically in a structure to accommodate expansion or contraction of the surrounding materials.

C.4 Firestop A solid, tight barrier in a concealed space, placed to prevent the spread of fire and smoke through such spaces.

C.5 Gypsum Board Products consisting of a non-combustible gypsum core, covered with materials specifically designed with respect to performance or application.

C.5.1 Gypsum Wallboard or Drywall - interior products with prefinished surfaces suitable for paint finishing, etc., after appropriate fastener and joint treatment.

C.5.2 Gypsum Sheathing - exterior products made of water resistant gypsum core completely enclosed with a bonded water repellent paper or fiber-glass facing.

C.6 Lintel Commonly describes a steel angle that supports the weight of masonry over a wall opening and is in turn supported by the masonry beyond the jambs of the opening.

C.7 Parapet A portion of a wall extending above the adjacent roof.

C.8 Prefabrication (Panelizing) Assembling steel framing components into dimensional panels or frames at a workplace away from the job site. This is often accompanied by the pre-attachment of the finish materials such as synthetic plaster, tile, etc.

C.9 Retrofit The reconstruction of an existing structure to enhance its appearance and/or its functionality. Renovations to exterior walls often incorporate steel framing components. The product is suited for retrofit applications because its weight generally does not overload the existing structure. Inspection of the existing structure is a critical aspect of the design of the curtain wall retrofit.

C.10 Shim A thin steel plate inserted between two surfaces to fill a gap or void.

C.11 Tolerance A permissible range of variation in a specified size or dimension.

C.12 Wall Tie (or Brick or Masonry tie) A metal anchor that connects a masonry unit to a stud. The ties act to transfer lateral forces out of the masonry into the stud. Dovetail wire or similar style brick ties are available through various manufacturers. Corrugated ties should not be used in construction involving steel framing components.

C.13 Bearing Stiffener (Web stiffener)* Additional material that is attached to the web to strengthen the member against web crippling.

SECTION 2: DESIGN LOADS

Typical design loads imposed on a cold-formed steel framed curtain wall assembly can come in the form of: gravity loads (self weight), thermal loads or stresses; seismic loads, and wind loads.

A. Dead Load The application of “self weight” needs no explanation. It should be noted that the effects should nonetheless be carefully evaluated. Aside from the ordinary single-story wall dead load, other applications include: the axial load at the lowest stud from the weight of a stacked wall system above; the concentrated loads, moments and stresses from a brick support angle attached to

a stud wall; the effects of eccentrically applied dead load from cornice projections, “eyebrow” framing, etc.

B. Thermal loads Thermal loads or stresses can be manifested in typically two ways: 1) axial forces induced by the member’s tendency to shrink or elongate under temperature change, while being restrained within a larger, very stiff and dimensionally stable primary frame (Figure. 1); or 2) bending forces induced by thermal bow which could be caused by an exterior assembly subject to significant exterior to interior face temperature differences - such as those inherent in an insulated composite

metal sandwich panel (Figure. 2). This is typically not an issue with properly insulated CFS framed walls.

C. Seismic Loads Seismic loads are typically lateral forces applied to the members due to the acceleration of the wall assembly mass during an earthquake. As such, the force is in relation to both the weight of the wall assembly, and the severity of the seismic event. The seismic event severity is usually codified based upon a particular seismic region or zone. Curtain wall forces are calculated in accordance with the applicable code separately from main lateral force resisting system forces under a parts and portions or secondary structural segment of the code. It should be noted that various parts of a wall assembly, such as parapets, ornamental projections, etc., as well as connections and fasteners, may be subject to different seismic design forces compared to the remainder of the wall.

D. Wind Loads Wind loads are the most typical controlling design force on a curtain wall assembly. Similar to seismic loads, they are codified according to wind velocity regions, and typically also as a secondary structural component. The building's height (above grade), horizontal dimensions, roof configuration, surroundings, proximity to hurricane coastline, and it's use all have an effect on the wind load development. The wind loads typically vary with height except corner area wind loads and negative wind loads.

SECTION 2: STRUCTURAL ANALYSIS AND DESIGN

3.A Structural Analysis The structural analysis determines the member required strength. The structural analysis of a curtain wall assembly is performed using generally accepted structural engineering principles. Members are isolated and modeled into free body diagrams, or engineering schematics with design loads applied and reactions indicated at connection points to the primary structure or other supporting members. The results can be calculated by hand or by any of a number of computer software options.

When performing the structural analysis, Section A3, Loads and Load Combinations, of AISI S211 should be considered.

3.B Moments and Forces Based on the curtain wall structural analysis, the resulting required strength (i.e. moments and forces) are compared to the member's design strength. These member strengths are calculated in accordance with the *North American Specification for the Design of Cold Formed Steel Structural Members* (AISI S100). The typical or critical strengths to be evaluated for a cold-formed curtain wall are:

- Bending strength
- Axial Strength
- Shear Strength
- Web crippling; and/or
- A combination of these strengths.

3.C Bracing/Bridging The most typical cold-formed steel curtain wall shape is the C-shaped stud. The C-shape is singly-symmetric and due to the attendant geometric properties, a C-shape stud will tend to twist and deflect (out of the plane of the wall) under wind load. This behavior tendency is known as torsional-flexural buckling. Mechanical bridging and/or the sheathing

materials may restrain the stud. A member's design strength for torsional-flexural buckling can be computed in accordance with AISI S100.

The stud section's ability to resist axial and bending moments can be calculated in accordance with AISI S100 and depends on the type of bracing used. In general, decreasing the bracing/bridging spacing will increase the member's design strength, whereas increasing the bracing spacing will decrease design strength.

Mechanical bracing/bridging (continuous channel, strap, blocking, or other) is the most common and preferred method for bracing a C-shape in a stud wall.

Sheathing braced design is permitted in accordance with section B1 (b) of AISI S211. Note that use of this section imposes certain restrictions to the assembly:

- Identical sheathing is attached to both flanges of wall stud. If sheathing types are not identical, the weaker of the two sheathings shall be assumed to be on both sides for design purposes.
- The sheathing is connected to both the bottom and top horizontal members (typically the tracks) to provide lateral and torsional support to studs.
- The engineering drawings shall identify the sheathing as a structural element.
- The wall studs shall be evaluated without sheathing bracing for the following load and resistance factor design (LRFD) load combination:
 - $1.2D + (0.5L \text{ or } 0.2S) + 0.2W$
 - D = dead; L = live; S = snow; W = wind
- Because of these requirements, it is often not practical relying on sheathing braced design, especially if there is a top slip connection, so sheathing cannot be attached to the top track, or where the load combination without sheathing would require one or more rows of steel bracing anyway.

3.D Serviceability/Deflections Typical serviceability concerns may include overall movement, vibration, visual considerations, or member deflections. In a typical stud framed exterior curtain wall, member out-of-plane deflections are the primary serviceability issue. Deflection limits are most often dictated by the architectural finishes. These are typically stipulated in the project specifications, sometimes under the advisement of the engineer of record. Although not a definitive listing by any means the following are some of the typical deflection limits used with stud framed curtain walls:

Exterior Finish:	Deflection limit:
Metal Panel	L/180 -L/240
EIFS	L/240 -L/360
Ext. cement Plaster/stucco	L/360
Stone	L/360 -L/600
Brick	L/600

At cantilevers (parapets, over-hangs, etc) a rule of thumb is to limit deflections based on twice the cantilever length as illustrated by Figure 3. These deflections should be calculated based on the cantilever deflection only, exclusive of the effects of member's rotation at the support, or by a check of the combination of cantilever and adjacent span deflection, over an equivalent length of twice the distance from the point of maximum span deflection to the end of the cantilever. The rationale behind either approach is that the final displacement of the cantilevered end, while accounting for rotation at the support, does not accurately reflect any curvature concerns that the serviceability limits are generally intended to reflect. One limiting check however, should be made on the overall cantilever displacement (i.e.: $< \frac{1}{2}$ " or some other actual deflection limit).

For deflections it is typical that the structural analysis be made based on the properties of the stud alone. When evaluating the deflection, AISI S211 stipulates that 70% of the components and cladding load is to be used.

3.E Primary Frame Movement Several different building movements pose concerns for the design of the curtain wall framing: story sway; torsional displacement; creep and shrinkage (typically in concrete structures) and gravity load deflection. Relative to a cold-formed steel stud wall the story sway and gravity load deflection warrant the most consideration.

Story sway may require very specific design allowances in high wind and seismic areas. Problems may arise in multi-span conditions with the members and connections, and in basic connection details at any of various curtain wall applications at basic connection details, especially at building corner areas. Solutions to these problems can vary significantly - from member stress or in plane shear strength verifications, to 2-way slip or drift clip connec-

tions.

Primary frame gravity load deflections are most critical to the curtain wall design when the spandrel beam is subjected to live load. Theoretically, the differential live load deflection from floor to floor can vary up to L/360 or even L/240 - which - in a moderately sized bay, can yield a required movement allowance of an inch or more. In all real probability, such movements will seldom amount to more than a small fraction of this.

In any event, once a movement allowance is determined, either by project specification, structural design notes, or under advisement of the engineer of record, this tolerance must be considered in design. The most typical solution methods include slip-track connections, slotted connections, and pre-manufactured slide clips. More about these types of connections is discussed in the CFSEI Technical Notes W101 (Common Design Issues for Deflection Track), W100 (Single Slip Track Design) and W103 (Design of Bypass Slip Connectors in CFS Construction).

3.F Design Documents and Aids The following is a compilation of related design documents and design aids:

AISI D110, *Cold-Formed Steel Framing Design Guide*, 2007 edition, American Iron and Steel Institute, Washington, D.C. This guide was written with a focus on the fundamental principles of cold-formed steel design as they relate to cold-formed steel framing construction. It shows how to use product literature when executing the design of building systems.

AISI S100, *North American Specification for the Design of Cold-Formed Steel Structural Members*, 2007 edition, American Iron and Steel Institute, Washington, D.C.

AISI S200, *North American Standard for Cold-Formed Steel Framing - General Provisions*, 2007 edition, American Iron and Steel Institute, Washington, D.C.

AISI S201, *North American Standard for Cold-Formed Steel Framing - Product Data*, 2007 edition, American Iron and Steel Institute, Washington, D.C.

AISI S211, *North American Standard for Cold-Formed Steel Framing - Wall Stud Design*, 2007 edition, American Iron and Steel Institute, Washington, D.C.

AISI S212, *North American Standard for Cold-Formed Steel Framing - Header Design*, 2007 edition, American Iron and Steel Institute, Washington, D.C.

Façade Attachments to Steel-Framed Buildings, Steel Design Guide 22, American Institute of Steel Construction, Chicago, IL, 2008. This guide focuses on attachment strategies and their effect on the design, fabrication, and erection of steel frames.

Steel Stud Brick Veneer Design Guide, CF03-1, American Iron and Steel Institute, Washington, D.C., 2003.

This guide was developed to assist engineers and architects to design steel stud brick veneer systems for commercial and high-rise buildings.

SECTION 4: CONNECTION APPLICATIONS

Aside from the slip connections already mentioned in this publication, the more typical connection details used in stud curtain wall design are illustrated in this Section. Electronic copies of these and other details may be obtained from the CFSEI website (http://www.cfsei.org/constructiondetails_1.htm).

A. Base Connections - Figures 4 and 5 illustrate typical stud to track to deck, concrete, or steel.

B. Head- or Sill-to-Jamb Connections - Figure 6 depicts a box header, however a back-to-back or L-header may also be used. A typical sill track is shown in Figure 7.

C. Continuous Angle Connections - This detail is usually used at spandrel framing and a field welded connection is employed. The angle must be installed string line straight and designed for lateral, gravity, and eccentric forces (Figure 8);

D. Clip Angle Connections - This connection is typically at non-slip-by-pass or spandrel framing connections. The connection is designed to carry both lateral and self-weight loads (Figure 9).

E. Wind Girt Connections - This connection is usually used for taller spandrel framing cases when the use of stud

F. Outrigger Clips - As illustrated by Figure 11, this connection consists of a short length of angle designed as an axially loaded strut to transfer curtain wall stud lateral reactions back to the structure.

G. Diagonal Stud Brace (“Kicker”) - Diagonal member functioning as a bottom spandrel stud support back to the structure. These braces are not as overall cost-effective as outrigger clips or girt connections. The brace also may add a significant vertical force to the curtain wall stud and the top of wall connections (Figures 12 and 13).

H. Stud-to-Stud Connection - Either a lapped or track-to-track may be used. On occasion these connections require movement allowance, which can be accommodated by a slip track or a slip-pin type detail (Figures 14 and 15). See also Technical Note W103, “Design of By-Pass Slip Connectors,” for situations where this detail may be used.

I. Knee Wall Base - As illustrated by Figure 16, this is a moment connection at the bottom of a knee or stub-wall usually either a free-standing parapet or a long segment of wall under a continuous or ribbon window condition. This connection may be problematic due to the relatively high moments and small base connection strength. Fastener pull-out or sheet pull-over as well as inadequate edge distance are design concerns.

J. Field Adjustment Connection - Attachments of panels may require field adjustments to account for construction variations such as fabrication and erection tolerances of the main frame. These adjustments may include:

- Means to adjust the slab edge closure plate in or out relative to the spandrel beam.
 - Means to adjust the location of the curtain wall panel frames in or out relative to the slab edge.
- Means to adjust the location of the attachment anchor either vertically or horizontally.

For additional discussion regarding field adjustments consult AISC Steel Design Guide 22 *Façade Attachments to Steel-Framed Buildings*.

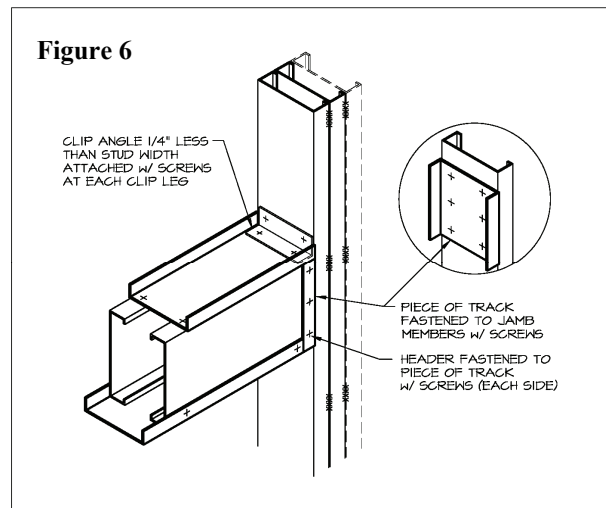
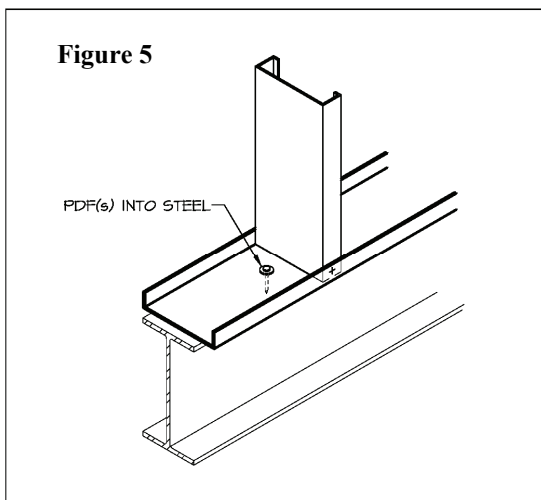
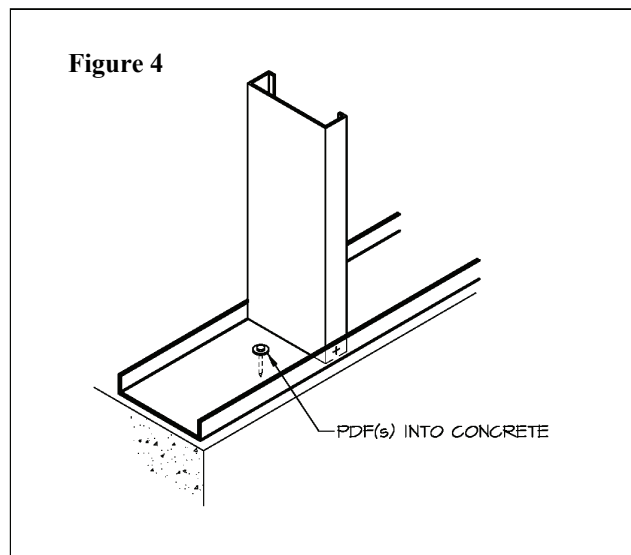
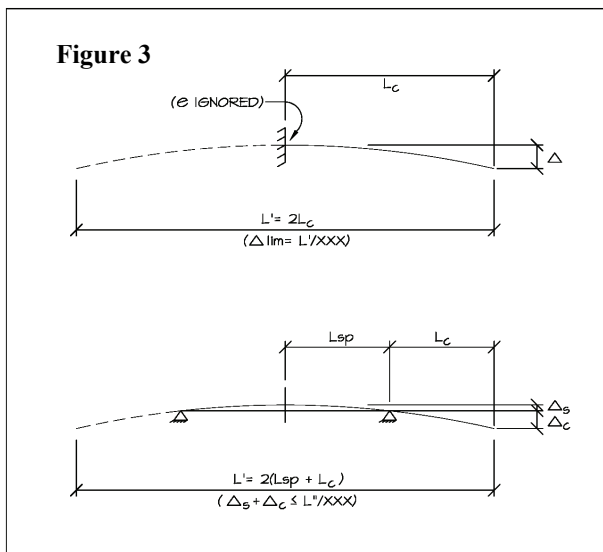
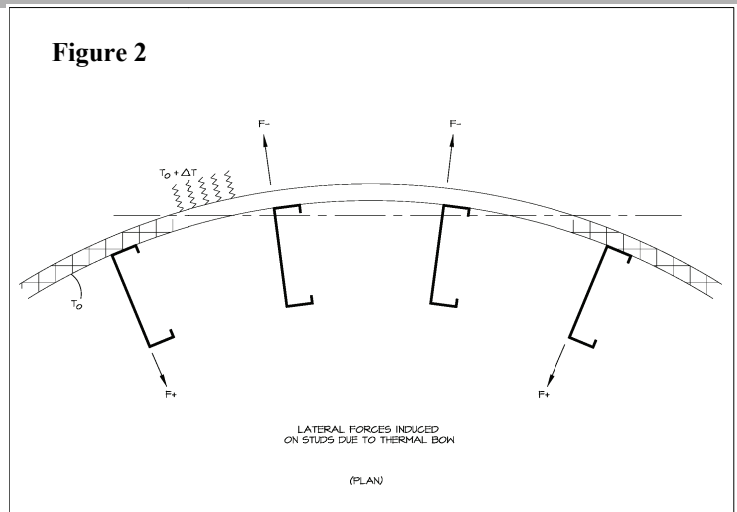
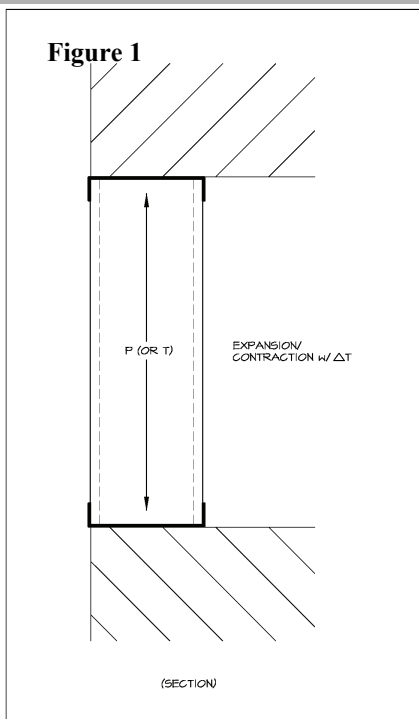


Figure 7

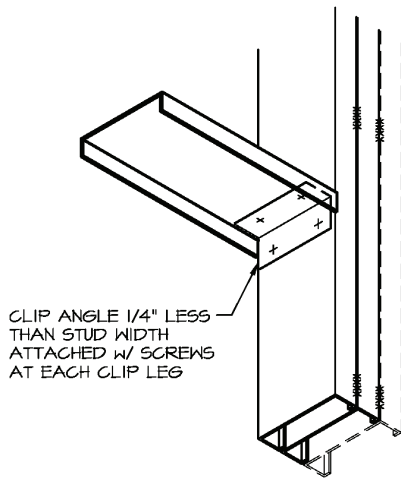


Figure 8

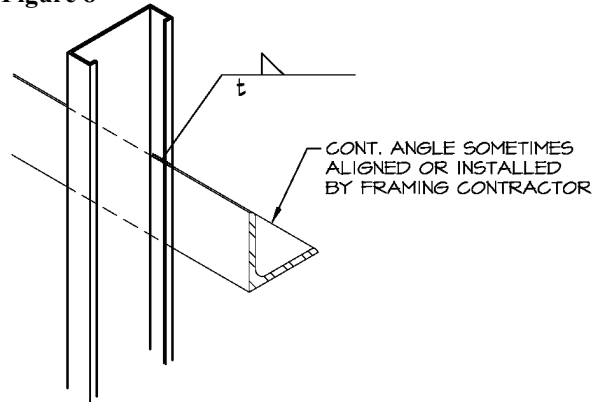


Figure 9

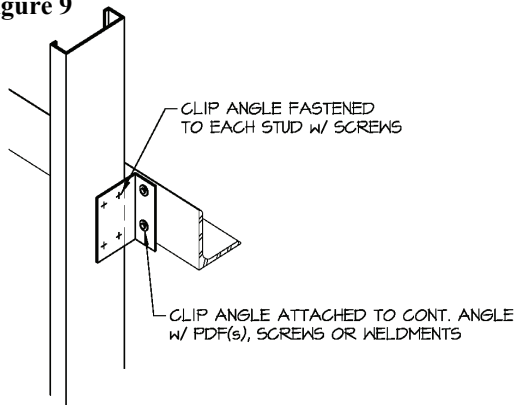


Figure 10

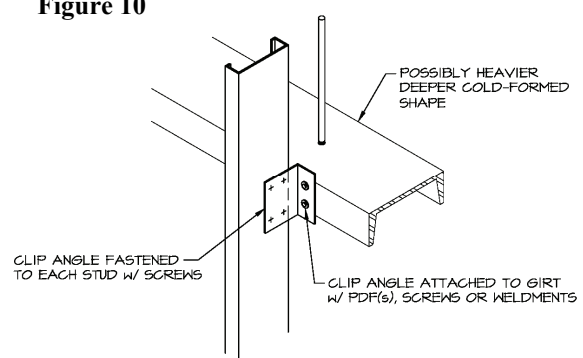


Figure 11

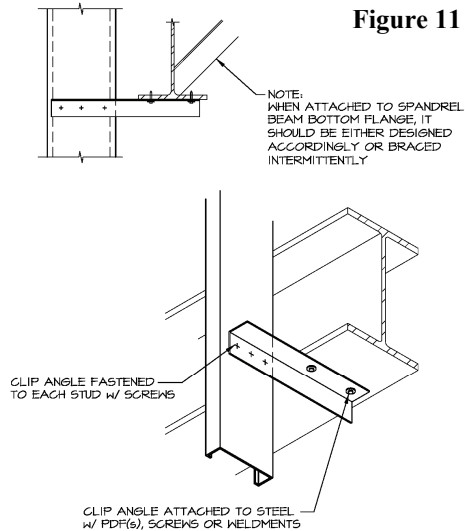
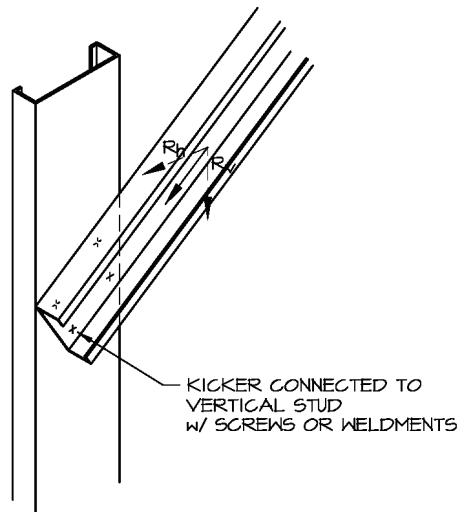
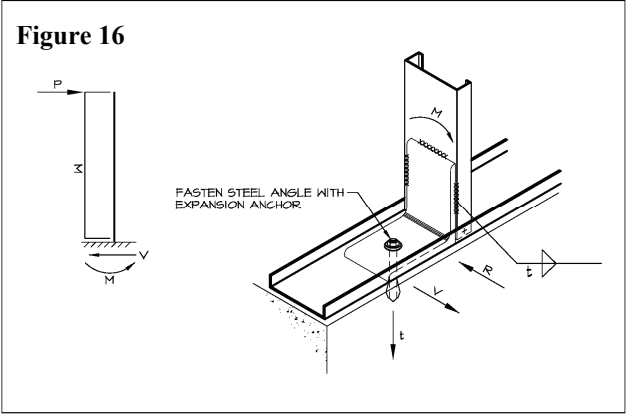
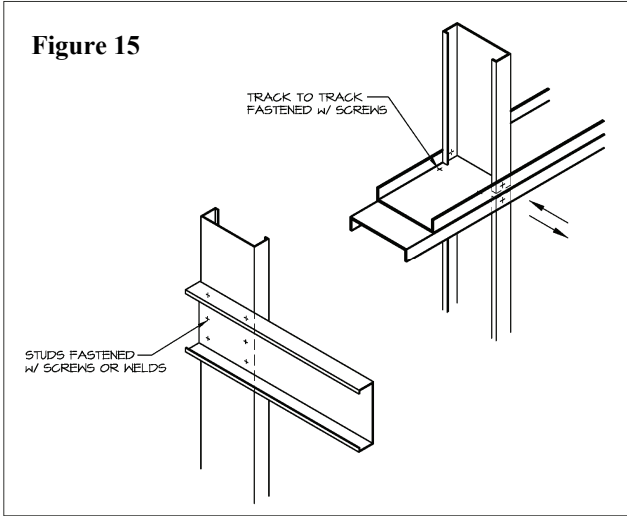
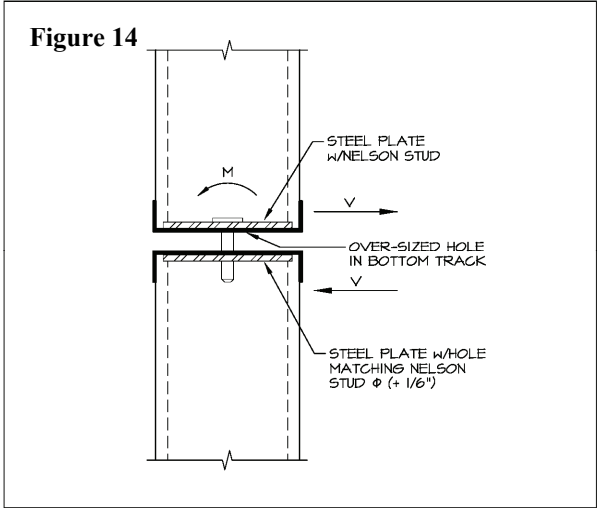
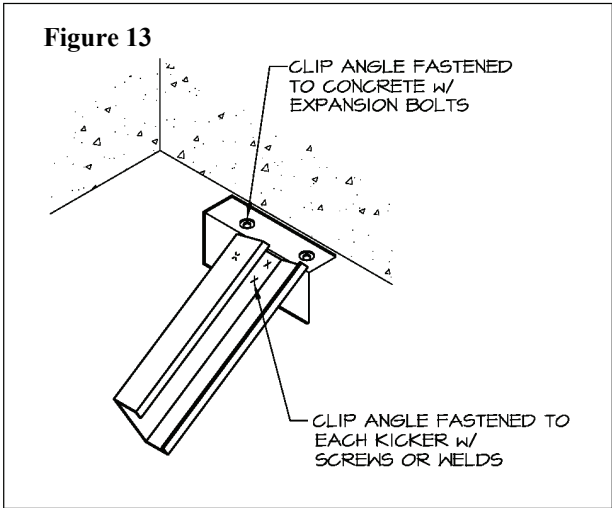


Figure 12





References:

AISC Design Guide 22. *Facade Attachments to Steel-Framed Buildings*. 2008. American Institute of Steel Construction, Chicago, IL.

AISI CF03-1. *Steel Stud Brick Veneer Design Guide*. 2003. American Iron and Steel Institute, Washington, D.C.

AISI S100-07. *North American Specification for the Design of Cold-Formed Steel Structural Members*. 2007 edition, American Iron and Steel Institute, Washington, D.C.

AISI S200-07. *Standard for Cold-Formed Steel Framing—General Provisions*, 2007 edition. American Iron and Steel Institute, Washington, D.C.

AISI S201-07, *Standard for Cold-Formed Steel Framing—Product Data*, 2007 edition, American Iron and Steel Institute, Washington, D.C.

AISI S211-07, *Standard for Cold-Formed Steel Framing—Header Design*, 2007 edition, American Iron and Steel Institute, Washington, D.C.

AISI S212-07, *Standard for Cold-Formed Steel Framing—Wall Stud Design*, 2007 edition, American Iron and Steel Institute, Washington, D.C.

BIA Technical Note 28B. *Brick Veneer/Steel Stud Walls*. 2005 edition. Brick Industry Association, Reston, VA.

Primary authors of original Tech Note:
Patrick Ford, Matsen Ford Design

Technical Review and updating for Revised Edition:
John Matsen, Matsen Ford Design
Roger LaBoube, Center for Cold-Formed Steel Structures
Maribeth Rizzuto, CFSEI

This “*Technical Note on Cold-Formed Steel Construction*” is published by the Cold-Formed Steel Engineers Institute (“CFSEI”). The information provided in this publication shall not constitute any representation or warranty, express or implied, on the part of CFSEI or any individual that the information is suitable for any general or specific purpose, and should not be used without consulting with a qualified engineer, architect, or building designer. **ANY INDIVIDUAL OR ENTITY MAKING USE OF THE INFORMATION PROVIDED IN THIS PUBLICATION ASSUMES ALL RISKS AND LIABILITIES ARISING OR RESULTING FROM SUCH USE.** CFSEI believes that the information contained within this publication is in conformance with prevailing engineering standards of practice. However, none of the information provided in this publication is intended to represent any official position of the CFSEI or to exclude the use and implementation of any other design or construction technique.

Copyright © 2012, Cold-Formed Steel Engineers Institute • Washington, DC • www.cfsei.org • 866-465-4732