Cold-Formed Steel Framing Primer:

A Guide to Understanding and Application

AWCI
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INDUSTRY

COLD-FORMED STEEL FRAMING PRIMER:

A GUIDE TO UNDERSTANDING AND APPLICATION

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Table of Contents

CHAPTER ONE
Introduction to Cold-Formed Steel Framing

Why should designers and contractors consider the benefits of cold-formed steel framing? There are many reasons, but foremost among them is economics. Thirty years ago engineers said that cold-formed framing was the wave of the future. This prediction has not only come true but has progressed beyond our wildest expectations.

Nearly every major commercial building in this country is constructed using interior non-structural drywall cold-formed steel framing. Many projects also use cold-formed steel framing for exterior curtain walls.

Current fabrication techniques allow the contractor to prefabricate panels in a shop under controlled conditions, in any weather, so that when the concrete slabs are complete, erection of the framing panels can begin immediately. The structure can be completed in a fraction of the time required for standard construction.

Cold-formed steel framing can be supplied in a wide variety of standard shapes. Studs are typically "C" shaped sections that are formed in a continuous process where dies gently form the final profile. In some cases, the profile is made by bending the steel in what is called a "press brake." The raw material from which these shapes are formed is steel coils, either galvanized or coated with a material that provides equivalent corrosion resistance. Depending on the project requirements, the steel base metal thickness ranges from 0.0147 inch (15 mil) to 0.1180 inch (118 mil). The industry has adopted a color coding system to clearly identify the steel thickness. The table below shows the mil thickness related to base metal thickness and the more traditional gauge thickness. The table is excerpted, with minor modifications, from the Steel Framing Industry Association's Technical Guides for Cold-Formed Steel Framing Products.

The depth of the stud is the web width of the "C" shape and generally is the designation for the basic size of the stud. Thus, a 3 5/8 inch stud has a web width of 3 5/8 inch and corresponds to the 3 1/2 inch width of a 2 x 4 wood stud. The flanges of a metal stud are those surfaces at each end of, and perpendicular to, the stud web. They are generally the surfaces that the covering panels are attached to, and they correspond to the 1 1/2 inch sides of the 2 x 4 wood framing stud. Typically, the flange width on non-structural studs is 1 1/4 inch, where the flange width on structural studs is 1 5/8 inch. The flanges of the stud require stiffeners to keep the flange "in plane" when a load is applied. The stiffening elements are lips, which are small returns off the flange of the stud. These lips vary in length and run parallel to the web, which also provides stiffening.

Many manufacturers produce studs with varying flange or leg widths. The "C" section flange widths, for the most part, are nominally sized at 1 1/4 inch up to 3 1/2 inch. Thus, the building designer can select a wide range of stud capacity by varying the thickness of the base steel as well as the flange and web dimension. This makes steel framing considerably simpler than wood. For example, to increase the load-carrying capabilities of wood studs, the designer must increase the stud dimension or stud spacing to 16 inches or less. Often these same load-bearing capabilities can be achieved with one steel stud simply by selecting the proper flange width, base steel thickness, and spacing without compromising the wall depth or spacing.

Corresponding to "top" and "sole" plates in wood stud construction, plain "U-shaped" channels (typically called "track" or sometimes "runner") are sized to receive the studs (Figure 1-1).

Designation Thickness (Mils)	Minimum Thickness (in.)	Reference Gauge Number	Color Coding
15	0.0147	27	None
18	0.0179	25	None
27	0.0269	22	Black
30	0.0296	20-Drywall	Pink
33	0.0329	20-Structural	White
43	0.0428	18	Yellow
54	0.0538	16	Green
68	0.0677	14	Orange
97	0.0966	12	Red
118	0.118	10	Blue

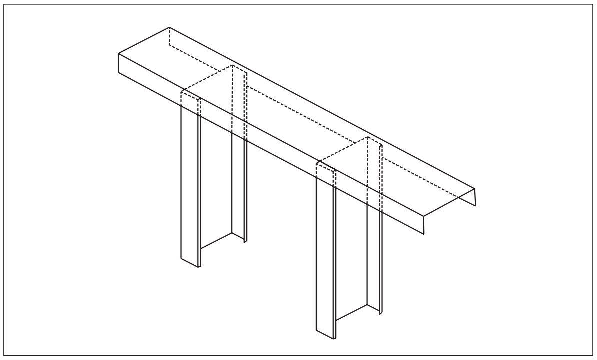


Figure 1-1

Thus, the stud is inserted perpendicular into its track of the same interior dimension as the stud. The stud web depth is the distance between the internal faces of the legs on the track. With the legs of track and stud flanges so lapped, the two members may be friction fitted or mechanically fastened together. This is done at the top and bottom of the stud.

There are essentially two ways that steel studs are mechanically attached to a track. The first is with the use of specially designed screws that are self-drilling and self-tapping. In one step, the fasteners penetrate through the two layers of steel and at the same time tap the holes to "lock in" the fastener. Screws come in various types, lengths, thread patterns, and head shapes. Each is designed for a specific application. The most common for framing applications is called a "panhead" and is a nominal ½ inch long.

The fastener is available with a corrosion-resistant coating. Depending on the steel thickness to be fastened, there are two thread types and screw tips available. One is for base steel thicknesses from 27 gage (15 mil) to 20 gage (30 mil) non-structural members. The other type is for steel ranging from 20 gage (33 mil) up to 10 gage (118 mil). The tips of the screw may vary as well. Fasteners must comply with ASTM C1006 or C1513.

Studs may also be attached to track by welding. There are two types of welds used in cold-formed steel framing: arc or resistance. Arc welding is the most common in construction. The predominant type of weld is a fillet weld along the edge of the track leg where it crosses the face of the stud flange. The second type is what is termed a flare-groove weld. There are two codes that govern the design and process of welding. The design is covered by the Specification for the Design of Cold-Formed Steel Structural Members (AISI). The process of welding is covered in ANSI/AWS D1.3 Structural Welding Code.

Floor and roof systems using cold-formed steel framing use the same screw or welding type of connections. Flat or pitched trusses where the web and chord members are cold-formed steel profiles (either the standard "C" shape or a proprietary shape) use both types of connections. Sometimes a steel gusset plate is used to facilitate the required number of screw fasteners.

First floor framing can be attached to the foundation or floor slab using several connection methods. In non-structural applications, the bottom track is fastened to the concrete floor slab with power-actuated fasteners shot through the track web into the floor. These are generally installed on 16 inch to 24 inch centers. In structural applications, depending on the intended loading and code requirements, the fastening method can vary from the same power-actuated fasteners, to epoxy or expansion anchors. Cold-formed steel framing can even accommodate threaded bolts or anchor bolts embedded in the concrete.

Construction specifications for non-structural interior partitions typically require that steel studs, also known as jambs, located adjacent to door and window openings, partition intersections, and at partition ends or corners be anchored to track by screws or by crimping at each stud and runner flange. The steel thickness and number of studs at the door frame are determined by the weight of the door and the size of the opening. Intermediate partition studs are not normally required to be anchored to track.

Whether cold-formed steel stud framing is fastened together by screws or welding depends on the steel thickness and contractor workforce capabilities. Welding is not recommended for cold-formed members 0.029 inch (20 Ga.) base metal thickness and lighter. Welding requires much more skill than for 0.0428 inch (18 Ga.) base metal thickness and heavier. Many contractors prefer screw fastening for all thickness because it offers uniformity of connection and simplicity of tools. This fastening decision depends on the specific nature of the contractor's organization. Screw fastening also can eliminate the need for special inspection, which is sometimes required for welding to verify the structural integrity of the weld.

In typical construction, fastening can be done by either welding or by screwing. For a few certain specific design conditions, welding is required to develop adequate strength. The project construction specifications should be consulted for exact fastening requirements.

Connecting the framing together is not very complicated. Framing for multi-storied structures subjected to axial (live and dead loads) and combined lateral loads may require secondary bracing. As mentioned earlier, gusset plates may be needed to strengthen connections, but the basic function of joining lapped sheet metal remains the same, simple, repetitive feature for all construction by this method.

Most of the prominent manufacturers of cold-formed steel framing publish instructive details, load specifications, and procedures to be followed in the installation of steel framing. There are also several steel framing associations that provide guidance as well. The information is developed using the standards provided by the American Iron and Steel Institute (AISI). Allowable span and height tables are available for the engineer or designer. The tables include information for non-structural as well as structural applications.

While such data is intended primarily for the building designer, the applicator's knowledge, acquired by exposure and experience, can be of invaluable assistance to the building designer. Thus, the professional applicator can be a valued consultant on the design team. A good source of information can be found on the AWCI website wallsystemdesign.org. This site offers standard system details that incorporate cold-formed steel framing. In addition, reputable framing manufacturers provide technical support. Some manufacturers provide fee-based shop drawings. There are several cold-formed steel framing associations that provide assistance as well.

Installed cost has significant influence on the selection of a framing system. The table in Figure 1-1 is a basic comparison of standard partition types.

The information provided in Figure 1-1, "Wall Cost Comparisons," was extracted from the 2014 edition of Means Building Construction Cost Data. From this cost comparison we note that steel stud construction is certainly competitive with wood and masonry. Note the labor savings of steel studs over the other types of support.

This fact is borne out in our spot surveys of Southeast wall contractors. When asked which support system they liked best and why, they unanimously responded with steel studs because jobs go quicker (lower labor costs by far) and a less skilled labor force is required. Another key factor is that there is less waste, which is very important when considering sustainability.

Bear in mind, we have been talking about walls. Manufacturers provide rolled members that also suit floor, roof, and truss construction. Steel framing is not confined to just walls, but can be sized for the whole building structure, if desired. Buildings up to nine floors tall have been successfully built with these members.

Here, then, is a building enclosure support that

- is provided straight,
- is dimensionally stable,
- will not warp, dry out,
- can be chosen with varying strength capabilities for a given depth size,
- is uniform in strength—not dependent on gradation variations in quality and species of wood,
- can be provided in precise lengths from the manufacturer,
- is noncombustible—will not burn,
- is much lighter in weight,
- is more design efficient,
- is resilient under stress,
- is easy to assemble,
- will resist termites,
- will not rot,
- has high recycled content,
- is inorganic—will not support mold growth.

On top of all this, installation equipment investment for a contractor is minimal. Cold-formed steel framing members can be cut readily with a power hand saw fitted with an abrasive, metal cut-off blade. Screw fastening only requires a variable-speed, adjustable clutch motor driver. A hand-held powder-actuated fastener for anchoring track to concrete or primary framing is useful.

CHAPTER TWO
A Technical Overview

The purpose of this chapter is to give you an overview of the technical aspects of cold-formed steel framing. More specifically, it is designed to improve your knowledge in the areas of:

- basic product application, terminology, and definitions;
- benefits and limitations of cold-formed framing versus other conventional construction methods;
- basic technical data and requirements of cold-formed steel design;
- basic uses of cold-formed steel framing include interior non-structural partitions, curtain walls, structural walls, floor joists, and roof trusses.

Interior Partitions

Although there are many different uses for cold-formed steel framing, interior partitions are probably the most common application.

These steel stud systems are designed to withstand minimal lateral loads and no axial loads. The building codes require a minimum lateral design load of 5 psf. Many interior partitions must meet specific performance requirements such as fire resistance and acoustic privacy. The strength and resiliency of the cold-formed steel stud makes it an ideal choice for these applications. The steel studs used for interior partitions range in size from 1 5/8 inches to 6 inches in depth, and from base steel thickness of 0.0155 inch to 0.0329 inch. Interior partition systems are normally specified by the architect and may demand shop drawings depending on the complexity of the project and the established performance requirements. Most projects call for submittals from the contractor or manufacturer. The head or top of the wall may necessitate special consideration, with assistance from a framing manufacturer, to accommodate building movement.

Curtain Walls

Curtain wall systems also comprise a major component of the cold-formed steel framing industry. Curtain walls are secondary framing systems that carry the exterior finish of the building. The steel stud frame is designed to transfer the lateral forces, such as wind loads, to the existing primary structure.

There are many different configurations of curtain walls. The next figures (Figure 2-1 through Figure 2-4) illustrate the different types of curtain walls. All the figures show welding as a primary method of attachment. That is not meant to imply that welding is the preferred solution; it is simply an option. The various options of attachment will be covered later. The decision on a fastening system should consider structural capacity, feasibility, production, and safety.

The most common types of curtain walls are infill panel, spandrel panel, and the bypass parapet. The simplest of these is the infill panel (Figure 2-1), where the stud framing system fills the void between the surface of a floor slab and the bottom of the next floor slab or to the bottom flange of a structural steel spandrel beam. Infill panels are simply supported, which means that the stud has supports at the two extreme ends.

Architects can achieve interesting lines with infill panels and exposed structural framing. Differential movement between the panel and the structure must be taken into consideration.

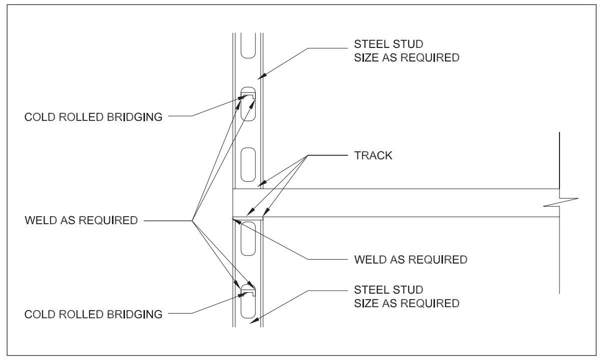


Figure 2-1 Stud infill panels

The spandrel panel (Figure 2-2) is commonly used in mid- to high-rise buildings. It is attached outside of the structural frame and clads the building.

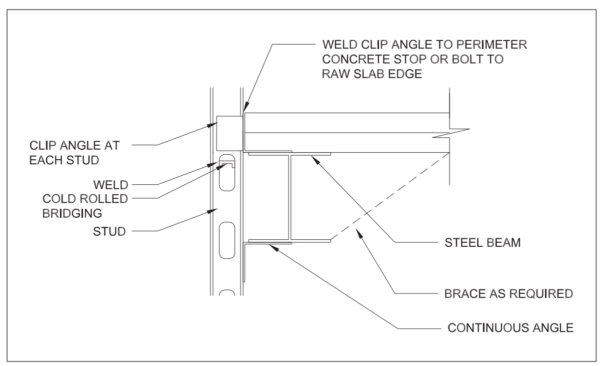


Figure 2-2 Spandrel Panel

The spandrel panel is a very useful system popular with architects, and it has some unique design conditions. The spandrel is usually installed beyond the end of a concrete floor slab. It then extends up a short distance on the next floor while dropping down a distance of the floor below. It is typically connected to the structure at the floor and possibly the spandrel beam below the floor. Sometimes a "kicker" is installed below the floor line to further support the panel to the floor or roof deck. This connection scheme leaves the spandrel panel with one or two cantilever overhangs, and normally a concentrated end gravity load from the window it supports. As with the infill design, the spandrel panel connection to structure must allow for differential movement.

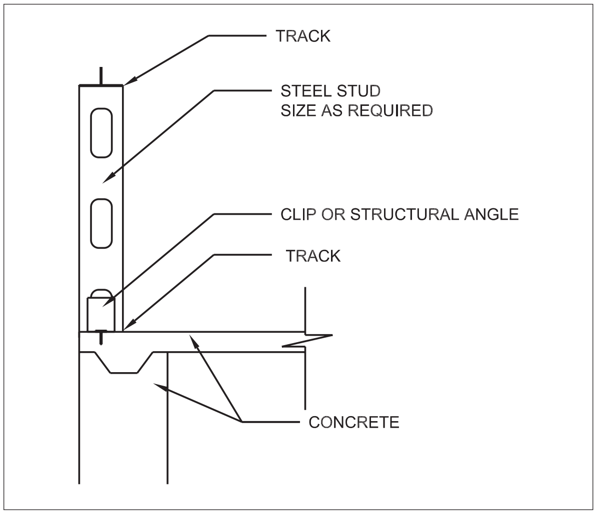


Figure 2-3 Knee wall supporting window

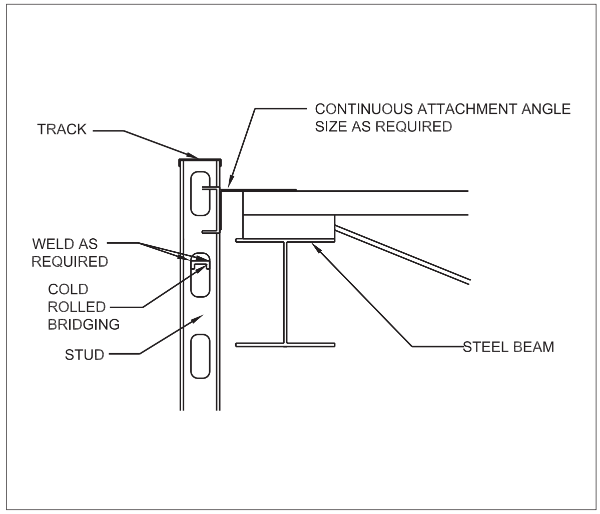


Figure 2-4 Roof Parapet

The other unique condition created by the use of spandrel panels is the stud or knee wall (Figure 2-3) that begins the system on the first floor. The knee wall is also a cantilever section with a concentrated gravity load and requires engineering analysis for sizing the connection to the floor slab. Spandrel panels must be analyzed and a design must be given to the contractor by the architect, engineer, or the manufacturer's engineer.

Often the architect requires the contractor to supply shop drawings for a curtain wall system. Most manufacturers have the capabilities to supply the shop drawings, either with an in-house engineering staff or by using outside consultants. When a specification requires shop drawings, the contractor should take this into consideration at the time of the bid, as manufacturers charge a fee for their engineering services. Most manufacturers will quote a lump sum or hourly price for shop drawings and/or engineering calculations if plans are provided for the project.

The third type of curtain wall system is the bypass parapet (Figure 2-4). This system is often used in conjunction with both infill and spandrel panels, as the top panel of the exterior wall system. This permits clean, efficient parapet construction without the necessity of building a separate parapet on the roof deck. The same member sizing and connection problems associated with spandrel panels are evident in bypass framing, necessitating that a qualified engineer review the design of this system. Architects normally require the same detail drawing submittals with this system as with a spandrel system.

Current energy codes have brought a new awareness of the exterior envelope of buildings. Today's requirements include the addition of continuous insulation and air/water barriers. Continuous insulation is the attachment of some type of insulation over the entire exterior wall surface. The insulation is typically attached over a sheathing material and to the exterior flange of the steel stud. Also, there should be an air/water barrier installed on the exterior envelope as well. Special attention to detailing and application is warranted. The requirements for air/water barrier and continuous insulation are required for all structure types, including wood and masonry.

Structural Walls

Structural wall systems use the steel stud framing system to support the entire structure. Structural walls can be integrated with a variety of combinations of cold-formed steel floor joists or other systems, such as bar joist or concrete floor systems. Steel stud structural wall systems have been successfully used in buildings from a single floor to nine stories high. This system will be described more thoroughly in a future chapter.

Cold-Formed Steel Floor Joists

Cold-formed floor joists, as mentioned earlier, can be an integral part of a load-bearing structure. Steel joists are best applied in conditions with light to medium load and short to medium spans. A 25 foot span is typically the maximum span for the efficient use of "C" shaped floor joists. As with the cold-formed steel stud, the load capacity or allowable span of a steel joist can be made greater by increasing the base steel thickness or increasing the joist web depth. Under certain span and load conditions, cold-formed joists are a very economical design solution.

Another option for a cold-formed steel floor system is to use a truss. In a truss the chords and webs of the stud are comprised of cold-formed steel members. This allows for greater spans. There are many truss fabricators located nationwide that can provide design services and manufacture the truss.

Roof Trusses

The last area of application for cold-formed steel studs is the construction of trusses or rafter and joist systems. A trussed unit can provide remarkable capabilities with regards to loads and spans. There are applications where this is a viable design alternative to a traditional rafter design due to the inherent load-carrying capabilities of the steel system.

There is a nationwide network of cold-formed steel roof truss fabricators available to assist with the initial design and build the truss.

Benefits of Steel Framing

Now that we've discussed the options available for the application of cold-formed steel framing, we should examine the advantages of using these systems.

Economy. When steel studs are used in lieu of other structural systems, such as concrete masonry unit, poured concrete walls, or structural steel, construction costs can be reduced.

Indirect Savings. Reduction on the structural frame and foundations can result in savings because of the light weight of cold-formed steel framing.

Non-combustibility. Building systems that use steel framing may be considered (depending on the cladding) non-combustible. This is a very important life safety issue.

Reduced Fire Insurance Premiums. It is most likely that fire insurance premiums will be reduced on the project.

Construction Risks. Utilizing cold-formed steel framing negates the need for temporary protection from freezing as with concrete and masonry. The concern of exposure to moisture and the hazard of fire prior to the interior finishes being completed is eliminated and may also reduce builders' risk insurance premiums when not using wood systems.

Design Versatility. With the vast product line available, anything can be built, from a simple soffit to a nine-story load-bearing building.

Speed of Installation. Most manufacturers provide cut-to-length products, eliminating costly field cutting; and with pre-punched holes, the electrical and plumbing trades save time.

Prefabrication. Most steel also lends itself to prefabrication with high quality and tight product tolerances available from production line fabrication in a controlled plant environment. Shipment and installation of entire wall systems make year-round working conditions possible by reducing the worker's exposure to inclement weather, which speeds the field erection process.

Product Consistency. The elimination of dimensional shrinkage improves the application of finished materials.

Resistance to Pests. Steel framing is resistant to rodents and vermin such as termites.

Recycled Steel. Steel is the most recycled of the common building materials. This makes it a very sustainable product.

Building Codes

There are many technical considerations that must be addressed when designing and constructing a safe building. The design criteria are listed in the local building code that address issues such as wind pressures, snow loads, seismic design, and other factors relevant to the use of cold-formed steel framing in building design.

Local municipalities typically develop a code based on what is called a model code. The municipality can either adopt the model code in its entirety or with amendments. The International Code Council (ICC) has developed what are called the ICC family of codes. The most prominent of these is the International Building Code (IBC). Other codes that impact the design and installation of cold-formed steel framing are the International Residential Code (IRC), the International Energy Conservation Code (IECC), and the International Green Construction Code (IgCC).

The IBC addresses the design and erection of buildings and structures with a goal of preserving life safety. It regulates the height and area of a building based on its intended occupancy. Also, it governs the building materials that are to be used, as well as the means of egress.

The IRC focuses on one and two family residences of three stories or less. It regulates all aspects of the structure that include mechanical, electrical, and plumbing services.

The IECC is a fairly new code. It addresses the issue of energy consumption of all building types. The federal government has mandated that all states adopt either the IECC or its parallel standard, ASHRAE 90.1. Both standards dictate the inclusion of continuous insulation and air/water barriers on the exterior envelope. There is also a requirement to test the exterior envelope once completed for air tightness.

The IgCC is the result of the increased awareness of sustainability and the built environment. Important to steel framing and the exterior envelope is the call for commissioning. This is a layer of oversight for the owner to ensure the designed building meets the needs of the owner, the building is constructed according to specifications, and it operates as originally planned.

All of these model codes have been established to ensure that the buildings that we design and build have life safety and energy conservation at the core of the design. They all impact the design and installation of cold-formed steel framing.

The model codes dictate the minimum requirements for building with cold-formed steel framing. Contractors should use only products that meet code. There are several framing associations in the industry, and they all provide information and certification on code-compliant products. It is important to provide products that qualify for these code-compliant programs.

The building codes rely on recognized standards to define materials, installation of materials, and test protocols to determine product and system performance. One organization that is widely used is ASTM. This is an organization whose membership includes technical and business leaders that develop consensus standards.

Engineering Criteria

Although the jurisdictional building codes relate to the design criteria for buildings, the allowable load capabilities of steel studs are governed by the American Iron and Steel Institute's AISI S100

North American Specification for the Cold-formed Steel Structural Members. There is a companion document called the Commentary on the Specification, which provides technical background information for the specification.

In addition, there are more documents available to assist the designer or builder. They are:

1. AISI North American Standard for Cold-Formed Steel Framing – Floor and Roof System Design

2. AISI North American Standard for Cold-Formed Steel Framing – Wall Stud Design

3. AISI North American Standard for Cold-Formed Steel Framing – Header Design

4. AISI North American Standard for Cold-Formed Steel Framing – Lateral Design

5. AISI North American Standard for Cold-Formed Steel Framing – Truss Design

6. AISI North American Standard for Cold-Formed Steel Framing – Prescriptive Method for One and Two Family Dwellings

7. AISI North American Standard for Cold-Formed Steel Framing – Nonstructural Members

8. AISI North American Standard for Cold-Formed Steel Framing – General Provisions

9. AISI North American Standard for Cold-Formed Steel Framing – Product Data

All of these documents are researched and published by the American Iron and Steel Institute. They are all ANSI accredited as well.

Specifications

Taking all of the available information and design criteria into account, the engineer can begin the design of a safe building that meets the client's needs. In developing the project specifications, most architects use the Construction Specification Institute (CSI), Masterformat™ format. All written information relating to a project is placed in specific divisions. Information pertinent to interior partitions is placed in Division 9 – Finishes, and that is further subdivided. Interior non-structural framing falls under section 09 22 16. Drywall steel studs are then under 09 22 16.13. Exterior curtain wall and structural framing is under 05 41 00 where cold-formed steel joists are 05 42 00. The appropriate section includes specific information on the materials and their proper installation that are approved for the project. These specifications include the size of studs, minimum steel thickness, acceptable coatings, and the type of submittals for approval (i.e., brochures, certification letters, shop drawings, engineering judgments). It also will contain what is needed to document for product sustainability attributes. If a manufacturer is not listed, designers can normally get approval for that manufacturer's product as an equivalent product by submitting the manufacturers' design data, product samples, and literature prior to the final bid. In many instances, the architect assigns the contractor the responsibility and expense of supplying an engineered design.

The yield strength of the steel will normally be part of the specification. The typical minimum yield strength for 43 and 54 mil steel thickness are as follows:

43 mil (0.0428 inch) thick base steel - 33 KSI
54 mil (0.0538 inch) thick base steel - 50 KSI

The yield strength designation is much like the minimum 54 mil (0.0538 inch) base steel thickness requirement. It is a starting point or a benchmark. Both thickness and yield strength are part of the physical properties that the manufacturer's engineers can supply. The strength and stiffness of a steel stud is the balance between steel thickness, steel yield strength, and the physical profile of the steel framing member. By changing those three parameters, steel fabricators have the ability to sometimes meet the project performance needs with a thinner than specified steel member. Designers should obtain the manufacturer's written recommendation and present it to the architect for approval before installing. During the bidding phase of the project, the quantity of technical information required can be overwhelming. Most manufacturers have personnel to assist in the technical aspect of the bid. After reviewing the specifications and drawings, designers should contact the stud manufacturer to assist in selecting the stud section that will meet the specified design requirements.

Another suggestion is related to adding specification requirements of quality assurance. The three major steel framing industry associations—SFIA, CSSA, and SSMA—all have code compliance programs. To maintain membership within the associations, a manufacturer must meet stringent code requirements. These requirements cover material and geometric properties of their products. Because of these programs, it is recommended that architects include language in their specifications that the cold-formed steel framing to be used on a given project be code compliant as recognized by these programs.

CHAPTER THREE

Cold-Formed Steel Framing and Mid-Rise Construction

With the increasing urbanization of society and rising land costs, mid-rise structures (typically buildings that are four to nine stories) enable developers to maximize their real estate values by building more square feet on the same footprint as a low-rise building. However, there are unique challenges to mid-rise structures that need to be addressed, including design for fire resistance, wind and seismic loads in a taller building, and lower story and foundation designs to carry increased weight per square foot. Cold-formed steel offers a number of inherent characteristics that meet these challenges and in many cases offers a number of advantages over wood and concrete.

Cold-formed steel is an ideal material choice for framing mid-rise construction. It offers features and benefits for the entire design team, including the owner. For the owner, it is noncombustible and offers speed of erection and other cost benefits. For the architect, it allows for complete design flexibility. The structural engineer will appreciate its structural capacity, which among other things accommodates long span conditions. It can also be the primary structural element for up to seven stories. The contractor on the team will experience better cost-controlled, efficient, accurate building systems that reduce construction scheduling and project conflicts.

The International Building Code (IBC) has provisions for cold-formed steel framing in mid-rise construction. The American Iron and Steel Institute (AISI) has consensus-based standards that serve as a guide for design. High-performance walls and floors can be designed and erected that meet the most demanding fire resistance and acoustical performance requirements. Designs using cold-formed steel framing in both structural and non-structural applications are available with fire-resistance ratings of up to four hours and sound transmission classification (STC) ratings up to the mid-60s. These capabilities enable designers and builders to meet the highest performance levels required in both categories.

Benefits of using cold-formed steel framing on a mid-rise building to the owner will include a maximum return on investment. Cold-formed steel is very competitive when compared to other non-combustible building materials. For example, the cost of using cold-formed steel can be as much as 30 percent less than using concrete. That relates to a typical savings of $15.00 per square foot.

Design flexibility will increase rentable floor space by using thinner structural elements. This aids both the architect and the owner. For example, a 1 hour cold-formed steel stud partition with a 4 inch stud has a 5 1/4 inch partition width, which is considerably less that an 8 inch concrete masonry unit wall. There will, in turn, be a reduction of hard construction costs using cold-formed steel framing in lieu of other non-combustible building materials.

The construction phase will require less time and that will slash the overall project cost. Depending on the scope of a project, using a cold-formed steel framing system can shorten the construction schedule by as many as 120 days. Unlike concrete and masonry, cold-formed steel framing does not require proper drying or curing conditions, so work can proceed in less favorable weather conditions. The owner then benefits from an accelerated time to a revenue stream, reduced financing, and a smaller window for insurance coverage and exposure to liability and construction related claims.

There is also a positive impact on insurance costs compared to other building materials. Significant savings were realized on a recent 190-unit condo project in California. The project had a $25,000,000 policy limit. The general liability premium was $2,000,000. It would have been $300,000 more had the project been done with concrete. There was also a significant amount of savings on the Builders Risk and Workers Comp.

Cold-formed steel framing has the highest strength-to-weight ratio of any building material. It weighs considerably less than a concrete structure; its use therefore reduces the required mass of the foundation and any related costs such as excavation, ground water management, form construction, and utility interruption. That could deliver savings of about $2.00 a square foot. Having smaller foundation requirements also allows cold-formed steel to be used in poor soil conditions.

Building with cold-formed steel leads to a healthier interior environment. Steel is an inorganic material. It does not contain any volatile organic compounds (VOC), and that translates to no off-gassing that could otherwise occur if engineered organic materials were used. Steel does not offer a food source for mold, nor does it support the growth of it. Cold-formed steel framing is a "dry" system; it does not introduce moisture into a building that could encourage mold growth. These claims cannot be made for wood, concrete, or masonry. Steel framing does not allow water to wick from point to point within a building, which can occur with any porous material, which in turn can result in moisture related problems far from the original point of moisture intrusion.

When reviewing material properties, steel quickly becomes the product of choice. Steel has a minimal coefficient of hygrometric expansion. This means that it is dimensionally stable under adverse moisture conditions. This minimizes the potential of cracking finish materials such as plaster, stucco, or even gypsum panels. It will not shrink over time; shrinkage could lead to breaches in the air/water barrier and eventually result in moisture migration problems.

From a structural standpoint, steel is considered isotropic, meaning it has the same dimensional properties in all directions. That also means that the strength is the same in all directions, as there is no "grain" with steel. A steel structure tends to be more stable than a wood structure because steel does not warp, shrink, or crack under loaded conditions. Column shrinkage is common in concrete structures, but it is virtually nonexistent in steel. The ductility of steel is a well-known attribute. It is not a brittle material such as unreinforced concrete or masonry. Steel will yield or bend long before catastrophic failure.

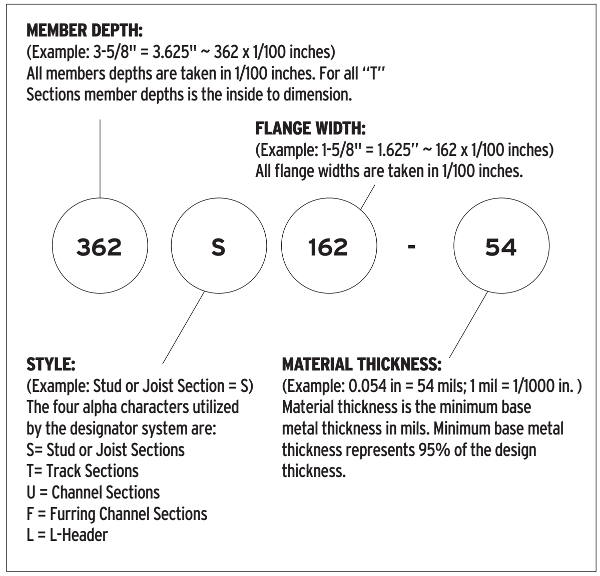
Steel is also much stronger by weight compared to lumber, which often allows steel studs to be spaced on 24 inch centers versus 16 inch centers required for wood studs. This saves on time and materials. On a recent project, the first floor of a six-story building used framing that was placed at 24 inch centers. This provided valuable access to the stud cavity for the other trades, as well as enhanced productivity of the framing crew. In this case, as in many mid-rise projects, the walls were panelized. Steel framing lends itself to this practice. Many projects utilize this practice to increase productivity and quality control, which will be explored more thoroughly in Chapter 13.

Cold-formed steel framed assemblies work well together to resist wind loads and what is called allowable drift. Allowable drift is essentially how much the building can move in the wind. Typically the actual amount of movement is governed by the ratio of L/500, where "L" is the height of the building in feet. This movement is controlled through shear walls and floor systems. Cold-formed steel framed shear walls have demonstrated the capacity to resist building sway in mid-rise construction.

Non-combustible floor systems are readily adaptable to cold-formed steel wall framing. Concrete poured over a metal deck fastened to bar joists is just one example of a floor system. Proprietary floor systems comprised of concrete panels over cold-fold formed steel joist members, or even a poured gypsum concrete over a metal deck, can be also used in mid-rise applications. They all provide the fire and acoustical performance that is required for this type of construction.

There are several steel framing associations, and each has adopted what is called a code compliance program. Steel framing products now leave the steel fabrication plant with a certification stating that they are code compliant. These code compliance programs use a third party inspection service that inspects both the plants and the individual products. These inspections, or audits, are conducted to document both the material properties of the steel being used and the physical properties of the framing member itself.

Another important feature in the cold-formed steel framing industry is the standardization of the individual physical profile and a subsequent naming protocol. In this system, first the member's web depth is expressed in 1/100th inches, followed by the type of member (S = stud or joist with flange stiffeners; T = track sections; U = cold rolled channel or channel studs without flange stiffeners; F = furring channels, L= L-header); followed by flange width (where applicable), and finally the minimum base metal thickness in mils. For example, an identifier reading 550 S 162 – 54 indicates a 5 1/2 inch C-shape with 1 5/8 inch flanges that has a base steel thickness of 54 mils.



Standardization and code compliance programs provide quality assurance to the designer and the owner of mid-rise buildings. This becomes the benchmark for performance. Similar to structural steel, when an engineer sizes a structural member for a given location on a project, there is a high level of assurance that the installed member will meet the required structural capacity, at a competitive price.

CHAPTER FOUR
Use of the Manufacturers' Literature from the Contractor's Perspective

This chapter will address the possible design criteria that the contractor might use to bid and procure steel framing jobs and how the contractor can use the manufacturers' literature to aid in this process. We will look at the information needed to size jobs, and avoid possible errors and confusion.

In this age of increasing product and design liability, most designers and specifiers are leaving nothing to chance. Some years ago it was not uncommon for design and load specifications to be left in the hands of the contractor. Today, however, the more common practice is for the specifier to list the specific items that make up the structural framework and include all pertinent information necessary to bid and complete a job properly. In many cases a structural engineer who specializes in the design of cold-formed steel framing is hired to complete the design.

Another source of reliable information for the contractor is the body of material provided by the various cold-formed steel framing associations. Currently, there are three different associations. The first organization is the Certified Steel Stud Association (CSSA). Technical information is available through their ICC-ES Evaluation Reports or from the individual members. Their website address is www.certifiedsteelstud.com. The second is the Steel Framing Industry Association (SFIA). They publish the SFIA Technical Guide for Cold-Formed Steel Framing Products. Their website address is www.steelframingassociation.org. The third is the Steel Stud Manufacturers Association (SSMA). They publish the SSMA Product Technical Guide. Their website address is www.ssma.com.

In the most simplistic terms, there is one question that a structural engineer must answer to determine the right steel framing member for a given application. That question is: Is the structural capacity of the framing member greater than the anticipated loads? To answer that question, the engineer must know all the applied loads. Examples of applied loads are the weight of the structure itself, wind loads, and what the floors must support. The capacity part of the equation is answered by the material properties, items such as allowable stress and modulus of elasticity. These materials are coupled with the strength and stiffness provided by the physical shape of the steel member.

Before discussing the use of manufacturers' and the available association literature, we must first address the basic information a contractor needs at the start. The contractor needs to answer the following questions in order to bid on a structural framing job.

Structural Framing: Load-Bearing

1. What type of load-bearing stud is required or specified? The structural "C" stud makes up the vast majority of the load-bearing studs sold today. There are several flange widths offered for the "C" studs and joists. Although 1 5/8 inch makes up the majority of what is sold, this product is readily available in 1 3/8 inch, 2 inch, and up to 3 1/2 inch flanges from some manufacturers.

2. What type of corrosion resistance coating is specified or required on the load-bearing studs? Base steel left exposed will, over time, degrade. Steel in the presence of oxygen will undergo a chemical reaction that forms an iron oxide. This iron oxide is commonly called rust, which will reduce the base steel's material properties.

There are different types of coatings that are available to protect base steel. The first is considered sacrificial; that is, it protects the base steel by sacrificing itself to the elements. Zinc is a prime example of that type of coating. It serves as an anode and through a cathodic process protects the base steel. This zinc coating is the most widely used and provides a baseline for performance in ASTM standards. The second method is termed a protective oxide coating. This method is not currently used for coating of cold-formed steel products used in the construction industry. There is, however, ongoing research in this area, and in the future this may prove to be a very viable alternative. The third is a simple protective barrier. At one time cold-formed steel framing products were available with a paint coating. This process is no longer used, as ASTM standards dictate a specific performance level for protection. An ASTM standard, specifically ASTM A1003, Standard Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members, is performance based in that it sets galvanization as a baseline, but allows for coatings that provide equivalent performance. There is an alphanumeric descriptor that defines the amount of galvanization that is provided. For non-structural applications the amount of corrosion is called out as G40. For structural applications, the base line for performance is a G60 galvanization. A recognized ASTM test standard, called a "salt spray," provides the basis for benchmarking the relative corrosion resistance of various coatings. This test method yields data on corrosion resistance, measured in hours, when exposed to a specific hazardous (salt spray) environment.

Many manufacturers supply galvanized studs and track as standard products. ASTM 1003 allows for alternate coatings other than zinc, but they must provide an equivalent level of protection to zinc. The standard makes specific reference to "other metallic coatings." For that reason some manufacturers offer aluminized steel and galvanized steel that has zinc and aluminum coating as an equivalent option.

3. What is the framing member size? Framing member dimension should be addressed next. Structural studs are available in a wide range of web sizes, from 2 1/2 inch through 16 inch.

4. What lengths of framing members are required? Another consideration in placing an order is the actual length of each framing member needed. Cold-formed steel framing can be supplied in

lengths as needed for each application, often to within a 1/4 inch tolerance.

5. Are the framing members specified based on minimum structural properties? Lastly, designers and specifiers occasionally list the structural items needed by certain design criteria. The intent is to provide a performance based design and allow for a more competitive solution. Working with an engineer, or with an initial design in mind, the designer might state that the 3 5/8 inch "C" stud must have a section modulus, "Sx," in excess of 0.753 inch3 and a moment of inertia, "Ix," in excess of 0.415 inch4 about the major axis. Section modulus is used to compute product resistance to stress. The moment of inertia is used to compute a product's stiffness or resistance to deflection. To the novice this sounds rather overwhelming, but all of this information can be found in most manufacturers' and associations' literature.

Typically, as shown in Figure 4-1, the literature provides dimensional information on each individual web depth and steel thickness. Also, the type of steel based on yield strength is usually provided. Structural steel studs are available in yield strengths of 33 and 50 ksi (ksi = 1,000 pounds per square inch). The yield strength is usually established by the mil thickness of the steel. For thicknesses of 43 mil and less, 33 ksi is the common yield strength available. Both 33 ksi and 50 ksi are available for thicknesses greater than 43 mil. Check with the manufacturer as to availability. Dimensions are given for depth or web size, flange width and return lip, the weight per lineal foot, and the effective area in square inches. All this information is useful in comparing one manufacturer's stud with that of another manufacturer.

Also typically listed are the physical and structural properties of each stud. These include the moment of inertia (Ix) and section modulus (Sx). In Table 4-1, the 3 5/8 inch "C" stud described earlier in terms of section modulus and moment of inertia was a 3 5/8 inch, 0.0538 inch base metal thickness "C" stud with 1 3/8 inch flanges.

Other information may be listed, such as radius of gyration, "Rx", as well as, "Sy" and "Iy", the section modulus and moment of inertia about the minor or y-axis, and several other physical properties. However, generally speaking, the contractor will usually be confronted with nothing more complicated than the physical and structural properties as already explained.

Specifying properties of individual framing members is not a good practice, as the member selection should be dependent on all of the design criteria of yield strength, wind load, and deflection. It is important to understand that even though the industry has made common profiles, there are proprietary shapes made by some manufacturers. Thus, to insist that a 6 inch 43 mil stud with a 1 5/8 inch flange meet a moment of inertia Ix of 2.335 inch4 could result in over-specifying the job. If the design calculations dictate that the required Ix is 2.308 inch4 and a manufacturer's member's property is 2.316 inch4, the stud width, mil, or flange size would have to be increased to meet what was specified, increasing the cost of materials and in some cases the labor.

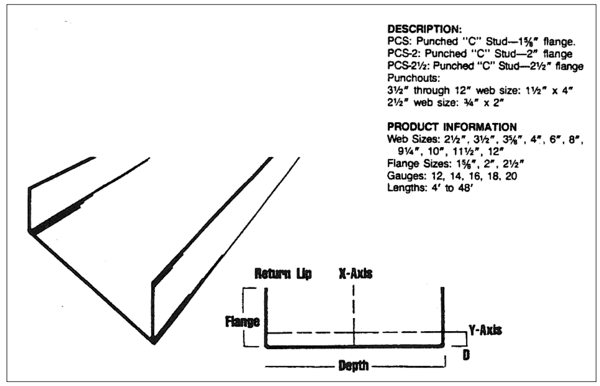


Figure 4-1

Structural Framing: Wind Loads

Every contractor should understand the concept of lateral loads such as wind loads. Structural "C" shape members are used in two basic ways: as load-bearing studs that bear only axial loads and seismic or wind loads, and as load-bearing joists. Studs that bear only wind loads are not required to carry an axial or gravity load (a load from above) and are usually called curtain wall studs. This wind or lateral force deflects or bends the stud toward the interior or exterior of the building. This load must be considered not only because of the possible failure of the stud, but also because of the effect of the deflection on the finish material such as stucco, EIFS, or brick veneer, attached to the studs on the building's exterior.

The weight of the finish material should be considered as well. In some cases, the weight of the finish material (such as brick veneer) exceeds the capacity of the stud, and independent supports such as lintels must be included in the final design. Fasteners play a key role for keeping the finish materials in place. Designers and contractors both should review what types of fasteners will be used to keep the finish material in place.

As shown in Table 4-2, the following information must be known in order to select the proper stud to handle the wind load for each job. First, we must know the appropriate wind load as specified in the applicable building code. There is a mathematical way to simulate wind loads into a uniform load. A 25 pound per square foot wind load is equivalent to a 100 mile per hour wind. This conversion is required to analyze the framing capacity. Next it is important to know the allowable deflection criteria and the length of the stud. Stucco, for instance, usually requires a maximum deflection ratio of L/360. This ratio limits the amount a stud can deflect based on the span. If the stud length or span is 10 feet (120 inches), then we would limit the deflection (120/360) to 0.333 inch. It is helpful to know what size stud wall is planned; for example, 3 5/8 inch. In some instances, the designer may want as thin a wall as possible to maximize floor space and economize on hardware.

As an exercise, say we have a wind load of 20 PSF with a design criterion of L/360 for a 16 inch stud spacing. If we are trying to find a stud that will span at least 10 feet, we simply follow the L/360 column under the 20 PSF heading down to discover that a 2 1/2 inch with a 1 3/8 inch flange, and 54 mil thickness "C"

Table 4-1

Member	Design Thickness (in)	F_y (ksi)	Area (in^2)	Weight (lb/ft)	Gross Properties I_x (in^4)	S_x (in^3)	R_x (in)	I_y (in^4)	R_y (in)
250S137-33	0.0346	33	0.197	0.67	0.203	0.163	1.015	0.052	0.515
250S137-43	0.0451	33	0.255	0.87	0.261	0.208	1.011	0.067	0.511
250S137-54	0.0566	33	0.316	1.07	0.318	0.255	1.004	0.080	0.504
250S137-54	0.0566	50	0.316	1.07	0.318	0.255	1.004	0.080	0.504
250S137-68	0.0713	33	0.390	1.33	0.386	0.309	0.995	0.096	0.495
250S137-68	0.0713	50	0.390	1.33	0.386	0.309	0.995	0.096	0.495

Table 4-2

			5 psf			15 psf			20 psf		
Stud Member	Spacing, in, oc	Fy, ksi	L/120	L/240	L/360	L/240	L/360	L/600	L/240	L/360	L/600
250S137-33	12	33	20' 6"	18' 7"	16' 3"	11' 10"	11' 10"	10' 8"	10' 3"	10' 3"	9' 9"
250S137-33	16	33	17' 9"	16' 11"	14' 9"	10' 3"	10' 3"	9' 9"	8' 10"	8' 10"	8' 10"
250S137-33	24	33	14' 6"	14' 6"	12' 11"	8' 4"	8' 4"	8' 4"	7' 3"	7' 3"	7' 3"
250S137-43	12	33	24' 9"	20' 2"	17' 8"	14' 4"	13' 9"	11' 7"	12' 5"	12' 5"	10' 7"
250S137-43	16	33	21' 5"	18' 4"	16' 0"	12' 5"	12' 5"	10' 7"	10' 9"	10' 9"	9' 7"
250S137-43	24	33	17' 6"	16' 0"	14' 0"	10' 1"	10' 1"	9' 3"	8' 9"	8' 9"	8' 5"
250S137-54	12	33	27' 2"	21' 7"	18' 10"	16' 0"	14' 9"	12' 5"	13' 10"	13' 5"	11' 3"
250S137-54	16	33	24' 0"	19' 7"	17' 2"	13' 10"	13' 5"	11' 3"	12' 0"	12' 0"	10' 3"
250S137-54	24	33	19' 7"	17' 2"	15' 0"	11' 4"	11' 4"	9' 10"	9' 10"	9' 10"	8' 11"

stud (spaced at 12 inches on center), not 16 inches on center, will span 10′ 0″. With a little practice, you will find that this is a simple operation as long as all pertinent information is available. Finally, most manufacturers list combined load tables for structural studs. These tables consider the effects of axial loads (dead and live loads) combined with wind loads. Generally speaking, these tables are designed for use by designers and specifiers.

Information in this section is usually listed in maximum allowable axial load in KIPS (1,000 lbs.) per stud. Due to the complex nature of the product, a great deal of information is required for structural studs. The selection of load-bearing studs that support the weight of multi-story structures requires detailed engineering analysis to aid the designer in this comprehensive and demanding task.

Non-load-bearing or non-structural studs, on the other hand, must support only their own vertically applied weight and that of the attached finish material. They must also be designed to support a nominal lateral load (typically 5 psf), even in interior applications. Though this is the case, manufacturers will supply the physical and structural properties in the same manner as they do for structural studs. Also included are limiting height tables that list maximum allowable heights for drywall and curtain wall studs that are non-load-bearing or used to support wind loads only.

With regard to drywall studs, other factors must be addressed. Most important of these is the minimum decimal thickness of the stud. AISI defines two different thickness values: a "design" thickness (representing the assumed thickness in design calculations or testing), and a "minimum" thickness (representing the minimum, or reject limit, thickness that may be accepted on the job). Per AISI, the minimum thickness may be no less than 95 percent of the design thickness. Because steel purchased for these studs falls within a range of thicknesses, manufacturers offer studs that have a minimum uncoated thickness of 0.0179 inch in conformance with ASTM C 645. Some manufacturers offer a product that has a minimum uncoated thickness of 0.0155 inch. It is important to know what minimum thickness the designer has specified. Another item that must be known is the intended finish materials. Abuse resistant panels and cement board manufacturers recommend a minimum thickness of 30 mils for these products. To provide a cold-formed steel product that meets specifications in every way, the manufacturer must have complete information.

There is a trend toward a more performance based approach to sizing non-structural framing. Many manufacturers are changing profile and yield strength to maximize the performance of the stud. This allows for greater heights with less base steel thickness. There are two things to keep in mind if designing based on performance. One is that the discussion on minimum base thickness as it relates to ASTM C645 is not relevant. The minimum thickness of the framing can be less than recognized in the standard. However, it will meet the project performance requirements. Second, these performance based framing members are proprietary to individual manufacturers.

Though most manufacturers' literature has basic similarities, each varies to some extent. Become familiar with your supplier's literature, and then take any questions you might have to their technical services department. Also, the steel associations' information on steel framing is readily available.

Many contractors have become so well acquainted with the manufacturers' data and design procedures that they have gained the confidence of designers, which has led designers to depend on the contractors. Contractors should always double-check the structural selections made by the designer, thus increasing the chances of an error-free job.

Many jobs specifying competitive products (such as concrete block) have been changed to steel framing because the contractor, working with the steel framing manufacturer, was able to redesign and prove to the architect and owner that a significant cost savings could be realized. Imagine how much additional business could materialize using this procedure.

The recognized growth of the cold-formed steel framing industry has increased the contractor's potential scope of work. This growth has also brought with it many sources of technical assistance that are now readily available to the contractor. A partnership between the contractor and the manufacturer provides an environment for enhanced business opportunities.

Sustainability and the Energy Codes

The American Institute of Architects (AIA) has proclaimed that sustainability is now mainstream in current building design. Sustainability issues are reaching the same level of consideration as life safety concerns. That has two implications for the contractor. The first is meeting the requirements of LEED, and the second is complying with the current energy codes.

The United States Green Building Council (USGBC) was formed in 1993. It is an organization comprised of design professionals, building product manufacturers, government agencies, and individuals from academia. Their mission statement is to "transform the way buildings and communities are designed, built, and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life." To that end they published a non-mandatory rating system for measuring design. This system, called Leadership in Energy and Environmental Design, or LEED, has transformed the industry.

Much like the model codes, the LEED program is evolving and changes every few years. The latest version is called Version 4, which was approved in 2013. The primary goals of version 4 were to enhance "transparency and performance." Prior iterations of the program had a section titled "Material and Resources." This section focused on individual building materials, their raw materials, and sourcing. Issues covered included recycled content. Version 4 has totally rewritten that section. Now the LEED program is interested in the following: 1) Life Cycle Assessments, 2) Environmental Product Declarations, 3) Disclosure of "Chemicals of Concern," and 4) Responsible Extraction of Raw Materials.

Cold-formed steel framing, in general, is a very sustainable building material. The industry has taken great strides in reducing energy consumption and greenhouse gas emissions in the production of steel. Steel's greatest asset is its recycled content and recovery rate. To better understand that term, the following is offered from the Steel Recycling Institute: "Recycled content is a measure of how much recycled material is contained in a finished product. On the other hand, the efficiency with which a material is recycled is indicated by its recovery rate. This is a measure of how often a product is recycled at the end of its useful life. Steel's high recovery rate is a direct result of the fact that it is a cradle-to-cradle material constantly being multi-cycled into the array of steel products in our economy." The Steel Recycling Institute (SRI) is an industry association dedicated to steel and recycling. Their website for more information is http://www.recycle-steel.org.

The Steel Framing Industry Association (SFIA) asserts that because steel is 100 percent recyclable, it should earn a point in the Raw Material Source and Extraction Reporting category. This is stated in their AIA-CES training course on "Cold-Formed Steel and Sustainability." Building product manufacturers are a tremendous resource for obtaining the required items such as life cycle assessments (LCAs), environmental product declarations (EPDs), and health product declarations (HPDs).

Energy codes are having a strong impact on how exterior walls are designed and installed. The intent of the codes is to control the amount of operational energy that is consumed on our buildings. Specific emphasis is placed on the exterior envelope. The International Energy Conservation Code (IECC) and ASHRAE 90.1, Energy Standard for Buildings Except Low-Rise Residential Buildings, have made requirements for what is termed "continuous insulation." Continuous insulation is defined as "insulation that is continuous across all structural members without thermal bridges except fasteners and service openings. It is installed on the interior or exterior or is integral to any opaque surface of a building envelope." Also of importance to contractors, both the Standard and the Code require continuous air and water barriers. This offers challenges and opportunity for contractors. Recognizing the issue, AWCI has developed a one-day and two-day training program on the exterior envelope. Further, AWCI has posted details to illustrate these conditions on their system based website, Wall System Design, which can be found at www.wallsystemdesign.org.

CHAPTER FIVE
Computerized Estimating and the Emerging Use of BIM and Other Technology Tools

At the heart of any contractor's operation is the estimating department. Whether the business volume is large or small, the company young or old, the opportunity to make (or lose) money begins with the estimate. An accurate estimate keeps the contractor competitive and ensures that the company will start the job with all material, labor, equipment, and overhead items covered, resulting in a good chance to make money on the job.

Most contractors have spent years perfecting and fine-tuning their methods of preparing a bid, their quantity takeoffs, and job cost calculations. The quantity takeoff is simply the amount of various materials that are needed to complete the contractor's portion of the project. The method is developed to the point that the contractor's employees are comfortable with it and have confidence that the system will produce a profitable job. Probably the only way to improve on any of these systems is to be able to price a job quicker and more accurately. That is where a computer estimating system can help.

Many drywall contractors still do their estimating manually. They have not been willing to purchase something that is unfamiliar and that they are not sure will produce the same accurate estimate that they can produce by hand.

The methods used to arrive at this accurate estimate are almost as numerous as the companies employing them. However varied these methods may be, they can usually be divided into two categories: calculation by complete assembly (or unit pricing) and calculation by individual components (component pricing). Both estimating methods are easily adapted to computer estimating software.

Unit Pricing

In the assembly or unit price method of estimating, the complete cost of all material and labor is calculated for all items of an assembly, based upon a set module size (e.g., 100 lf at 10 ft. high). Some contractors include general conditions, equipment, and overhead charges in these unit prices, while others prefer to add those costs based on the total job cost. Either way, this cost is then converted to a "per square foot cost" or "per lineal foot" cost.

These unit prices are modified from time to time as material prices or labor costs fluctuate, but the material quantities and production rates are generally assumed to be the same from project to project. Usually, contractors who employ the unit price method of estimating have done so because of the speed with which they can "price out" a job after take-off is complete. However, if you are the successful bidder, you must then calculate from your take-off quantities the exact amount of each material item required for the job, the amount of labor estimated, and the other costs included in the pre-calculated unit prices. If there have been changes in the drawings or specifications, these changes must be incorporated into the unit prices and the entire job recalculated.

Using a computer estimating program, the assemblies can be "built" and unit prices calculated as easily as by hand. But then the tremendous speed, organization, and storage ability of the computer takes over. After your quantities for each assembly have been inputted, the estimating program can immediately provide you a complete material list for the entire job. It can accept material price updates and recalculate the price of the job accordingly. Software estimating packages can divide the job into different phases, and provide cost breakouts for those phases. It can keep all of this information on file so you may change quantities and pricing again and again.

Component Pricing

Some estimators feel that the unit pricing method, even when done by computer, is not accurate enough for them. They prefer the component pricing method. All the necessary material quantities and costs, and labor hours and costs, are calculated for each wall type. When done by hand, this involves an extremely large number of calculations. The chances for error greatly increase, but the estimator can more closely analyze each job condition. Also, the estimator can apply costs to it based on the particular job rather than using a broader, pre-calculated unit price.

Quite obviously, there is not much speed involved when this method of estimating is done by hand. Perhaps for that reason many estimators have chosen not to price their jobs based on the component pricing method even though it probably provides a more accurate analysis of job conditions. With the time involved and the increased chance for mathematical error, it may not be worth the effort.

But, thanks to the computer, a multitude of calculations can be accomplished in a very short length of time. In fact, with the use of the computer, the time necessary to input data for a complete job in the unit price format is about equal to the time required to input the same job in the individual component format.

Most of the estimating programs, or software, available uses one of the above methods of estimating. There are a variety of data entry methods, material and labor calculation formulas, and types of reports and summaries provided by the software. Some estimating systems use special keyboards, probes, light pens, or wheels that act as data input devices so the estimator can measure quantities on the plans and input them directly into the computer—there is no need to write anything down. Special keyboards can be programmed by the estimator to handle many typical conditions, which reduce typing by the estimator to input the data. The pens or probes serve as counting mechanisms to input doors, corners, or the like. A wheel is ideal as a rolling scale to input the lineal footage of walls. Of course, these systems require the estimator to have the plans near the computer when a takeoff is performed.

Unit Pricing Software

Most of the estimating software based upon the unit price method allows the estimator to personalize the formulae to calculate material and labor quantities. These programs can usually be adapted to estimate a variety of different products. This is because the basic software design allows the user to build specific assemblies. While a database of material items is normally included, a good deal of time is still required to build the basic assemblies, verify the calculations, and essentially become familiar with the overall program operation. Formulas and assemblies can be fine-tuned or even deleted from the system at any time.

Component Pricing Software

Estimating software using the component method of material and labor calculation is usually more structured than the assembly-based software. That is, the software asks the estimator specific questions about the type and amount of materials required for the project. This is done one wall type at a time. The formulas are generally built into the software when it is purchased and usually cannot be changed. This provides a certain measure of protection from under- or over-estimating quantities. The question-and-answer format of data entry serves as a good checklist for materials required for the wall condition. As with the assembly-type software, a database of materials and labor functions is normally included. One advantage to this approach is that these programs are usually (but not always) easier to learn. The estimator can begin generating computer estimates almost from the time the program is installed on the computer.

Regardless of the method of estimating a program uses, computer-generated estimates provide many advantages over an "old-fashioned" hand estimate.

Speed. An estimator with a calculator is no match for the computer.

Accuracy. Again, the estimator is only human. He or she will make mistakes.

Time. Material summaries are printed at the touch of a button. The entire job can be calculated in a matter of seconds. Adds, deducts, and unit prices are produced in a flash.

Money. The initial system is no small investment, but speed, accuracy, and time give a good return on that investment. Another subtle advantage noticed by many companies using computer estimating is that new estimators are better trained and become productive more quickly. Since they do not have to learn the many formulas and calculations required to estimate a job, they can concentrate on improving their take-off skills.

If you have already made the move to computer-generated estimates, you certainly have seen these advantages and maybe several more. If you have not made that move yet, talk to some of your fellow contractors who have; read all you can on the subject and look at as many of the programs on the market as you can.

While there is a considerable investment in hardware and software, the long-term benefits will more than offset the initial cost. A few weeks after you are "computerized," you will wonder how you got along without it.

Building Information Modeling and Cold-Formed Steel Framing

An ever increasing trend is for architects to design their structures in a three-dimensional process. The traditional process employed construction drawings primarily done in two dimensions. Software development has evolved to allow the design to be completed in three dimensions. The really important part, though, is not that the design is in three dimensions; it's that the design called a model contains embedded information. This process is called BIM or Building Information Modeling.

Although it requires a significant investment in hardware and software, this type of modeling reduces both the amount of time for design and the number of errors that typically arise. There is a process called "clash detection" that identifies potential conflicts between the structural design and the mechanical, electrical, and plumbing services layouts.

The 3D model of the building is made of 3D elements, or systems. An example of a system could be a cold-formed steel framed exterior wall. Therefore, the element can provide critical information on that wall system. Information such as stud profile and spacing, exterior and interior cladding, wall thickness, and eventually system performance (fire, acoustic, and structural) information are readily made available. From there links can be made to develop design requirements for sustainability and eventually cataloged to make an effective architectural specification.

The practice of BIM has been commonplace for a few years. Primarily it has been relegated to the structure of the building and its mechanical, electrical, and plumbing needs. Interior stud layout and finishing has not been in the spotlight. That is changing, and the aggressive contractor is driving the change.

Many contracts now require that the contractor be able to work in this new BIM environment. There is a competitive advantage to being able to effectively participate in this collaborative approach.

Cold-formed steel load-bearing framing could benefit from a BIM approach to design. The architect, armed with cold-formed load-bearing steel 3D elements, can quickly develop a working mid-rise design solution. It provides a simplified delivery system for designated design.

Building product manufacturers are providing needed assistance in BIM elements. The contractor who requires support to work efficiently in this environment should reach out to local manufacturers for assistance.

There are many sources in the industry where contractors can receive electronic information of the cold-formed systems that they install. Most common is what are called "design tools." An example of one is on the Steel Framing Alliance website: http://www.steelframing.org/search/search-directory/

This tool allows users to find cold-formed steel framed assemblies based on non-load-bearing and load-bearing applications. From there it can locate the proper systems that meet project-specific fire and acoustical performance attributes.

Many contractors now use tablets and smartphones to make life on the job site more productive and efficient. As a result there are many apps that are available to contractors to ease the need for cold-formed steel information requirements. These apps are especially beneficial when the user is at a remote location with no access to a PC or laptop. Most websites have the ability to function on these new platforms. Check with your local sources for apps that may be of benefit to cold-formed steel framing.

Social media is becoming more important in the construction industry. It has transitioned from a personal communication media to a professional platform. It may be too soon to see how much of a role social media will play in the cold-formed steel arena, but at some point in time it will.

CHAPTER SIX
Estimating for Cold-Formed Steel Framing Systems

"I never seem to make money on cold-formed steel framing jobs!" Why do experienced drywall/carpentry estimators miscalculate the labor factors involved in curtain wall, spandrel, and load-bearing type framing? As a result of a labor study on all the phases of cold-formed steel framing, some general principles became quite apparent and are applicable to all types of framing.

Drawings

In the bidding stage, very often the architectural drawings are vague in critical areas such as exact base metal thickness, specific connection details, and spacing. Other details that may affect the steel framing layout, such as fire ratings and control joint requirements, may also not be clearly identified. The steel framing manufacturer's engineering staff can assist contractors during the bidding stage by providing these "missing links." The manufacturer reviews the drawings and issues all the appropriate data necessary to bid the project with confidence, including the cost of shop drawings, when required, along with appropriate engineering calculations.

Labor Factors

The next problem is assessing the appropriate labor factors to "dial in" for the complexity of the work involved. Obviously there is no replacement for firsthand experience. Basic to understanding the labor factors involved in cold-formed steel framing is that every stud, joist, clip, angle, bridging, head, jamb, sill, and header must be considered as something that has to be distributed, sorted, cut, assembled, and set.

This process is made even more complex by the base metal thicknesses used in cold-formed steel framing, essentially 15 mil (0.0155 inch) to 118 mil (0.1180 inch) base metal. So the labor involved has to be predicated on the thickness of the metal. For example, the labor cost to assemble a built-up jamb or lintel unit using 43 mil (0.0429 inch) thick metals will differ from using 0.0966 inch thick material because the cutting, assembling, and setting will be significantly slower. Now, consider that same thought process on a dozen or more assemblies made from various base metal thicknesses that may be on the project, and the need for careful analysis and precision becomes apparent.

The next factor to consider is the height of the assembly and the base metal thickness of material. Basic to all drywall framing is layout and track and stud installation. Using a 10 foot high steel stud wall as an example, how are the above factors affected when you increase the base metal thickness to 0.0677 inch, the height to 20 feet, then change from screw attachment to welding? What about gypsum board installation? The labor factor varies with every base metal thickness and height condition.

Curtain Walls

Consider an exterior curtain wall in-fill panel. Layout and installation of studs and track are basically dependent on base metal thickness and height. Define these simple areas as "straights."

Starting with this basic labor factor, apply separate added labor factors for the window, door, louver, and air conditioning sleeve areas. For each of these built-up assemblies, ask the following questions: Which base metal thickness is required? Are they welded or screwed? What will productivity be? Is the condition repetitive or one-of-a-kind? What type of bridging is required? Is there an alternate detail that is easier to produce and just as acceptable?

The degrees of complexity are further increased when the curtain wall becomes a spandrel exterior to the slab or structure of the building. Spandrel framing often involves built-up lintel and jamb sections, back bracing, clip angles, and strongbacks. The installation of structural brick angles may also become part of the scope of work. Jurisdictional problems can occur with other trades. Estimators should carefully review any spandrel work that requires attachment directly to structural steel. What detail is needed so the panel can be adjusted if the structural steel is out of plumb or location?

With the emergence of the new energy codes, the requirements of continuous insulation and air/water barriers will have an impact on the estimate. Fasteners to adequately attach the insulation as well the finishing materials must be taken into consideration. The fasteners themselves will be longer, which impacts material costs. Their greater length will also slow down production rates.

The inclusion of the air/water barrier has its cost implications, the most obvious being the material cost itself. Beyond that, there are issues of sequencing with other trades. A negative impact on production rates can be expected, thus increasing installed costs.

Flooring

For floors, mezzanines, and loft framing, additional labor factors relating to movement and distribution of material must be considered.

Floor joists range from a 6 inch web depth, 33 mil (0.0328 inch) base metal thicknesses to 14 inch and 118 mil (0.1180 inch) base metal thicknesses with a weight ranging from 1.5 pounds per lineal foot to slightly under 10 pounds per lineal foot. Therefore, as construction progresses to upper floors, additional labor percentage factors for the movement and distribution of material must be included in the estimate.

Other factors to be considered include the following:

- Built-up lintel/header assemblies can become quite heavy and cumbersome and may require the use of a crane or similar mechanical equipment to facilitate installation.
- Time must be allotted for verifying heights and shimming.
- Installation of web stiffeners may be required to prevent web crippling.
- Solid and strap bridging must be installed.
- Built-up posts may need to be cut, assembled, and set in critical stress areas.
- Stairwells require built-up lintel/header sections.
- Joist or bridle hangers may need to be installed in these areas to facilitate attachment to structural steel.

Load-Bearing Construction

With load-bearing construction, there are additional factors to be considered. Wind bracing is frequently required at set locations designated in the structural/shop drawings, and anchor bolts must be placed in the concrete footings. Structural angles and gusset plates may also be needed at these locations. Built-up stud members are often needed at these crucial points. The load-bearing walls must receive bridging, and the labor intensity of constructing head, jambs, and sill areas must be addressed in a manner similar to curtain walls. Also similar to curtain wall estimates, the impact of the energy codes must be included. The inclusion of continuous insulation and the air/water barrier will certainly increase material costs and slow down production to accommodate sequencing.

Minimizing Products

If there are multiple windows or doors, different assemblies must be cut, constructed, and set. This introduces the additional factor of workers handling the variety of products involved. Therefore, a consideration on the job might be to minimize the number of base metal thicknesses and the variety of products. In this regard, shop drawings are "value engineered" to ensure that products and connections represent the most cost-effective overall method of installation.

Here's an example of how minimizing the number of base metal thicknesses affects sorting and handling:

Depending on the spans, a multiple floor system might utilize 8 inch joists of a variety of different metal thicknesses. Would it be wise to eliminate some of the thinner metals and construct all the spans using a smaller variety of thicker base metal studs? Also consider the possibility of six to 10 varieties of built-up header/lintel sections. Could this be reduced to four? If you reduce the number of different sections, you also reduce the varying labor costs for the handling, cutting, assembling, and setting. At the same time you minimize the opportunity for errors.

This may mean paying more for the heavier base metal thickness material in the beginning, but it must be weighed against 10 to 15 carpenters with a high pay scale. To offset a high payroll, the minimizing of base metal thicknesses and sections can be very important and should certainly be considered.

Roofing

A phrase often used in cold-formed steel framing is that the contractor "...goes to kindergarten on the first floor and gets his diploma on the top." At the top, the contractor must frame the roof. Roof framing is probably the most labor-intensive part of cold-formed steel framing.

Careful attention must be paid to the utility angles, base metal thickness, weight of the rafters, composition of headers used as ridges, and the valleys. Solid and flat stock bridging must be installed. Collar tie beams and posts may need to be incorporated. The ends of the roof may need to be "dressed off" with stud and track to form fascia, soffits, and gutter recesses.

If the roof is a simple gable configuration with no "breaks," the possibility of prefabricating the trusses on or off site should be considered. If we use this same simple gable as a labor "straight" factor of 100 percent, it would then be reasonable to put additional labor on all other configurations. If the estimator establishes a 100 percent factor for the "straight" gable configuration, then the dormers, hips, valleys, and cupolas must be accounted for with a much higher labor factor. Considerations include compound cuts on rafter and built-up hips, ridges and valleys with compound cuts, and clip angles with other than 90 degree bends. The sheer weight of built-up members may require a crane or similar mechanical equipment to lift the members into place. Staging and scaffolding may be required, depending on the heights involved. Good advice is to consider a worst case scenario.

This worst case scenario approach to estimating involves a comprehensive material takeoff of all pieces in a given wall, floor, or roof assembly. If the architectural/structural drawings are insufficient, contact your supplier or manufacturer for engineering support to guide you during the bid process.

Apply a labor factor to all the pieces predicted on height, base metal thickness, and degree of complexity. Labor is the overriding factor, so let it stand by itself. Material, with appropriate waste factors, must likewise stand on its own. Scaffolding, cranes, job conditions, and cleanup can be amortized into the man-days required for completion. Potentially, construction demolition and waste may have an increased cost due to compliance to sustainability and energy code requirements.

Cold-formed steel framing is an engineered system that must be treated with respect for both the system's capabilities and limitations. The key to success is to be thorough and thoughtful. Estimate the project by walking through the process one step at a time. The reward is a profitably completed project and a call to bid on the next job.

CHAPTER SEVEN
Estimating for Cold-Formed Steel Framing Systems

There are many proven ways to reliably prepare a "bill of materials" of cold-formed framing. A bill of materials is simply a list of all the building materials needed for a given project. Most good estimators learn through trial and error which method best suits their needs. Regardless of the approach, there are several definite steps most successful estimators observe.

First and foremost is a complete architectural specifications review. The specifications are part of the contract documents that an architect prepares. The contract documents are essentially the architects' "deliverables." There are two parts to the documents. The first document presents the drawings that illustrate the composition of a building. The second contains the specifications that reveal the composition of a building.

Architectural specifications are written in a very structured format. Most architects follow MasterFormat®, which is administered by the Construction Specification Institute (CSI). The following is taken from MasterFormat® Numbers & Titles:

MasterFormat is the specifications-writing standard for most commercial building design and construction projects in North America. It lists titles and section numbers for organizing data about construction requirements, products, and activities. By standardizing such information, MasterFormat facilitates communication among architects, specifiers, contractors and suppliers, which helps them meet building owners' requirements, timelines and budgets.

MasterFormat® categorizes data into divisions. The individual divisions cover broad topics like General Requirements (01 00 00), Concrete (03 00 00), Metals (05 00 00), Thermal and Moisture Protection (07 00 00), and Finishes (09 00 00). These divisions are then subdivided into sections, where information on specific materials can be found. Each section is broken into three parts, and they are Part 1 General, Part 2 Products, and Part 3 Execution.

The primary division that should be reviewed is 09 20 00 Plaster and Gypsum Board. Under this division one can find gypsum drywall and gypsum plaster systems. An important section to review is 09 22 16.13, which covers non-structural cold-formed steel framing.

An important division to research is 07 20 00 Thermal Protection. This division is essential if the contractor's scope of work includes all or part of the exterior envelope. If the scope of work includes cold-formed steel framing used as primary structural members, walls, floors, and roofs, then the section is 05 40 00 Cold-Formed Metal Framing.

Related sections that prove useful to read are the following:

09 70 00 Wall Finishes
09 81 00 Acoustical Insulation
09 90 00 Painting and Coating

Important questions for this review include the following:

What specific items are included in the bid-related section?

What related items are elsewhere?

Are metal framing thicknesses already specified? Unless otherwise specified, all cold-formed framing must meet ASTM criteria—that is, a minimum base steel thickness of 15 mils (0.0155 inch). Should the contractor propose to use proprietary non-structural framing, it will be important to provide data on thicknesses less than what is specified.

Are fire-rated walls specified? If so, what are the UL, FM, or Intertek design numbers? All fire-rated systems must be built exactly as specified within these listed designs. Also, in non-structural applications it is important to establish the anticipated floor movement. This information is critical in providing an adequate head-of-wall fire-resistive design.

Do any of the walls require insulation to enhance sound control?

What type of insulation is specified? What thickness and density?

If the scope of work includes the exterior envelope, then a complete review of the air/water barrier and continuous insulation is warranted. Air barrier information will be found in Section 07 27 00. Insulation is in 07 21 00.

Review of the "General Scope" section also reveals key information regarding the project bidding:

Is the project bid complete or in phases? The bid form will alert the estimator to his pricing strategy. Are unit prices required?

Is lineal footage pricing specified? Many tenant projects require base bids to include shell and core work, while all divider walls are quoted on a lineal foot basis. This allows potential tenants the flexibility to specify walls where they need them.

Finally, there is one important question to ask on any project:

Have any addenda to the specifications been issued since the last contract with the project? All addenda should be reviewed to assess possible impact on the framing portion of the project.

From a thorough specification study, a complete scope of the work is accurately identified and understood. The estimator is then ready to review the detail sheets.

Scanning for unusual details or conditions may reveal the need for additional materials and/or labor. To miss these "special details" can be disastrous to the overall bid. For example, "blocking" can add a lot of cost to a project, especially in a health care project. The estimator should compare the detail sheets to the floor plan.

Ceiling heights for specific areas can usually be found in the section titled "Room Finish Schedule." During this review, mark ceiling heights on the floor plans, which will simplify material take-off.

By reviewing the specifications, detail sheets, and room finish schedules, an estimator can then segregate wall types—for example, which walls are smoke walls, one- or two-hour fire walls, sound control walls, double studded chase walls, etc.

The next step is to isolate each wall by type on the floor plans. Most estimators either color-code or symbolize each wall type for easy identification later. For a typical office project, this may be a relatively simple task with few differing wall types. On more complex projects, such as hospitals or large health care facilities, there easily could be dozens of different wall types.

Once all the wall types have been located and highlighted, a bill of materials is prepared for each type. All wall types are then taken off by lineal footage. To produce the job total for each wall type, multiply the parts and pieces developed in the bill of materials for that wall type by the lineal footage of that wall type. After all components have been taken off by wall type, similar components can be combined to produce the final bill of materials.

Conditions generally taken off separately include corners, intersections, finished ends, door frames, glazing, blocking, and "special detail" components.

Now it's time to assign labor costs for the project. For purposes of this discussion, labor units are those designated in the RS Means US Average Cost Data as averages for favorable working conditions and normal labor productivity. (These units have been determined on the basis of complete installations only and may not be accurate for very small jobs or for small changes to big jobs.)

It is also assumed that the estimator thoroughly understands the effect of various changes in installation conditions under which the same component may be installed and how these changes directly affect the labor consumed. Without such understanding there is a danger of indiscriminate application of labor data.

Estimating labor must begin with the stocking of the project. As an example, consider a one-story building easily accessed by delivery vehicles. One man-hour minimum is allowed per 375 lineal feet of partition for steel parts and accessories, with one man-hour minimum also per 2,000 square feet of gypsum drywall.

Once the material is stocked, labor is assigned for distribution of materials throughout the project. For framing components, allow one man-hour minimum per 200 lineal feet of partition. Add one man-hour minimum per 1,000 square feet of drywall.

After distribution of materials, the mechanic lays out the project and locates partitions, frames, glazing, etc. As a rule, there should be one man-hour needed per 50 lineal feet of partition. Add on for "runs" of partition calculated as 3.6 runs per man-hour. (A "run" is defined as each time a line of partition changes.)

Once the layout is completed, the mechanic installs the top and bottom tracks. For ceiling heights of 10 feet, there should be one man-hour for every 40 lineal feet; for ceiling heights of 12 feet, one man-hour per 30 lineal feet; and for ceiling heights of 16 feet, one man-hour per 25 lineal feet.

Size	Man-Hours Required
1/2 in. x 8–10 ft.	2.8 boards per man-hour
1/2 in. x 10–12 ft.	2.3 boards per man-hour
1/2 in. x 12–16 ft.	1.5 boards per man-hour
5/8 in. x 8–10 ft.	2.4 boards per man-hour
5/8 in. x 10–12 ft.	2.0 boards per man-hour
5/8 in. x 12–16 ft.	1.3 boards per man-hour

Stud installation (assuming 33 mils 3 5/8 inch studs at 24 inches on center) requires one man-hour per eight pieces of stud 8 to 12 feet high. Reinforcing channels, if needed for stiffness, call for one man-hour per 100 lineal feet of channel.

To install hollow metal door frames, one man-hour per two frames is usually adequate. For frames wider than 42 inch, it takes one man-hour per frame.

Framing for window openings typically requires one man-hour per 6 foot section for framing and one man-hour to set up to 6 foot of window frame.

Board rates for 48 inch wide drywall vary by board size. Typical man-hour requirements are listed in Table 7-1.

Partition runs that are higher than 16 feet require scaffolding and should be calculated accordingly.

Cleanup of materials is generally excluded from a contract. If not, the estimator should analyze man-days required for cleanup and make provisions in the estimate for this item.

Many estimators have computerized their estimating breakdowns and estimate projects simply by entering types of walls into their estimating programs. They typically build in a waste factor, approximately 5 percent on track, and 3 percent on studs. Obviously, the waste factor is increased or decreased according to the size and complexity of the project.

There are, of course, numerous other factors to address on a job-by-job basis. For example, in the overlap of trades, who installs the exterior polystyrene and air barrier? And, is this responsibility clearly defined in the specifications? If not, it pays to qualify the final bid by spelling out exactly what is and is not included.

In estimating cold-formed steel framing, or any job for that matter, good estimators have an eye for details and variables that can make or break the bid. It's a matter of covering the basics—low enough to get the job, high enough to make a profit.

CHAPTER EIGHT
Interiors Installation

Cold-formed steel framing provides an effective support method for interior finish systems such as gypsum drywall, veneer plaster, and conventional plaster. These systems help satisfy the performance requirements of a building structure by forming the backbone for a wide variety of wall and ceiling assemblies. These include basic space dividers, sound-attenuating space dividers, fire-resistive space dividers, shaft way enclosures, exterior wall furring, ceiling systems, etc. Cold-formed framing in interior walls is typically non-load-bearing but can range from 18 mils (0.0179 inch) to 97 mils (0.0966 inch) base metal thickness.

ASTM Standards

Cold-formed steel framing members for interior applications are addressed by two ASTM standards, ASTM C645: "Standard Specification for Nonstructural Steel Framing Members" and ASTM C754: "Standard Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products." The ASTM C645 specification defines what a non-structural cold-formed steel framing member minimum must be when used in interior construction. It must have a corrosion-resistant coating, and the steel thickness and profile shall be sufficient to carry the transverse design loads. There is also a performance test where the steel must have the capacity to pull a screw head through the face of an attached piece of gypsum board. The specification establishes a minimum base (uncoated) steel thickness of 18 mils (0.0179 inch.). However, many steel framing manufacturers have developed what may be considered a new generation of steel framing members that provide essentially the same performance levels as required, but with thinner steel. These manufacturers will provide contractors with documentation that validates the use of their proprietary products.

Relating to the corrosion resistance, ASTM C645 uses G40 galvanization as the minimum level of corrosion protection. The specification further states "…G40 minimum or shall have a protective coating with an equivalent corrosion resistance." (ASTM C645 Paragraph 4.2). Some manufacturers use this option and will provide the necessary documentation to support the variance.

ASTM C754 includes a tabulation of allowable limiting heights, which is the maximum permissible height such that framing members still satisfy stress and deflection limits under an assumed design load. For interior non-load-bearing walls, a uniform live load of 5 psf is required. The three major steel framing associations—CSSA, SFIA, and the SSMA—all have technical guides that provide load and span tables as well. These tables provide wall heights based either on the stiffness contribution provided by the presence of gypsum panels, or by the capacity of the steel framing alone. The composite tables offer greater heights, but specialty detailing is required.

These tables are based on standard profiles. Many manufacturers provide proprietary shapes, and in those applications, their technical data must be consulted. To ensure that the framing members shipped to the job site meets ASTM and code requirements, each association has a code compliance program. Using a recognized third party, manufacturers are required to submit to audits and plant inspections. This program assures building officials, architects, and contractors that the supplied materials are code compliant and meet the required standards.

Fasteners

A key component that probably made cold-formed steel framing a practical reality is the self-drilling, self-tapping screw with a corrosion-resistant coating. There are many screw types and lengths available to accommodate different thicknesses of finish material and to fasten metal framing members. The basic screw for applying gypsum drywall has a Phillips head recess for rapid driving and a bugle head shape for seating in the drywall. An electric screw gun with an automatic clutch drives and seats the screws to the proper depth. Properly driven screws will not break the face of the paper and will be sufficiently recessed to be concealed by joint compound.

Some high-performance gypsum panel manufacturers recommend that a special fastener should be used with the new generation cold-formed steel framing. This bugle head fastener has what is termed a high-low thread pattern that helps minimize the potential of screw spinout. Screw spinout is where the screw removes too much of the steel framing material, and does not allow for the setting of the fastener. Also, it is recommended that the tip of the screw come to a sharp point (termed Type S screw), as opposed to a drill point (Type S-12). A final suggestion is that the installer consider using a lower RPM (3000 RPM or less) screw gun. This is all done to help ensure that the fastener has adequate holding power and the system performs as was tested by the gypsum manufacturers.

A different drywall screw is required for thicker steel applications. The tip of the screw is different to accommodate the heavier steel. Thin steel is easily penetrated by the piercing tip, and the screw threads engage the steel almost immediately. In the thicker steel, the tip must drill through the steel. The general designation is Type S for steel from 18 to 30 mil, and Type S-12 for steel from 43 to 97 mil.

Where fastening is required between two pieces of steel, the tip configuration is the same as for drywall screws; that is, Type S and Type S-12. The head of the screw will vary based on application. The pan-head screw is the most common. The head itself has a radius allowing for the Philips head recess. The hex-head allows for installation using a nut-driver screw gun attachment. This type of fastener is normally used where greater fastener loads are required. If the steel-to-steel fastener is to be covered with gypsum panels, then a low-profile head should be used. It is important to pay attention to material build-up over the flange of the stud, for this build-up will force the gypsum panel out of plane.

The fastener that is used to attach the top and bottom track to structure is typically of the powder-actuated type. This fastening system is analogous to firearm technology. A hardened steel nail is driven through the track web and into concrete as the result of an explosion.

Partitions

Partitions constitute the major use of cold-formed steel framing for interior finishes. In this application, tracks are secured to the floor using suitable fasteners typically spaced 24 inches on center. Top runner tracks are secured to the structure or to the suspended ceiling grillage components. The stud depth and thickness are determined by calculation based on height of the installation, the anticipated (design) transverse load. The studs are installed into the top and bottom track. They should all face the same way, meaning the open side (the one opposite the web) should all be in the same direction. Failure to do this may result in misaligned gypsum panel joints and deformation at panel joints.

Cold-formed steel framing members are not symmetric. That results in the tendency for the framing members to rotate under load. Lateral bracing is used to resist this movement. Gypsum panels installed full height on both sides of the partition act as bracing. In the absence of the gypsum panels, metal mechanical bracing is used. The most common solution is to install a metal channel through the punch-outs found in the webs of the studs. Thus, the punch-outs should all be at the same elevation. Some manufacturers provide proprietary bracing solutions to facilitate installation.

In non-structural applications the studs are not mechanically attached to the tracks; they are initially held in place by the tension exerted by the tracks. They are secured in their final position as the finish panels are screw attached—the panels generally are not screw attached to the tracks, only to the studs. Studs used in such applications are typically cut to a length of 3/8 inches less than the actual floor-to-floor height. This will allow for minor concrete creep and differential building movement (building drift in high-rise buildings and live load floor deflection). There is a trend to design for significant differential movement. Significant building movement can be defined as floor deflections over 1/2 inch. If the anticipated deflection is up to 1 inch deflection, there are single leg proprietary tracks available. Any movement more than 1 inch requires the contractor to consult with the preferred framing manufacturer for appropriate solutions. Solutions in any case must account for adequately transferring the lateral load to the structure while maintaining any acoustical or life safety requirements. The cost of the installation will drastically increase with the amount of movement. Thus, the contractor should determine this movement during bid stage.

Studs are typically spaced 24 inches apart maximum, but may be installed at 16 inch or 12 inch intervals, depending on particular job requirements. The tighter spacing will allow for taller walls, but the trade-off will be in acoustical performance. Published test data on the acoustical performance of wall systems are based on the 24 inch spacing and 18 mil studs. The Sound Transmission Classification (STC) falls off drastically at tighter spacing.

The three steel framing associations publish data on how to select the proper size stud for a given wall height and applied load condition. Tables are available that detail how tall the wall can be based on load, stud depth, and stud thickness. The tables also illustrate the contribution to stiffness that installed gypsum panels provide. There are two tables for non-structural applications. The first table is based on stud properties alone but still requires the stud to be restrained from twist and the second table accounts for the stiffness contributed by the gypsum panels. This is called "Non-structural Composite." One association provides a third table, and that accounts for alternate spacing of lateral bracing. In summary, there are three ways to account for the required lateral bracing. The first is with gypsum panels installed full height on both sides of the stud installed in a specific manner. The second and third are with no gypsum panels, but with lateral bracing provided by the addition of strap bracing at 48 inches on center (Table 2) or the spacing of the bracing as dictated by the condition (Table 3). The contractor should use only the table that simulates the proposed installation.

Considering an allowable deflection criterion of L/240, nominal 0.0188 inch design base metal thickness 2 1/2 in. steel studs with a 1 1/4 inch flange having a Moment of Inertia (I) of 0.098 inch4 and a Section Modulus of 0.060 inch3, and no gypsum for stiffness contribution, at a 5 psf lateral load, the following minimum height is attained from the three associations SFIA, CSSA, and SSMA 2012 tables:

Stud Spacing Height

24 inch on center 8 feet 3 inches

Heavier gauge (greater design base metal thickness) studs provide increased stiffness. Studs as cited above framed from nominal .035 base metal thickness steel provide the following minimum height capacities:

Stud Spacing Height

24 inch on center 10 feet 6 inches

The CSSA data is not included, for they use a different stud profile with different material properties.

Door Frames

Doors installed in steel framed systems must be properly addressed to ensure that the integrity of the assembly is not impaired. Door frames should be a minimum of 18-gauge with 16-gauge steel plates welded to trim flanges for anchorage to the floor with two powder-driven anchors per plate. Frames should be furnished with proper 18-gauge steel jamb anchor members welded in place.

The proper cold-formed steel framing requirements (i.e., the number and thickness of jamb studs used) for a door opening are determined by calculations based on the size of the opening and the weight of the door. According to the Gypsum Construc-

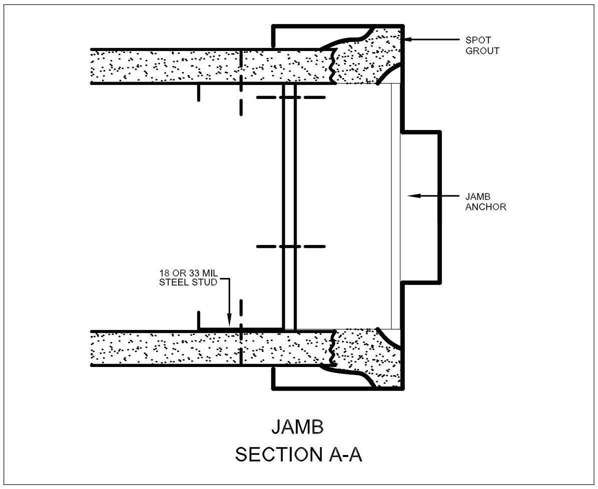


Figure 8-1 Door Frame Section

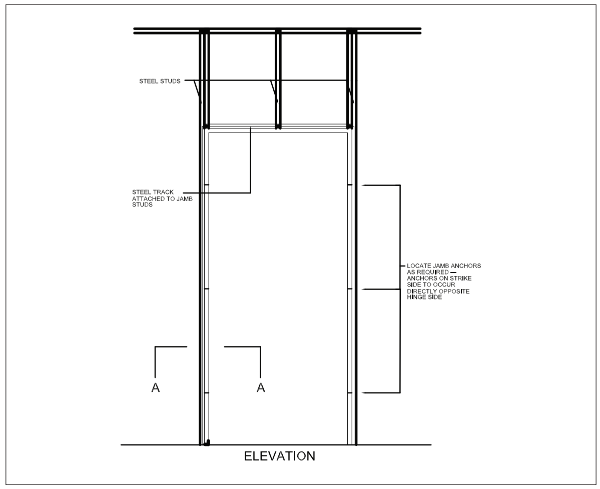


Figure 8-2 Door Frame Elevation

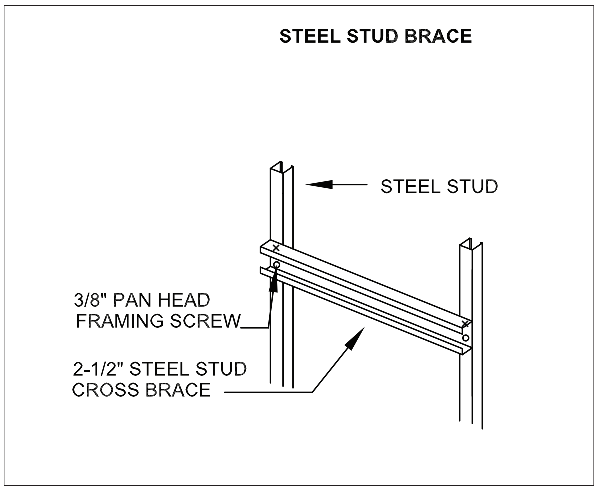


Figure 8-3

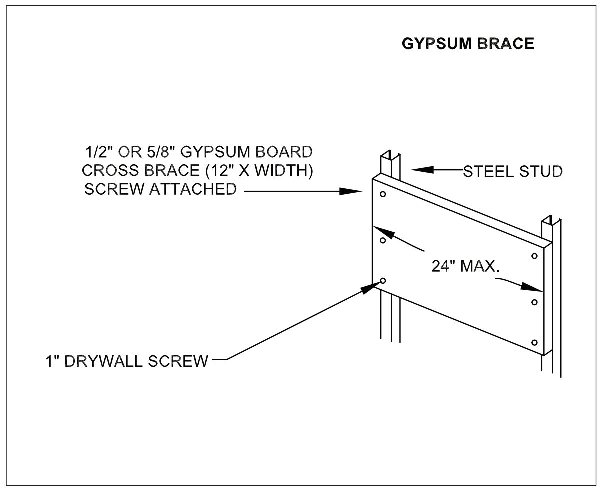


Figure 8-4

tion Handbook published by USG Corporation, 18 mil studs and track are acceptable for building door openings up to 2 foot 8 inches wide with doors weighing up to 100 pounds. The jambs should be mechanically attached to both the base and head track. For openings ranging from 2 foot 8 inches up to 4 feet wide, the jamb studs should be 30 mil. Larger openings and heavier doors require a specific engineer's analysis.

The above section A-A is taken from www.wallsystemdesign.org. It shows the relation between the jamb studs and the frame. The spot-grout is only required if needed by the door frame manufacturer. The elevation below is from the same website and details the general cold-formed steel framing around the door.

The wall system design website offers CAD details for many cold-formed steel framed conditions. The details are divided into interior and exterior structural and interior non-structural conditions.

Chase Walls

Chase walls are constructed using two rows of studs spaced apart as necessary to accommodate pipes and other service installations. These walls require bracing of the unsupported stud flange facing into the chase (Figures 8-3 and 8-4). This can be accomplished by connecting the opposing rows of studs with gypsum panel cross braces or cold-formed steel bracing.

One and a half inch - 54 mil (0.053 in.) base metal thickness channel is passed through the stud's aligned punch-outs and secured to the stud with a clip angle. Spacing of the cross braces or horizontal channels needs to be determined by calculation based on the height of the wall, stud size and thickness, and lateral load conditions. Typical construction requires bracing to be installed at 4 feet on center.

There have been numerous chase wall applications aimed specifically at obtaining high STC ratings. In some cases the two rows of studs are installed in a single top and bottom track. The studs are offset, with insulation woven into the cavity. Although providing acoustical decoupling of the framing, the assembly does not allow for lateral bracing by way of the gypsum panels. This results in a requirement to use metal channels through the stud web punch-outs as described earlier. Another caution for double row (chase wall) applications for high-performance applications is the head detail as it relates to fire resistance. It is important to balance any design with structural, acoustical, and fire-resistance requirements.

Fire-Rated Assemblies

For fire-resistance considerations, Underwriters Laboratories addresses the gauge and width of steel stud framing. The following is quoted from the UL Online Certifications Directory: "The dimensions and gauge of steel studs are minimums. The hourly ratings apply when the steel studs are of a heavier gauge and/or larger dimensions than specified in a design."

Fire ratings are possible with cold-formed steel stud gypsum drywall partitions ranging from one to four hours, thus satisfying virtually all building code requirements. It is essential that fire-rated partitions be constructed exactly as specified. Material substitutions or dimensional variations may invalidate the fire rating.

Attention to detail requires that the required fire resistance of the wall must be evaluated with any head-of-wall designs. The magnitude of differential movement and its resulting design must be compatible with the structural/fire-resistive requirements of the total assembly.

Acoustical Assemblies

Sound attenuation is also satisfied with partitions constructed with cold-formed steel framing. The web of an 18 mil (0.0179 inch) base metal thick steel stud in effect acts to decouple the two gypsum panel membranes. A single layer of 5/8 inch type X gypsum panel on each side of 3 5/8 inch 18 mil (0.0179 inch) base metal thick steel studs spaced 24 inches on center will yield a Sound Transmission Classification (STC) rating of 40. Steel studs spaced 16 inches on center will not reduce that rating. Conversely, stiffer 2 x 4 wood studs substituted for the steel studs will yield an STC of 37 when the studs are spaced 16 inches on center. A three point STC difference is considered noticeable.

Partitions using steel framing in conjunction with resilient channels, multiple layers of gypsum panels, and high density sound attenuation blankets can achieve sound attenuating characteristics as high as 65 STC and have been further evaluated for their ability to control low frequency sound transmission, which is prevalent in machine noise and music. Thus, cold-formed steel framing can address sound attenuation from a basic space divider to a high-performance specialty music studio enclosure. It might be beneficial to seek the advice of an acoustical consultant for obtaining and maintaining high-performance acoustical walls.

To maintain the acoustical performance, it is important to minimize the impact of flanking paths. Special detailing is required at the intersection of wall-to-walls, as well as to walls-to-ceilings. It is critical to include the use of acoustical sealant around the perimeter of any acoustical partition. Testing has proven that a single bead of sealant that is in contact with the gypsum panel, the concrete structure, and the leg of the runner is sufficient to maintain performance. The following detail, Figure 8-5, is taken from the CAD library of wallsystemdesign.org.

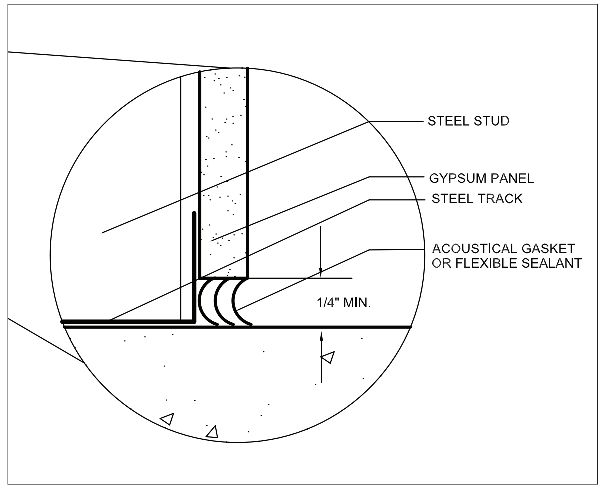


Figure 8-5

Shaft Wall Systems

Progress in construction technology necessitated development of specialty partitions using cold-formed steel framing. The prime example of this is the shaft wall system developed to enclose the required fire-rated elevator, stair, and mechanical shaft ways necessary in multistory construction. Foremost was the ability to build the shaft walls from one side to eliminate the need for scaffolding. Equally important was the ability to resist air pressure loads created by high-speed elevator movement.

More than 30 years of improvements to the system have resulted in a strong and economical cold-formed partition capable of satisfying the fire safety requirements of building codes. The system today is the accepted standard for shaft way enclosures in all types of low-, medium-, and high-rise buildings.

Furring

Finishing the interior surface of exterior concrete masonry or concrete walls is accomplished using noncombustible steel furring that supports the gypsum panel membrane. Furring products are available in several depths to accommodate different thicknesses of insulation. Furring the inside face of exterior concrete or masonry wall takes on added significance in light of the new energy conservation codes. Any exterior wall should be constructed with consideration of climatic conditions and should properly address the need for, and proper location of, a vapor retarder. Failure to do this can result in condensation in the wall with potential development of mildew and rust. Also, the codes require air/water barriers to be included in all exterior envelope designs. Special attention to design and installation is warranted here as well.

Ceiling Systems

Suspended and contact ceilings are achieved with cold-formed steel framing members. Suspension can incorporate 1 1/2 inch cold-rolled channels cross-furred with drywall furring channels. There are also proprietary versions that incorporate the concepts of a lay-in acoustical tile grid. When the ceiling membrane is part of a fire-rated assembly, the requirements of the particular fire-rated design must be followed. A typical floor-ceiling assembly with bar joists supporting a concrete deck will usually require additional furring channels at the gypsum panel end joints. Insulation used in the plenum of a fire-rated ceiling assembly might impair the fire-resistance rating by contributing to early failure of the gypsum panel membrane.

Area Separation Fire Walls

Even in buildings constructed primarily with wood framing, steel studs can be used to cost-effectively address specific code requirements. Steel framed, gypsum-clad area separation fire walls, or "party walls," are common walls that provide fire-resistive protection for adjacent properties. These lightweight, non-load-bearing assemblies are designed as vertical fire barriers separating occupancies in wood-framed apartments and townhouses. They also meet the code requirements of remaining in place if the structure on one side is totally consumed in fire.

CHAPTER NINE
Load-Bearing Structural Wall Construction

The applications and benefits of a steel framed load-bearing wall are numerous:

▪ Single or multi-family residential.

▪ Assisted living complexes.

▪ Modular construction.

▪ Motel and hotel construction.

▪ Reconstruction of interior spaces such as the addition of office spaces "inside" an existing building or the renovation of a masonry shell.

▪ ▪ Where dead weights must be held to a minimum; e.g., poor existing soil conditions or multi-level residences requiring unique ground level construction such as a parking structure or open areas such as meeting and dining rooms, etc.

▪ ▪ Compatibility with a wide range of floor and roof systems.

The use of "C" joists in sloped roof assemblies, coupled with stud bearing walls, have increased dramatically in recent years as more architects shy away from conventional flat roof systems. Additionally, steel studs are adaptable to wood trusses, steel bar joists, and composite concrete deck systems. Fortunately, many aspects of load-bearing cold-formed steel construction follow conventional framing methods. This chapter will familiarize the reader with the technical considerations of a cold-formed steel load-bearing wall. It serves as an overview to the many items you should consider when preparing an estimate, purchasing materials, or constructing a bearing wall assembly.

A steel framed load-bearing wall is unique for a number of reasons:

- It resembles traditional wood construction using steel components that are sometimes pre-assembled and installed as manufactured frames.

- Unlike the "secondary" components of a curtain wall application, steel framing used in load-bearing walls acts as the "primary" frame.

- It requires a comprehensive engineering analysis coupled

- with unique construction bracing and installation methods.
- Heavier framing components are used, adding to fabrication and finishing time.
- It is constructed in predetermined sequences demanding a coordinated effort, particularly if the floor or roofing installation is performed by others.
- Beyond those challenges, these are basically the same components and common sense framing methods you have become familiar with over the years.

Components in a Load-Bearing Steel Stud Wall

A load-bearing stud wall (Figures 9-1a and 9-1b) generally consists of the C studs and track framed openings, including headers and jambs. Distribution headers, shear wall, and miscellaneous hot-rolled steel shapes may also be incorporated into the wall system.

Studs

"C" studs used in the construction of a load-bearing assembly are characterized by the following:

Minimum Flange Width: 1 5/8 inch.

Increasing the flange width to 2 inches or 2 1/2 inches strengthens the stud's resistance to rotation and thus increases its axial and bending capacities. Consider the benefits of increasing the flange width before increasing the base metal thickness.

Base Metal Thickness and Yield Strength.

A minimum base metal thickness of 33 mil (0.0329 inch) and minimum yield strength of

33,000 psi (33 ksi) is used in load-bearing construction. Expect to generally see 43 mil (0.0428 inch) base metal thickness and heavier.

Thirty-three mil (0.0329 inch) base metal thickness framing has its applications. However, it is generally limited to single-story construction involving relatively light axial loads. Note that base metal thickness and yield increase as you descend a multi-level application. Also, where a single 97 mil (0.0966 inch) base metal thickness component is specified, it may be more economical to install a built-up section composed of two lighter gauge components.

The track provides end support for the studs and wall anchorage. The base metal thickness of the track will not necessarily match the base metal thickness of the stud. As part of a shear wall frame, for example, the tracks resist axial forces in the same manner as a stud. Therefore, base metal thickness of the track and yield are critical.

The track is not designed to transfer axial load. That means that ideally there is a clear load path from roof to foundation. The roof members bear directly on the studs. The studs bear directly on the floor joists beneath, which in turn bear directly on the first floor studs. In some cases that is not possible, so distribution beams or headers are introduced.

To ensure proper axial loads transfer, the stud ends must seat firmly into the tracks (Figure 9-2). ASTM C1007 allows for up to 1/8 inch gap tolerance. Failure to meet these requirements may result the addition of expensive shims. Mechanical bridging is advised in any structural stud axial load-bearing wall application. Failure to include bridging may allow the stud to rotate under a minimal load

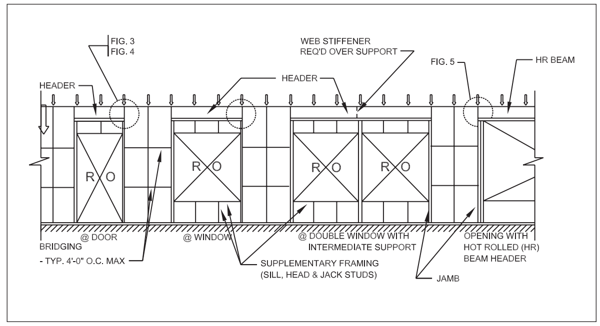


Figure 9-1a Components of a Steel Stud Bearing Wall

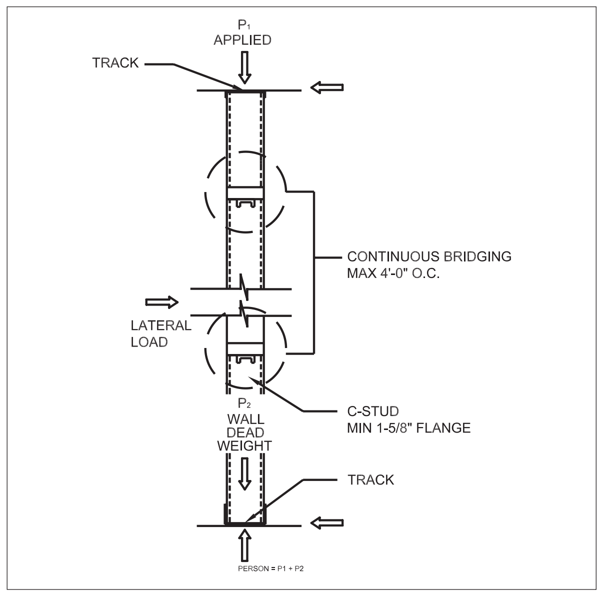


Figure 9-1b Vertical Section Bearing Wall

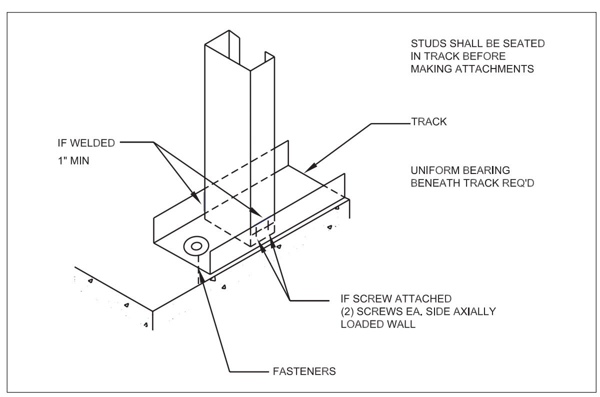


Figure 9-2 Stud to Track Attachment Alternatives

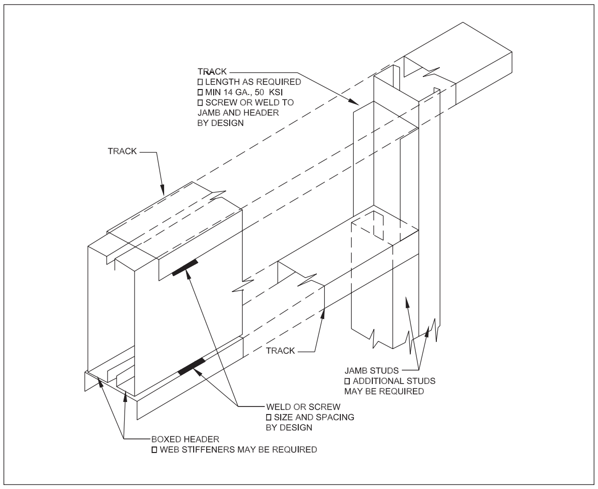


Figure 9-3 Boxed Header at Jamb

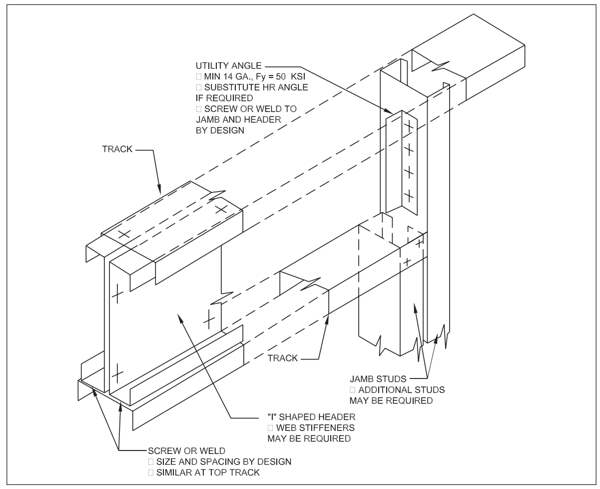


Figure 9-4 "I" Shaped Header at Jamb

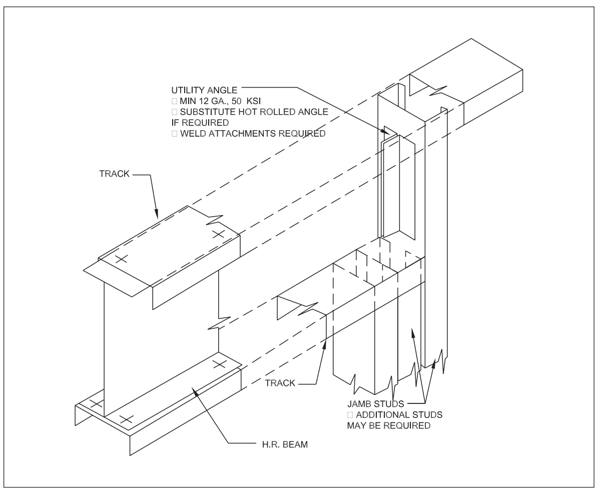


Figure 9-5 Hot-Rolled Beam to Jamb

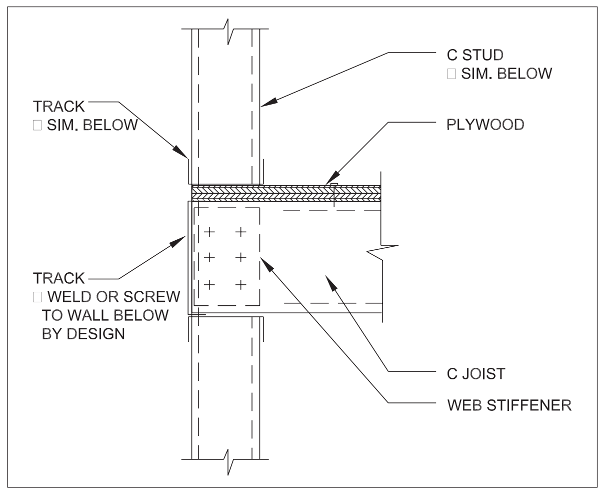


Figure 9-6a "C" Joist Aligning with Bearing Stud

and fail well in advance of the design load it was intended to carry. Remember, the axial loads induced on a frame during constriction may exceed any loads it sees during its service life. It is therefore paramount that the installation of bridging is completed before any axial loads, such as floor or roof loads are applied to the system.

Two methods of bridging are commonly employed. Typically, 1 1/2 inch, 54 mil (0.0538 inch) base metal thickness channel is passed through the stud's aligned punch-outs and attached to the stud with clip angles, or it is welded directly to the sides of the opening.

The "Flat Strap and Blocking" method is a permissible alternative in screw-attached applications.

A framed opening in a load-bearing partition consists of a header, jamb supports, and supplementary framing.

Headers and Jambs

Headers are generally constructed using one of three methods:

- Turning two "C" shapes to form a box (Figure 9-3).
- An "I" shape (Figure 9-4).
- The substitution of a hot rolled shape where the combination of span and load warrants its use (Figure 9-5).

The header is normally placed at the top of the wall in lieu of its traditional location directly above the opening. This allows the load to be carried over the opening without having to seat the jack studs to transfer the load to the header below.

Normally, headers are fabricated from un-punched framing. A punched web lowers the component's web crippling resistance capacity. Furthermore, end connections are more accommodating when made to a solid web instead of one that is punched.

A minimum of two studs should be used in the construction of a jamb, more if the load warrants. As an alternative, 3 inch wide flange jamb studs can be used if the load warrants. In any jamb grouping, extend one stud to the top of the wall and place the remaining studs underneath the header.

Clip angles or track pieces are usually added to make the attachment between the header and the jamb. As an alternative, the header end can be cut to closer tolerances and directly welded to the jamb. This detail is generally reserved for prefabricated assemblies.

The balance of the components beneath the header and between the jambs is considered supplemental framing. Conventional framing methods are used to complete the installation.

Distribution headers are installed continuously over the top of a bearing stud wall. They accommodate nonalignment of a roof or floor joist component with the bearing stud below.

Understandably, the distribution header could be eliminated if the layout of the joists and studs are dimensionally coordinated (i.e., each is spaced at 24 inch intervals) and aligned (Figures 9-6 and 9-7).

The "I" shaped header should not be used in applications involving a flush (side) mounted floor system. Similarly, a hot rolled tube shape is more accommodating to a flush mount joist than a wide flange beam.

Distribution headers aside, a load-bearing steel stud wall may incorporate other hot rolled steel shapes. Installing a single tube shape, for example, may be more economical than a multiple stud assembly, particularly when more than three studs are required.

If the application involves bar joists spaced at odd-centers (Figures 9-7a and 9-7b), it may be necessary to use a hot rolled steel distribution angle or tube to provide an adequate base for the weld attachment of the bar joist to the wall. If a cold-formed steel framing distribution header is considered, local forces at bearing locations may necessitate the installation of web stiffeners.

L-shaped Headers

Another header configuration, the L-shaped header, which until recently was only occasionally used, has begun to be used more commonly. As the name suggests, the main component of an L-shaped header is a piece of cold-formed steel angle with one short leg lapping over the top track of the wall and one leg extending down the side of the wall above a window or door openings. Each angle is fastened to the top track above an opening with minimum #8 screws spaced at 12 inches on center. The "L" angle is placed on both sides of the wall opening to form a double angle L-shaped header (double L-header). (Figures 9-8a and 9-8b)

Shear Walls

A building must have the capacity to resist applied loads in two directions, vertical and horizontal. The vertical loads are carried by the studs. The horizontal loads (wind or seismic) are carried by floor assemblies and shear walls. In both the vertical and horizontal case, the loads must be carried down to the foundation. A shear wall assembly is often the most complex assembly of a load-bearing system, particularly in multi-level conditions. The shear wall can be constructed using cross straps, wood panel, steel sheets, or another combination of steel sheets and gypsum board.

The potential for uplift forces should be carefully considered when designing a shear wall. It is beneficial to terminate the straps used in shear walls at jamb stud or column assemblies. The deadweight

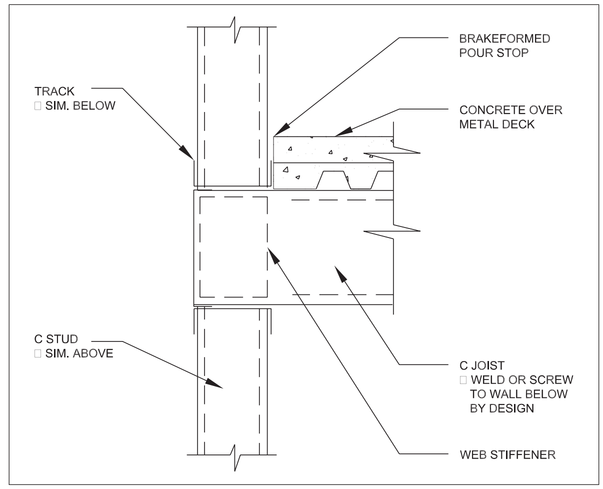


Figure 9-6b "C" Joist Aligning with Bearing Stud

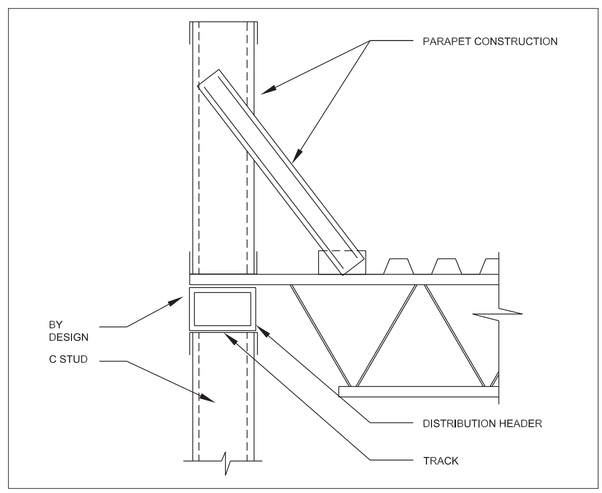


Figure 9-7a Non-aligning Bar Joist at an Exterior Bearing Wall

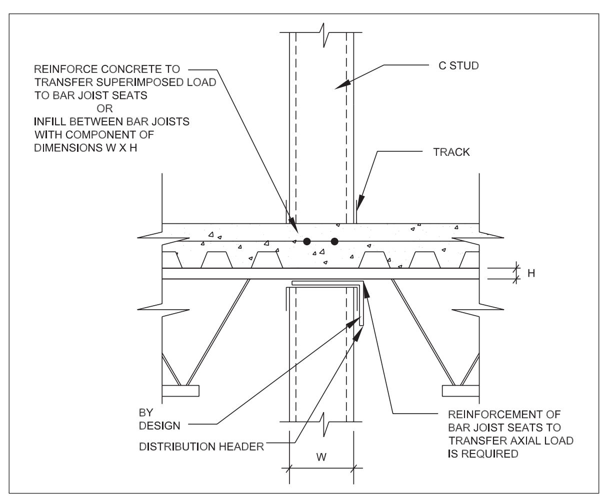


Figure 9-7b Non-aligning Bar Joist at Interior Wall

(gravity) loads supported by the jamb or column will oppose or counteract the uplift forces resulting from the action of the shear wall frame.

A conventional, steel framed shear wall consists of a series of axially loaded vertical, horizontal, and diagonal components. Multiple studs generally form the verticals, while track and built-up shapes make up the horizontals. Flat straps placed in an "X" formation are used to transfer the load in tension through the descending floors to the foundation. Flat straps of equal size are installed on both sides of the wall; this ensures a balanced distribution of the load. Shear panels are normally installed on one side or exterior or interior wall or both sides if necessary.

Base attachments to the foundation must resist the accumulated shear (horizontal) force and uplift (vertical) forces. In multi-story construction, this assembly requires considerable field labor due to the magnitude of the forces through the system.

Definition of the shear wall requirements should precede any estimate. If not clearly defined, check with the Owner's Engineer of Record to see if cold-formed steel framed shear walls are used.

In some low-level structures the attachment of sheathing products such as steel sheets or other shear panels to one side of the wall will form a diaphragm that will replace flat strapping. Other times, reinforced masonry walls are used. In any case, investigate the shear wall requirements. Do not assume that because it is not shown, it is not required. You may be told later the architect/engineer classified the shear walls as "supplemental strappings and anchorings."

Also note the thickness of the flat straps. As they are often shown in an "X" formation to each side of the wall, appreciate the difficulties associated with hiding the bulge that would result from crossing the straps at a stud location.

Attachment Methods

Welding or screw attachment methods are acceptable in the construction of a load-bearing wall assembly. Welded frames are preferred when the walls are prefabricated into panels because most of the welds can be made without turning over the frame, as would be the case if screws were used. Welded frames also offer greater resistance to racking during shipping and handling. As with any cold-formed steel framing assembly, take into account the expense of treating all welds with a compatible protective paint coating to restore the component's original coating properties.

Screw attachments are necessary where a 33 mil (0.0329 inch) base metal thickness product is specified, and they are preferred when stick-built methods are employed. The use of two screws on each side is preferred over the typical single screw attachment used in curtain wall construction. Consideration should be given to the cost of screwing into heavier gauge components. Also, since the walls could be subjected to the elements over an extended period of time, the screws should be polymer-coated in addition to the usual protective coating. Concrete attachments range from powder-actuated fasteners (shear loads only) to expansion bolts (adequate

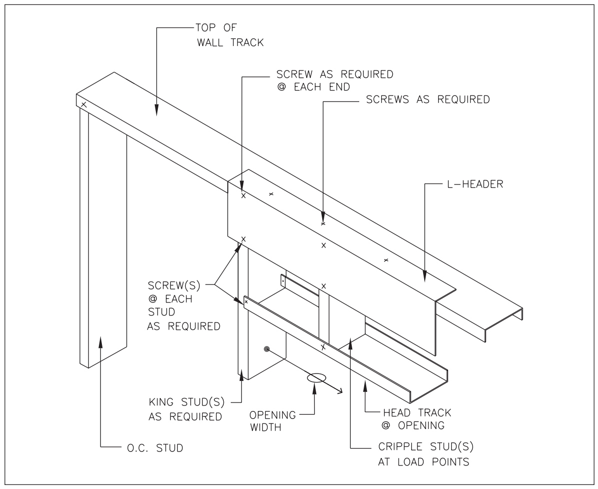


Figure 9-8a Single L Header

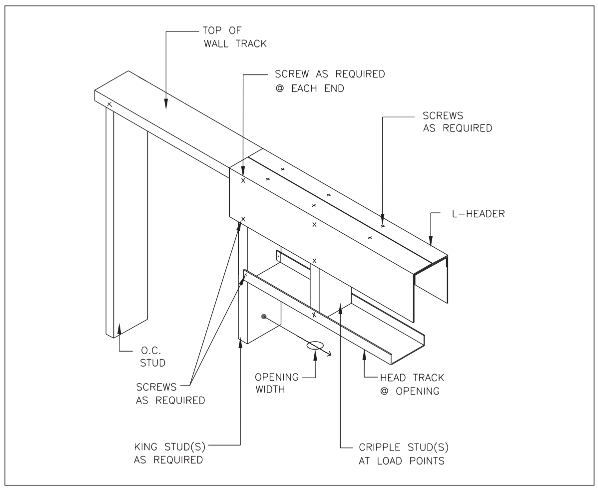


Figure 9-8b "I" Double L Header

edge distances and depth of concrete permitting) to cast-in-place threaded bar and dimensionally oversized embedded plates (the preferred method for anchoring a multi-level shear wall frame).

Construction Methods

The virtues of prefabrication in the construction of load-bearing assemblies have been well recorded over the years. The prefabrication of repetitive conditions curtails construction time and financing. From a technical standpoint, assembling frames in a compressible fixture table promotes proper seating of the stud ends into the track, which ensures the transfer of axial force.

Many load-bearing projects are smaller in scope and quite often removed from the fabrication shop. This type of project would lend itself to a field assembled application. The tilt-up wall, a method borrowed from wood construction, is often used.

Commonly, carpenters will use extendable clamps in conjunction with a header plate at the ends of the wall to compress the studs into the tracks. In any case, piece by piece stick-built applications should be avoided. It is difficult to restrain the top of the wall, and the potential for gap between stud and track is great. The installation of shims to achieve complete bearing is unavoidable. The increasing use of steel stud bearing walls will create opportunities to promote and quote this work.

To prepare for the challenges and rewards of the cold-formed steel framing load-bearing market, remember to pay close attention to the system's unique design and installation. The bid documents should clearly describe the structural intent, components, spacings, and connection requirements. Questions can be addressed by a qualified structural engineer familiar with cold-formed steel framing construction. Contact your suppliers of steel framing for manufacturer's literature or further information.

CHAPTER TEN
Truss Fabrication

The construction industry is continually providing products and systems that provide sound structural integrity, are economically feasible, and can provide protection from fire hazards. Cold-formed metal-framed roof trusses provide all of these.

Cold-formed steel trusses have been in use for many years. The many depths and thicknesses of cold-formed steel framing members offer flexibility in design to allow for spans up to 70 feet. The spacing of these trusses in some cases is limited by the intended roofing material. Any truss configuration is available including mono pitch, Fink, Howe, truss joints, and scissors trusses. See Figure 10-3.

Truss configurations are similar to those built of conventional steel (but with lighter loading) and those built of wood (with comparable loading). Cold-formed steel trusses generally are used for roof construction, and as such fit the same niche as light wood trusses: single-family dwellings, apartment complexes, retirement villages, small offices, schools, and churches. The trusses are typically spaced at 16 inches or 24 inches on center.

Terms and Definitions

A truss is an assemblage of members that allows a single system to span longer distances than a single member could span. Most trusses are built in a series of triangles. This is because the triangle is inherently stable. For that reason, a truss has a minimum of three members: the top chord, bottom chord, and web members. See Figure 10-1.

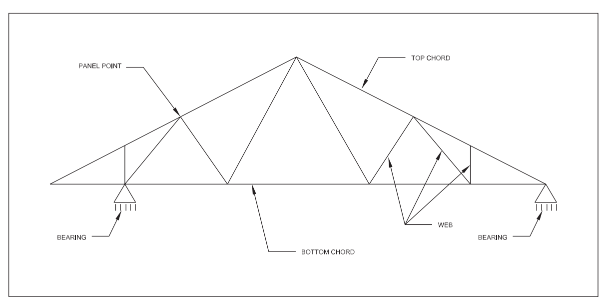


Figure 10-1

The roofing and ceiling materials are generally attached to the top and bottom chords respectively. This attachment can either be direct or through a furring channel. The chords are the main load distributing members and, as a result, are the greatest depth. The web members provide the transfer of loads between the chords and ultimately to the bearing points.

The members of a truss resist three types of stress (Figure 10-2): tension stresses that tend to stretch the member, thus elongating its length; compression stresses that tend to shorten its length; and bending stresses that tend to rotate or bend the member out of its straight configuration.

The chords are the members that make up the perimeter of the truss assembly. The roof system usually bears on the top chord, and a ceiling is supported by the bottom chord. Chords are usually designed for bending loads in addition to axial (tension or compression) loads.

The web members of a truss are the internal members that form the legs of the desired structural triangle configuration. They provide the truss assembly with the ability to span long distances. These members usually are designed for axial (tension or compression) loads.

A panel point is the location where two or more members of a truss are connected. The ridge is where the two slopes of the top chord meet or the highest point of the mono pitch truss. The bearing is where the truss is supported by a wall or some other structural member such as a column or beam. Usually the bearing is at a panel point. If bearing happens at a point other than a panel point, then additional bending stresses occur that may significantly impact the required size of the chord member. There is a minimum of two bearing points, but there can be more depending on the truss spans.

The proper design of a truss must take into account the potential for buckling in the individual truss members. There are two types of buckling that must be considered in the design of cold-formed steel truss members. The first is where a member under axial bending load may curve out of its straight shape and become unstable and collapse. This is individual member buckling. The second is localized buckling, and that is when a portion of a member, such as the flange or web, warps or crimps under load.

Loads

When designing trusses there are three types of loading that must be considered. They are live, dead, and wind loads. Live loads consist of people on the roof, snow, and ice. This would occur on the top chord only. The bottom chord live loads would consist of people in the attic, and storage of goods in the attic. The dead load is the weight of the truss, roof material, ceiling material, lights, and other ceiling fixtures. The dead load is also broken down by top and bottom chords. Special loads include mechanical units, dormers, and other single or widely dispersed loads.

The wind load is applied to the top chord only. Local building codes determine what and how the wind load is to be applied. In most, but not all cases, the wind creates uplift on the truss.

The load to which a truss is subjected comes from a number of sources. Some are known quantities, such as the "dead loads" of the weight of the truss, the weight of the roofing, and ceiling materials as well as the weight of equipment attached to or supported by the truss, such as lighting and HVAC (heating, ventilating, and

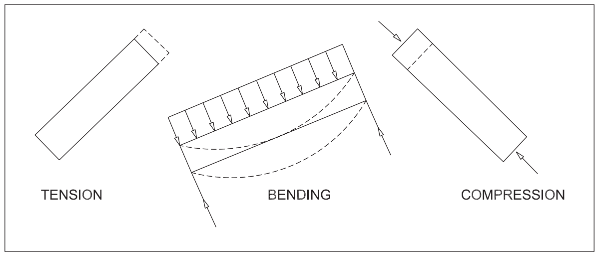


Figure 10-2

air conditioning) units. Some are unknown quantities that have been codified by authorities, such as the roof "live loads" of rain and snow, "wind loads," and the "seismic (earthquake) loads." There are unique load requirements if a green roof is part of the design. The required amounts of unknown loads to consider in the design of a truss are listed in the code that has been adopted by the local building code department.

Trusses should be designed by a licensed professional engineer familiar with cold-formed framing systems. The design of cold-formed steel trusses can most easily be accomplished by using a computer. Some of the process can be standardized, such as minimum nominal stud sizes of minimum steel gauge. Or, if a series of trusses with the same roof slope and different spans and loading condition can be assembled in a manufacturer's catalog of designs, some standard trusses can be built. Each truss for a building must be designed individually. Designing the truss starts with sketching the truss shape, determining the dimensions, and inputting the configuration, member sizes, and loading into the computer. After the computer has analyzed the truss, each individual member of the truss must be checked for all the loading conditions from the output. Most members will have tension or compression loads, and many will have bending loads. These combined loads may change for different loading conditions.

Types of Trusses

There are many different truss configurations. Since a cold-formed steel truss is configured to support the roof and ceiling, the basic shape of the truss is set by the design of the building. The roof or ceiling can be level or sloped. Some common shapes are shown in Figure 10-3.

Some considerations need to be made as to the type of truss selected. If the roof is steep, a pre-manufactured truss may be too tall to deliver in one piece. If the ceiling is not level, a scissors truss may be used, but remember that a scissors truss spreads as it is loaded or additional axial (tension or compression) loads are added. A scissors truss is also more difficult to handle during erection. If the span is long, trusses may need to be delivered in several pieces and assembled in the field before erection.

Connections

Truss member connections occur at the panel points. These connections can be welded, screwed, or bolted. The strength of the connection depends on the type of steel, the thickness of steel, and the allowable load of the fastener as tested.

Truss members can be assembled using pre-fabricated connectors,

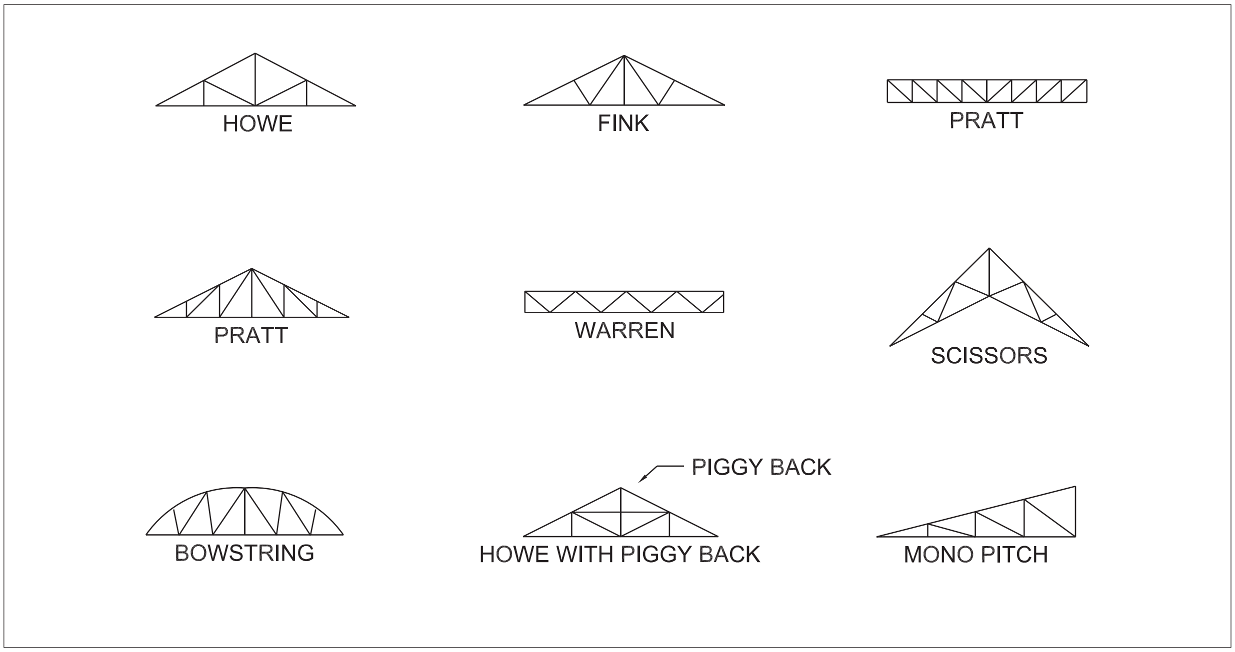


Figure 10-3

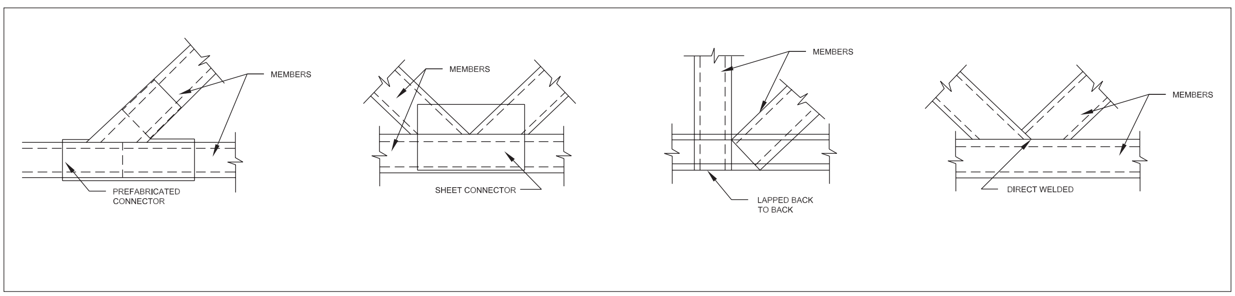


Figure 10-4

lapped back to back, or connected with sheet material or direct welding. Examples of each are shown in Figure 10-4.

Trusses are capable of transferring heavy loads in the vertical direction but can carry almost no load in the horizontal direction. Due to this fact, horizontal bridging running perpendicular to the trusses is attached to the panel points. This allows the truss to be positioned in a true vertical plane and prevents the load from distorting the truss in the horizontal plane. The amount of required bracing is a function of the span.

Individual Member Bracing

The design of an individual member of a truss must take into consideration whether the member may buckle. The probability of a member buckling depends in great part on its length. If a member's buckling length can be reduced by attachment to other material, then a lighter truss can be designed. Thus, the roof sheathing can be used to brace the top chord, and the ceiling can be used to brace the bottom chord.

Individual web members and unbraced top and bottom chords can be braced by bridging or bracing placed perpendicularly to the members (Figure 10-5). Care must be taken to show this individual member bracing on erection drawings, and inspection must be made to ensure that this bracing is installed, and installed properly, because failure to do so could result in collapse of the roof structure.

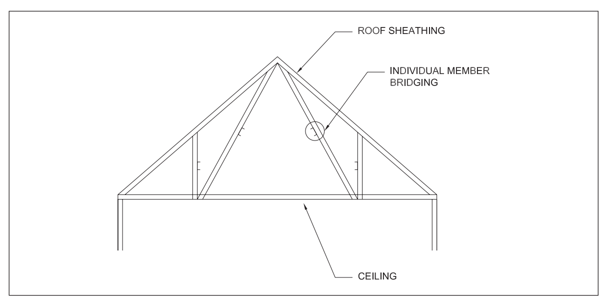


Figure 10-5

Roof Stability Bracing

As with individual member bracing, the entire roof structure must be braced to ensure stability. This is particularly true during erection, or if the top and bottom chords are not suitably braced by roof sheathing and ceiling. It is difficult for a single truss to stand alone. The bracing of two or more trusses provides strength and stability.

During erection and before the roof sheathing and ceiling materials are placed, bracing is required in at least three locations. The plane of the roof should have a flat strap bracing and horizontal struts on the top chord. The plane of the ceiling should have a flat strap bracing and horizontal struts on the top chord. The trusses themselves should be braced together, generally with X-bracing and horizontal struts composed of studs. All this bracing is in addition to the individual member bracing. The amount and location of the erection bracing should be determined by the truss designer.

Permanent stability bracing is primarily provided by the roof sheathing and ceiling, but may also require additional X-bracing and struts. The erection bracing, with careful planning, may be left in place as the permanent bracing (Figure 10-6).

Truss Fabrication

A jig is made to build the trusses. This can consist of a table at least as large as the truss itself, and steel angles fastened to the table at the location of the various members. The top and bottom chords as well as the web members are cut to the needed length, put into place, and either welded or mechanically fastenend together. Top chords must be bevel-cut at the peak, and web members must be beveled to fit onto the chords. Since most truss jobs require repetitive trusses, the bevel cuts can be made at one time in a separate step.

Truss fabrication can be done in a factory or on the job site, or "stick built" in place. Quality control is enhanced with either factory or job-site fabrication. Trusses can be treated as panels and fabricated in a panel shop, thus allowing for greater utilization of the panel shop.

Off-site prefabrication allows the contractor to avoid weather delays and on-site crowding. This will enhance the quality control of the project and allow the contractor to better control the labor force. Materials are generally on hand, and work may proceed into the night hours, if needed.

Consideration must be given to the following:

Size of Truss. Shipping restrictions may require the truss to be built in several different sections. This will require final assembly to be made at the site and require the use of additional materials to create the truss.

Measurements. Field measurements must be relayed back to the shop, creating a potential for erroneous information that cannot be double-checked without causing further delays.

Handling. Trusses will need to be handled at least three or four times before the final placement on the job. The size of the trusses might require heavy cranes or many employees to handle each truss. The more a truss is handled, the more likely it is to be damaged.

Storage. Trusses must be stored prior to shipment to the job site. This requires a large area, preferably in a safe, out-of-the-way place.

On-site fabrication of trusses is probably the most economical method of building trusses. No shipping costs are involved, and the handling of trusses is kept to a minimum. Also, dimensions can be checked throughout the process to ensure proper fitting of the trusses. The general contractor usually has a crane for the other

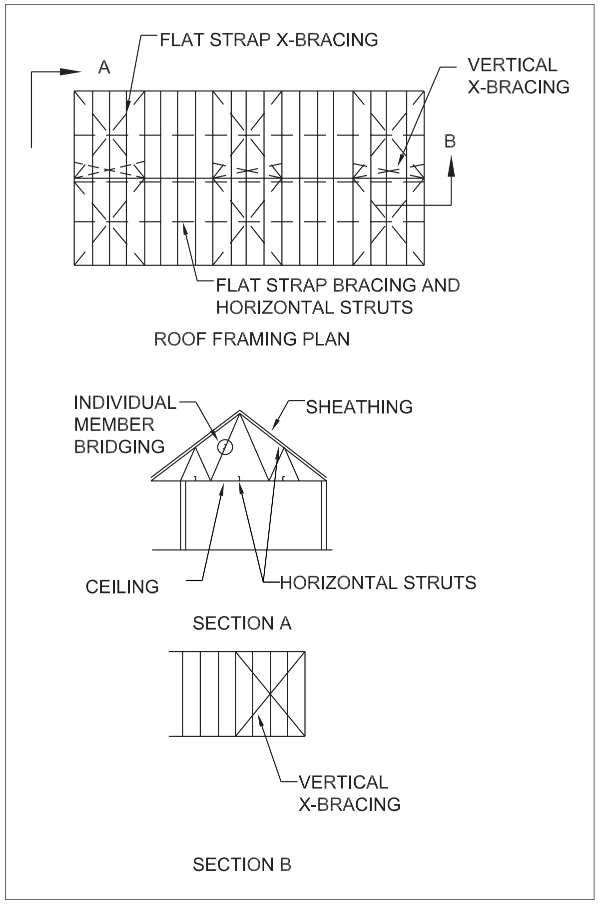


Figure 10-6

trades, and this can be shared, cutting down on the expense. Manpower is already at the job site, reducing the need for extra help.

Consideration also must be given to the following:

Available Space on the Job Site. Most job sites are very crowded and have limited space.

Weather. Jig and work areas will be exposed to the weather. Delays due to rain or cold could shut down the operation.

Utilities. Access to utilities may be limited on the site; electrical outlets may be scarce.

Delays in Building Erection. Delays will require storage of trusses on site. Again, space may be limited, and damage may occur from other trades.

Truss Erection

Comprehensive knowledge of the design of the trusses, bracing, and roof as a whole is necessary, and is imparted to the erector through the use of shop and erection drawings and job-site meetings.

Since cold-formed steel trusses are designed to be light, the shorter spans may be erected using manual labor and experienced foremen. The longer or more flexible trusses will necessitate the use of lifting equipment. Many times, erection can be simplified by ganging trusses together on the ground, and lifting an assembly of units complete with bracing. In any case, a system of bracing the first trusses is essential to the safety of the installers. Each truss subsequently erected must be braced back to the other trusses to maintain stability.

CHAPTER ELEVEN
Welding Cold-Formed Steel Framing Members

Panelization and prefabrication with cold-formed steel framing is one of the most common construction applications of welding. Welding offers many benefits including strength when used in curtain wall assemblies and load-bearing exterior wall systems. This chapter will cover the basics of welding, including equipment and worker training. It will also provide a comparison of various welding methods commonly used to fasten cold-formed steel framing.

Theory of Electrical Current

An understanding of the basic theory of electrical current is necessary to fully comprehend the welding process. Electrical current is the rate of electric charge flow. There are two types of current: alternating (AC) and direct (DC).

Alternating current (AC) travels in one direction for a period of time and then reverses its direction in the circuit for an equal period of time. The number of cycles per second is measured in units called Hertz (Hz). For example, at 60 Hz (60 cycles per second) the current travels in one direction for 1/120th of a second and then reverses its direction.

Direct current (DC) flows constantly in one direction. That is from negative to positive or from positive to negative. This is referred to as polarity. Current is measured in amperes, and power in watts or kilowatts (1,000 watts).

Voltage is the pressure that supports the electric arc across the gap between the electrode and the work surface.

Power is the rate of transforming, transferring, or consuming energy. It is computed as the product of current and voltage:

Current x Voltage = Power.

Therefore, the power of a 300 ampere, 30-volt arc would be computed as follows:

300 amp x 30 V = 9,000 watts.

9,000 watts = 9 kilowatts.

The arc has a power rating of 9,000 watts or 9 kilowatts.

In welding, power is the rate of transferring electrical energy from the power source to the metal base.

Shielded Metal Arc Welding

Although several types of welding are used in cold-formed steel framing applications, the most popular is Shielded Metal Arc Welding (SMAW), commonly called "stick welding." This popularity is due to its versatility, the portability of equipment, and the joint strength and quality of the resulting weld.

SMAW can effectively weld metals as light as 43 mil (0.0329 inch) base metal thickness. It can be used either in the shop or at the job site. Because the power supply leads can be extended long distances, SMAW can be performed at some distance from the power source. In addition, SMAW is adaptable to multi-position welding in difficult locations. SMAW can weld joints in any position that can be reached with an electrode (even overhead and vertical joints). Using bent electrodes, a welder can create joints in blind areas normally inaccessible for most other welding processes.

Specially designed assembly fixtures (jigs) are used to hold components at a convenient working level and ensure accurate dimensioning.

These fixtures, in combination with other assembly-line techniques, make SMAW a fast and efficient method for accurate shop fabrication.

Since SMAW electrode materials are available to match the properties of most ferrous base metals, the welding rod and the framing member can be a metallurgical match. This results in stronger welds.

The SMAW Process

In SMAW, an electric welding machine produces an electrical current, which is conducted through a cable to an electrode. The electrode is the welding alloy or "stick" that conducts electricity. When the electrode is brought close to the base metal, an arc is produced. The arc is the electrical current jumping across the gap between the electrode and the metal.

The electrical current meets considerable resistance at the gap between the electrode tip and the base metal. This buildup of resistance results in an arc of high temperature, ranging between 10,000 and 12,000 degrees F. This heat melts the base metal and causes it to form a molten pool. The tip of the electrode also begins to melt, forming droplets. These droplets mix or fuse with the growing molten pool.

As the welder moves the electrode along the base metal, the electrical current causes the metal to flow away from the electrode, creating a weld on the base metal. Eventually the bead cools and solidifies into a homogenous alloy of the base metals and the welding electrode.

SMAW Equipment

A welding machine (also called a buzz box or hot box) provides the correct voltage needed to maintain the arc. Generally, higher settings are required for welding heavier gauge steel members. Historically, stick welding of cold-formed galvanized steel framing has been accomplished with transformer/rectifier welding units requiring single or 3-phase, 230-volt, 50-ampere, DC electrical service. These welding units can typically furnish a current output range of 30 to 250 amperes at 30 arc volts, with positive or negative polarity. The welding of cold-formed galvanized steel framing is normally accomplished within the range of 30 to 75 amperes of current.

While most early welding machines use DC, some manufacturers offer AC equipment, which has some advantages over DC equipment. AC equipment usually costs less because it does not require a rectifier to convert AC to DC, and AC equipment can be used at some distance from the power source without the resistance buildup and cable overheating that is common with DC equipment. On the other hand, DC welders can provide a uniform, continuous flow of current to help maintain a smooth, stable welding arc.

Electrodes

Electrodes are made of various kinds of metal wire, and their selection depends on the composition of the metal to be welded. The American Welding Society (AWS) has simplified the electrode selection process by establishing a classification system. Numerical codes identify electrodes made by different manufacturers that have the same general welding characteristics.

With DC welding units, the electrode selected determines if the welding unit is set for positive or negative polarity.

The electrodes used in SMAW range in size from 1/16 to 5/16 inch diameter, and from 9 to 18 inches long. As an electrode is consumed, the welder replaces the electrode, strikes a new arc, and continues the welding process. Small, portable, automatic wire feed units are available that use coils of flux-core wire electrode with welding machines in field applications. These automatic wire feed units allow the entire electrode to be consumed, and there is less interruption to the welder since the "stick" does not have to be replaced frequently.

Electrodes are also available in coils of flux-core wire ranging in weight from 14 lbs.—used in automatic portable wire feeder units—to coils weighing several hundred pounds for stationary, mounted wire feed units in the shop.

Electrodes are coated with a material called a flux, which dissolves during welding. The dissolving flux becomes either a neutral or reducing gas (such as carbon dioxide or carbon monoxide) that surrounds the arc. The electrode's flux melts more slowly than the core wire so that the flux projects slightly beyond the tip of the electrode. This extension of flux concentrates and directs the arc stream, and it protects the melting tip and the molten puddle from the oxygen and nitrogen in the surrounding air. In addition, the chemicals in the flux keep the arc stable, control metal fluidity, and prevent porosity. Plus, they inhibit the formation of hard spots in the molten puddle.

As the weld progresses down the surface of the base metal, a coating called "slag" forms over the completed weld bead. Although the slag must be wire brushed away later, its formation serves several

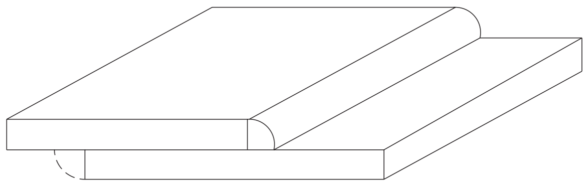


Figure 11-1
Lap Joints

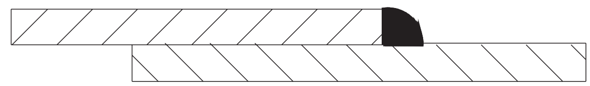


Figure 11-2
Lap Joint with Fillet Weld

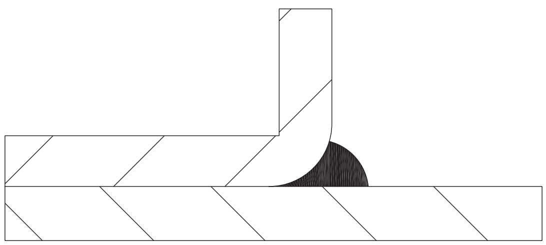


Figure 11-3
Flare Bevel
Groove Weld

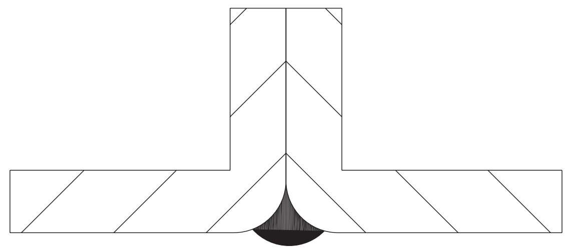


Figure 11-4
Flare Vee
Groove Weld

useful purposes: it aids in fusion, floats impurities to the surface of the weld beads, and insulates the welded point against the cooling (annealing) effects of the atmosphere.

Types of Welds

The types of weld typically used for joining cold-formed steel framing components to each other are lap joints, fillet welds, and groove welds.

Lap joints. Probably the joint most frequently used in welding is the lap two joint (Figure 11-1).

Figure 11-2 shows a lap joint with a fillet weld. The cross section of the weld is essentially triangular. Groove Welds. Perhaps the most prevalent weld used in cold-formed steel framing is the flare bevel weld (Figure 11-3). It is similar to a simple fillet weld, except the ends of the framing members are beveled. The flare vee-groove weld (Figure 11-4) joins the beveled ends of two studs.

Gas Metal Arc Welding (GMAW)

Gas Metal Arc Welding (GMAW) is an arc welding process in which a stream of chemically inert gas—such as argon or carbon monoxide—is fed through the welding gun. The gas (or mixture of gases) creates a shield that effectively controls the atmosphere. In this way the gas shield produces much the same results as the flux in SMAW. The gas shield protects the electrode, the weld pool, the arc, and adjacent areas of the framing member from atmospheric contamination.

Because the gases used to shield the electrode are chemically inert, the GMAW process is often called Metal Inert-Gas Welding (MIG). GMAW is also referred to as a Tungsten Inert Gas Welding (TIG) when using a tungsten metal electrode.

GMAW Equipment

GMAW processes are controlled through the use of three basic pieces of equipment: the gun, the wire feed unit, and the power source.

The gun guides the electrode and conducts the electrical current and shielding gas to the weld. In this way it provides two important elements: the energy necessary to create and maintain the arc and melt the electrode, and protection from the ambient atmosphere.

The wire feed unit and power sources are normally coupled to automate self-regulation of the arc length. This regulation is possible due to a constant voltage power source (flat volt-ampere curve) and a constant speed wire feed unit. Automatic maintenance of the arc length and current level means that essentially the only manual controls the welder needs are gun positioning, current level, guidance, and travel speed.

GMAW-S. The short circuiting mode of metal transfer, called GMAW-S, is a lower heat energy variation of the process. In this method, the electrode is put in contact with the molten puddle on the work, and the arc is established intermittently. The relationship between the arc and the short circuiting is controlled by the power source characteristics. Heat input is low, and so weld bead penetration is very shallow, allowing for welding out of position and on thin gauge sections.

A Comparison of SMAW and GMAW

While both GMAW and SMAW processes provide high-quality welds, each is best suited for certain applications. Criteria for selecting an appropriate welding method include the location of the welding equipment costs, efficiency, and welder skill requirements.

SMAW is probably used most frequently for field work, while GMAW is preferred for shop use. The SMAW electrode—a short rod or stick—is more portable than GMAW's continuous feed wire spools. However, the continuous feed method is far more efficient.

SMAW equipment typically costs less than GMAW because it does not require special hoses to carry shielding gas. In addition, SMAW equipment that uses AC is available, which eliminates the need for a rectifier.

SMAW requires wire brushing after each pass to remove the slag covering the bead. In contrast, GMAW wire doesn't produce slag, thus allowing multiple welding passes without interruption—another efficiency advantage.

Generally, SMAW is harder to master than GMAW because the heat is more difficult to control, requiring almost constant adjustment as job and weather conditions change. For this reason, operator skill is a limiting factor in SMAW.

Producing Good Welds in the Field

Welding requires considerable skill. The welder must move the electrode across the base metal at a constant height and rate of travel, which are to maintain a continuous arc, and at the same time keep the weld in place. Also, this ability promotes proper consistency and uniformity in size.

Pre- and post-weld cleaning techniques are important for producing high-quality welds. Before welding begins, the steel framing component must be free of paint, excess moisture, dirt, oil, and rust.

After welding (SMAW only), the cooled bead must be wire brushed to remove excess slag. Welds on galvanized steel should be coated with a rust-inhibitive, zinc-rich paint, as specified by most steel framing manufacturers.

Common Welding Problems

Certain problems seem to recur when welding cold-formed steel framing. These problems include freezing, distortion, arc blow, porosity, and surface holes. Welder skill is an important factor in avoiding these common welding problems.

One of the first skills a welder must acquire is making a clean arc. Sometimes the electrode accidentally comes into direct contact with a framing section, creating an instantaneous fusion of the electrode and the work surface. This fusion or freeze can be corrected by firmly twisting the electrode holder.

Another problem, distortion, usually occurs when large cold-formed steel sections are welded, requiring welds at frequent intervals. The base metal becomes twisted out of its original design so that the two components no longer fit. Distortion occurs most often with SMAW, which heats the welded component to a greater degree than in GMAW and GMAW-S. The only solution to severe distortion is to cut the affected components apart and re-fabricate the panel.

Another issue is when stray magnetic fields cause the arc to wander from its switch to AC welding. The solution, if possible, is to use lower currents and smaller electrodes, reduce the arc length, and weld in the direction of the flow.

An additional common welding problem is surface porosity, which occurs when holes are formed by gas trapped in the weld during cooling and solidification. To avoid this problem, ensure that the component being welded is clean; remove all rust, paint, moisture, or dirt from the area to be joined immediately prior to performing the weld. Keep the puddles molten longer. This allows the gas bubbles to boil out before the molten puddle begins to harden.

Safety

The basic elements in the welding process create potential hazards to the worker. Welders should be aware of the hazards of radiation, heat, and dangerous gases and fumes. Their training should include the selection and use of personal protective equipment.

Radiation. The radiation generated by most welding processes falls into three major categories: visible, infrared (IR), and ultraviolet (UV). The presence and intensity of UV is not immediately detectable by the senses, and it is considered more dangerous than infrared and visible light. UV is the most frequent cause of injury to the eyes, but IR and visible radiation can also damage the eyes.

Even brief exposure to radiation can cause a condition commonly called "arc eye" or "welder's eye." The symptoms, irritation, and inflammation may not be noticed for several hours. When the damage finally makes itself known, the pain can be excruciating. To treat arc eye, apply ice packs immediately. If the pain persists, the victim should receive medical attention as soon as possible.

Eye damage is the most common injury sustained by welders. Care must be taken to shield the eyes from burns, light, and heat. The best eye protection is provided by safety glasses or goggles as well as welding hoods, which can be worn with safety hats. The glasses should have specially tinted lenses designed to filter out dangerous rays and side shields to protect against flying sparks and chips.

The welder is not the only person at risk from radiation. Anyone near the welding site could be endangered. Published studies have shown that many cases of eye damage can be attributed to another welder's equipment. For this reason, arc welding operations should be isolated to avoid exposing others to direct or reflected rays. In the shop, all exposed inner surfaces should have a dull finish of non-reflective paint, portable, fire-resistant screens, similarly painted, or fire-resistant curtains.

Heat. Hot metal is always present in welding: the melting electrode, the molten pool, and the base metal, which becomes heated during the welding process. For this reason, welders must remain constantly alert to the dangers of heat, including skin burns, hyperthermia (heat stroke), and heat stress.

Control heat by a combination of methods, personal protective equipment, and welder caution. Engineering methods include cooling fans to increase the air flow over the worker, mechanical air conditioning systems in conjunction with the makeup air system, and increased general exhaust ventilation at the point of high heat production. Air should flow across the worker from one side for optimum control.

Appropriate personal clothing plays a vital role in protecting the welder from heat. Protective clothing must be fire-retardant (no polyester or double knit) with sleeves rolled down, pocket flaps closed, and trouser cuffs turned down to avoid catching sparks and slag. In addition, the welder should wear steel-toed shoes and heavy leather gauntlet gloves.

Fumes and Gases. Health hazards are created by two types of gases present during the welding process: toxic gases and asphyxiants. Although toxic gases are never used as fuel or to shield the arc, such gases may be produced as welding byproducts. Common examples include carbon monoxide and the nitrogen oxides (nitric oxide and nitrogen dioxide). Carbon monoxide may be produced when carbon dioxide in the shielding gas breaks down to produce carbon monoxide and oxygen. Fumes and gases concentrate in what is called the "fume plume," a column of hot gases that flows upward from the arc. Welders should avoid welding with their faces in the plume.

Welders should be made aware that the gases used in GMAW—argon, helium, carbon dioxide, nitrogen, hydrogen, and fuel gases—can cut off the supply of oxygen to the body tissues. Humans require between 16 and 21 percent oxygen in the air to survive. Simple asphyxiants dilute the oxygen present in the air to levels below this required percentage. An oxygen deficiency below 16 percent will cause unconsciousness and death (asphyxiation).

Chemical Contaminants. Many of the chemical contaminants present in the welding workplace are capable of damaging body organs and systems. For example, inhaling cadmium, copper, fluorides, lead, magnesium, zinc oxide, or nitrogen oxide may produce a condition called "metal fume fever." Symptoms include a high fever and shaking chills, which occur anywhere from four to 12 hours after inhaling excessive quantities of fumes.

Some welders experience nausea when welding galvanized steel. To avoid inhaling the fumes, welders may wear respirators, from simple respirators to fully air-pressurized masks. Airborne contaminants generated during welding processes are usually controlled with a combination of dilution ventilation and exhaust ventilation. Dilution ventilation reduces the airborne contaminants in the shop while local exhaust ventilation captures the contaminants close to the weld and then carries them away. Welding booths should provide circulation of air at the floor level. Be certain that removal of contaminants from the welding area does not merely transfer them into an adjacent area of operations or the general workplace atmosphere.

Specialized safety equipment has been developed to cope with the problem of hazardous fumes and smoke in the welding area. Smoke and fume removal units are available as separate equipment or as a vacuum attachment on some larger welding units. Floor ventilating systems, which draw fumes downward and away from the welder, are also available.

Welder Training and Certification

Training is available from a variety of organizations, including community colleges, vocational schools, and commercial training centers.

Certain state and local government agencies have established certification requirements for welders. In order to receive written certification, welders must perform specific weld tests that meet standards prescribed by these agencies. These tests are normally performed at and evaluated by an accredited testing center.

The American Welding Society's ANSI/AWS D1.3-98 Structural Welding Code: Sheet Steel outlines methods for establishing a welding procedure for the qualification of welders on cold-formed steel framing. The document includes sample recordkeeping forms and lists tests that can be completed in-house by the contractor's welding employee under the supervision of a previously qualified welder.

CHAPTER TWELVE
Engineering Considerations

There are several important considerations that go into the fabrication and application of members used in cold-formed steel construction to achieve a code-compliant safe design. The proper design incorporates the requirements of the building codes balanced with good engineering judgment used in a rational approach.

Forming of Cold-Formed Framing

Cold-formed structural shapes are fabricated by pulling a width of flat sheet steel through a series of rollers. Each set of rollers forces an incremental change in shape on the metal until the final profile is achieved. The thickness of metal that can be processed in this matter is limited. The practical limit is 0.1242 inch base metal material.

Channel

The framing member that dominates cold-formed steel application is the channel, a singly symmetric shape (Figure 12-1), which is symmetrical about the x–x axis. It is formed in the roller process as a horizontal flat plate with each side bent vertically. The channel is a structurally efficient shape and compares favorably with the more efficient I shape (doubly symmetric shape).

When the member rotates as illustrated in Figure 12-2, high stresses are introduced. These stresses can lead to buckling and ultimately structural failure. There are analytic provisions and structural bracing elements that accommodate the undesirable twisting.

The basic channel profile or section used as a structural member is C-shaped (Figure 12-3), consisting of three elements.

These elements are the lip, flange, and web. The American Iron and Steel Institute (AISI) has developed measures to control this tendency for buckling by placing limits on the dimensional ratios between the three elements (lip, flange, and web). By itself, the lip is an unstiffened element, meaning it has a free edge. However, the lip provides stiffening of the flange, which then can be considered as a stiffened element. This permits a larger flange width. The length of the lip varies from 3/8 to 3/4 inch for all ranges of flanges (1 3/8 to 2 1/2 inch). It also allows for greater thicknesses of base material. This narrow range is within the code requirements for unstiffened elements, meaning using a longer lip will not provide additional strength capacity.

Another section that is widely used in conjunction with the channel is a track, which is a channel shape without lips. It can be used as a joist or axially loaded stud. However, the load-bearing capacity is significantly reduced because it does not have stiffened flanges. The track is readily used in conjunction with the stud.

The track web depth dimension does not include the metal thickness of the flanges. The web dimension of the joist/stud channel, on the other hand, does include both flanges. This permits nesting (fitting of one member into another). In a typical wall system, a track is placed horizontally on top and bottom. The studs are then cut to length, and can be snapped into place vertically. The studs/joists are "nested" inside the track. The flanges of the stud/joist are connected to the flange of the track to prevent rotation. With a floor joist system, a track member at the ends of the span provides a connection to prevent end rotation of the spanning joists. It also provides a closed exterior surface (Figure 12-4). For greater structural capacity, the track section can be connected to joists/studs to produce combined sections.

Single Sections in Bending

Single joist members are designed to stress levels permitted by AISI code requirements. When a floor joist has a live load applied in a normal manner, the top flange goes into compression. If the

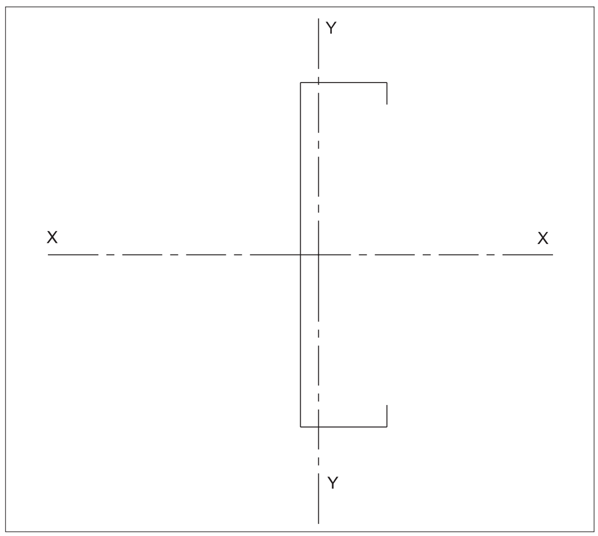


Figure 12-1

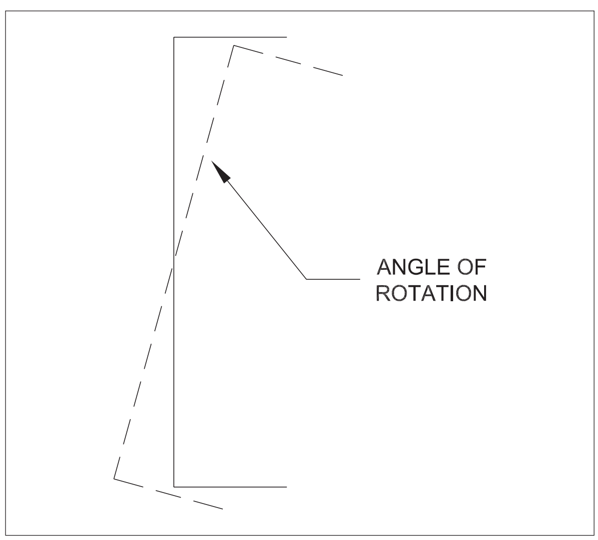


Figure 12-2

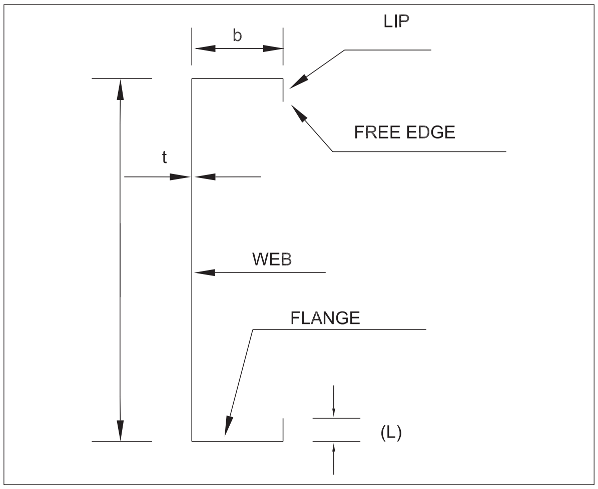


Figure 12-3

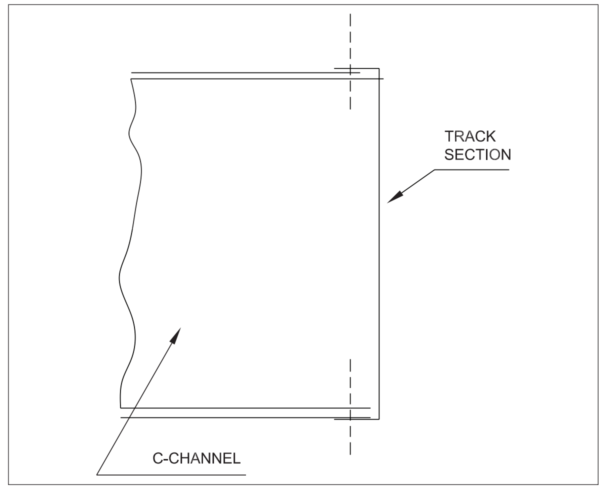


Figure 12-4

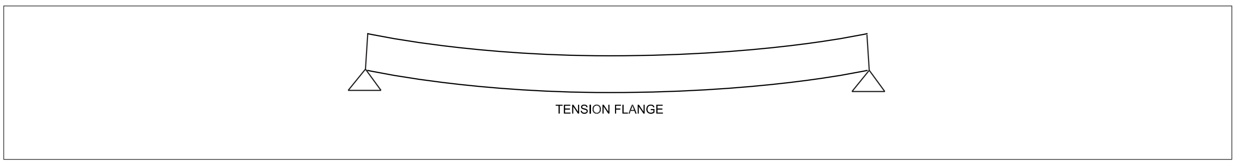


Figure 12-5

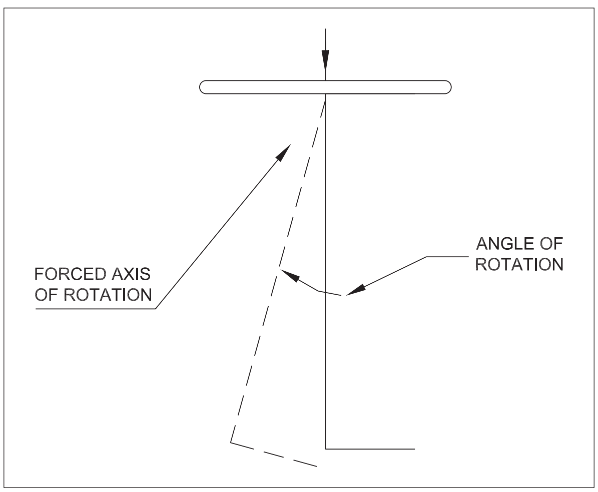


Figure 12-6a

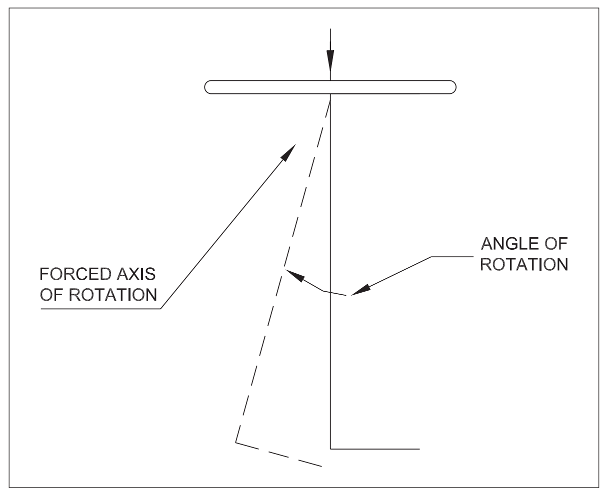


Figure 12-6b

flange is unbraced, the allowable stresses in this flange must be reduced to control buckling.

However, in the usual bending condition from imposed loads (Figure 12-5), the upper or outer compression flange is connected to the floor or sheathing so that additional bracing is technically not required, and there would be no reduction in allowable stresses. The lower flange is in tension where the maximum stress level is allowed without bracing. Bridging is where framing members are attached to floor joists. Although bridging is not required for this consideration, it will be called for in the design of all systems.

The singly symmetric channel is subject to twisting even under its own dead weight. Twisting is further precipitated when materials are loosely placed on joists that are supported only at the ends, and when workers walk around on them when setting up to secure the flooring. If the joists are connected in an out-of-normal position (not perpendicular to the flooring or plumb), then any applied loading creates additional twisting stresses. Bridging is fastened to top and bottom flanges to assure that the members are initially normal. Even with the top compression flange connected to flooring, the singly symmetric channel is subject to twisting about a forced axis of rotation (Figure 12-6).

To stabilize this twisting, the steel framing industry recommends bridging is provided.

Load-Bearing Studs (Axially Loaded)

Single sections are designed in accordance with AISI code requirements for a singly symmetric shape. There are several approaches or design philosophies.

Contractors often ask, “Why is bridging used on the wall studs? Doesn’t the sheathing provide required bracing?” The answer is

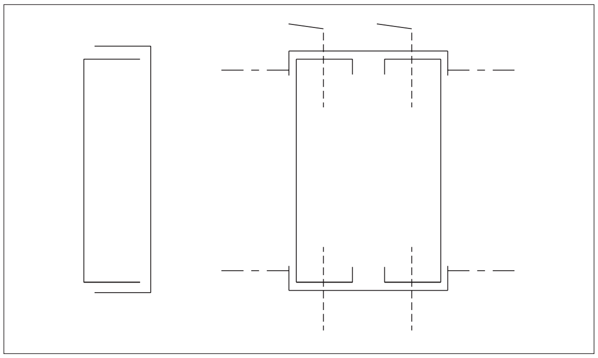


Figure 12-7

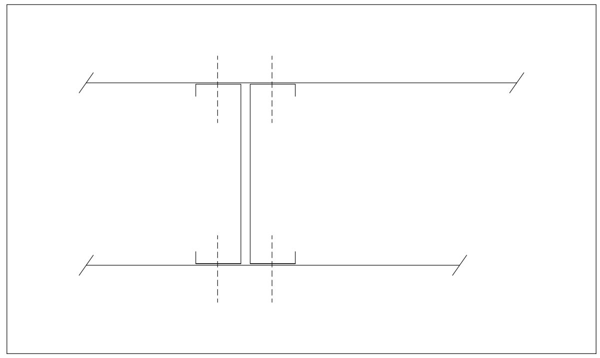


Figure 12-8

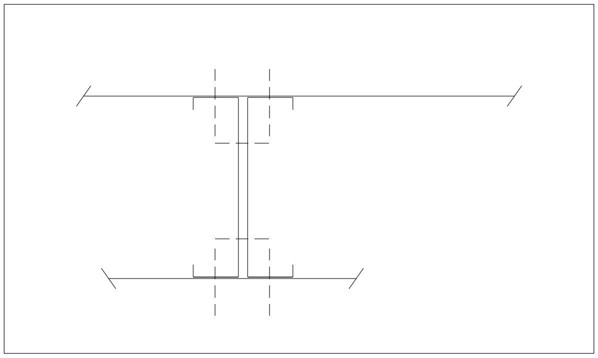


Figure 12-9

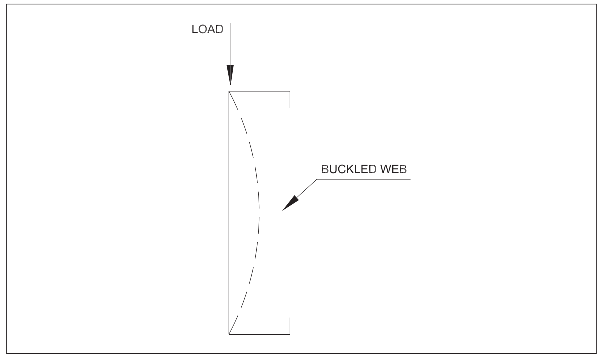


Figure 12-10

that an axially loaded stud can be selected and installed without bridging. The sheathing does provide bracing, but it must be installed before any loading can be imposed. While a building is under construction, the sheathing is probably not in place. Therefore, to carry the loading of construction (materials and workers), the studs must be designed and braced for that loading condition. Care must be taken to distribute the weight of construction materials to avoid imposed concentrated loads from stacking building materials.

The engineer would be contacted to ascertain the loading limits. A properly sheathed wall can carry more load than the exposed braced (using only bridging to provide the bracing) wall (depending on bracing). Therefore, the required minimum stud size should be obtained by initially designing with the maximum live and dead loading for a sheathed wall condition. The same size can then be checked for the exposed stud with bridging, using the construction loading.

Some building codes permit a 10 percent increase in allowable stresses for construction loading. A more conservative design approach considers the maximum live and dead loading for the exposed stud with bridging condition, which may result in using heavier gauge studs. This approach is particularly applicable to a condition where sheathing might be removed after the building is occupied. Special attention must be given to the transfer of axial loading at floor levels and the base foundation.

Combined Shapes

Sections can be combined to give greater load-carrying capacities than the individual members. For example, the axially loaded channel and track sections in Figure 12-7 are combined to form closed, doubly symmetric sections. These are not subject to torsional buckling.

Additionally, the screw connections at flanges and web can permit consideration of greater effective areas. As a result of greater effective area and allowable stress, the load-bearing capacity can be increased over the sum of the single members. Built-up sections are used under heavy load concentrations at columns supporting girders and headers.

Very often, on the lower floors of load-bearing walls, two thinner studs are provided and installed back to back in lieu of one thick member. Some of the reasons are:

- Studs with the same base metal thickness can be used for the entire job.

- Multiple layers of drywall with staggered edges are more readily attached to the double flange.

- Combining single studs develop more stable symmetric cross sections, which reduce eccentricities from axial loading.

When double studs are used web to web, they can be designed as two channels connected only at the top and bottom, with bracing at the center of span (Figure 12-8).

The load-bearing capacity can be increased if the members are connected together (Figure 12-9) to form a composite doubly

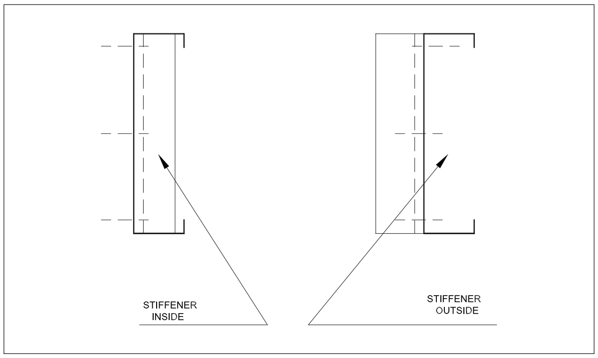


Figure 12-11

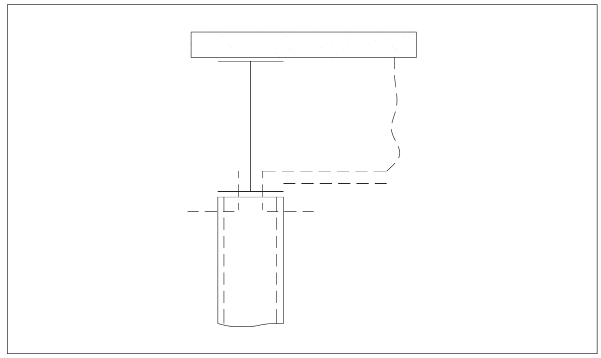


Figure 12-12

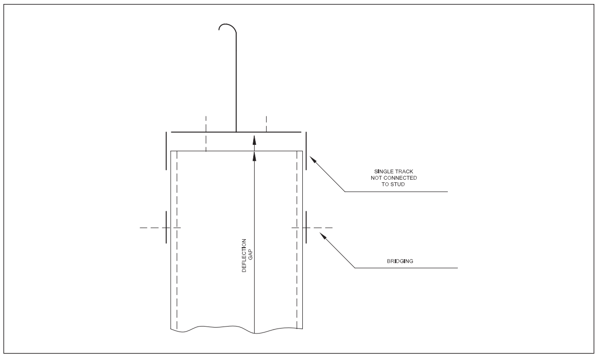


Figure 12-13

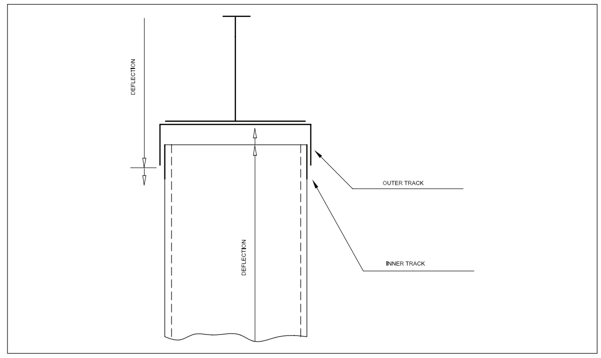


Figure 12-14

symmetric shape. There may be savings in material to offset increased labor in the extra connections. This detail should be discussed with the cold-formed steel framing manufacturer's technical staff for the particular stud loading.

Connections and Web Stiffeners

Where joists or girders are supported on a wall, or heavy loading is introduced on a span from a post above, there is a high local concentration along the bearing length of a thin web panel. Locally, the web element acts as a column and may buckle (Figure 12-10), depending on the depth/thickness of the member, bearing length, and magnitude of load.

If analysis shows that the beam web by itself is not sufficient to support the load, a web stiffener is introduced to accommodate the high load concentration and distribute it below. The stiffener can be cut from a stud or track as designed for the loading to be carried and attached to the member as shown in Figure 12-11. The type and orientation of the stiffener is developed to suit other framing conditions.

Slip Joints

Another connection that requires special attention is a slip joint for a non-bearing wall attached to or near a load-bearing, deflecting structural beam that is specifically designed to transfer the loading to structural columns. If the wall studs bear up tight to the structural beam (Figure 12-12), then accumulated loading may be directed into these studs (which were not designed or intended to support such loading) and down to the base foundation.

In curtain wall construction, it is common that the curtain wall stud will terminate at the bottom flange of a spandrel beam. Where this occurs, a slip joint is required. This allows the spandrel beam to deflect, while also transferring the load on the curtain wall to the beam. This is shown in Figure 12-13. The lateral load reaction is carried by one flange of the track. Special deep leg tracks with slots are available that can accommodate both the load transfer and movement. If a contractor is not aware of slip joint requirements, it can be a costly oversight in preparing a construction bid.

Wind Wall Bracing

On buildings with cold-formed steel framing as the primary structural system, the structure must be designed to resist the overturning effect of wind loads. This is commonly accomplished through horizontal floor systems and interior wind walls, or shear walls (Figure 12-15).

The wind load imposed on the wall studs is supported by flooring stiff enough to distribute these forces to a framing system that, in turn, can transfer them to the support foundation. In the wind wall panel (Figure 12-16), extra bracing and heavier posts are provided for the higher compressive and uplift forces.

It is often asked: How is there uplift when there is so much weight from the building? Unlike heavy structural steel framing, where girders impose high load concentrations on support columns, the dead weight and floor live load in a cold-formed

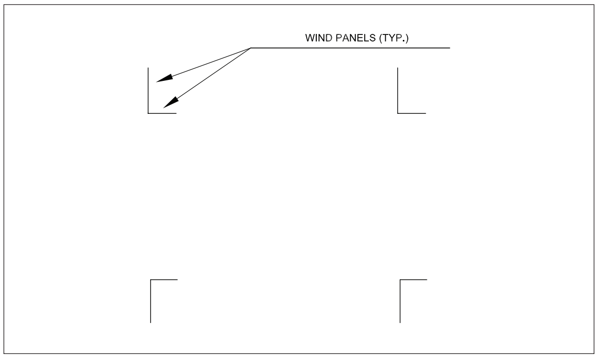


Figure 12-15

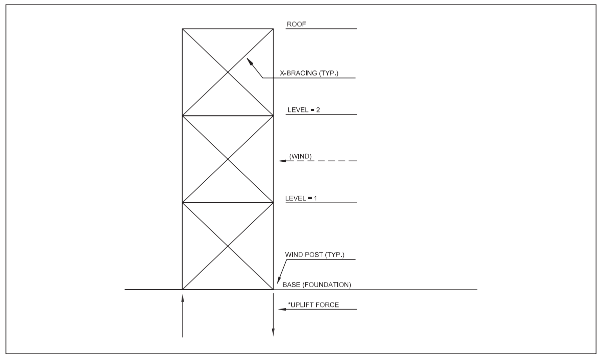


Figure 12-16

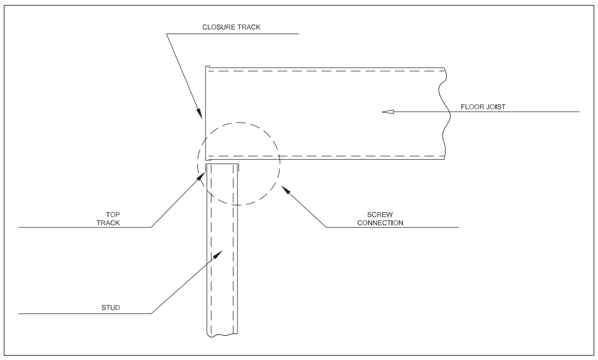


Figure 12-17

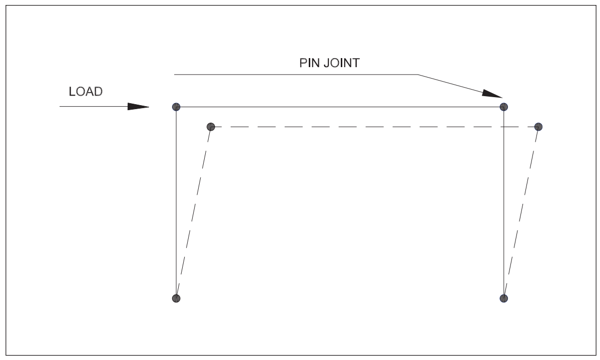


Figure 12-18

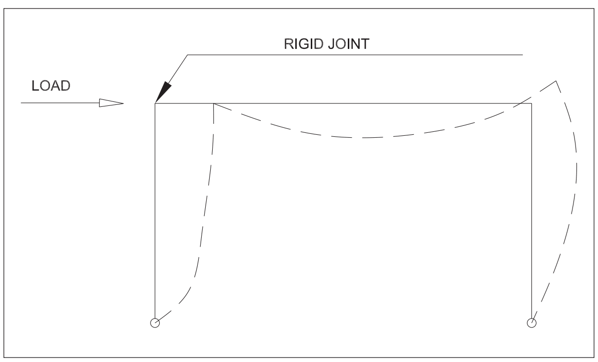


Figure 12-19

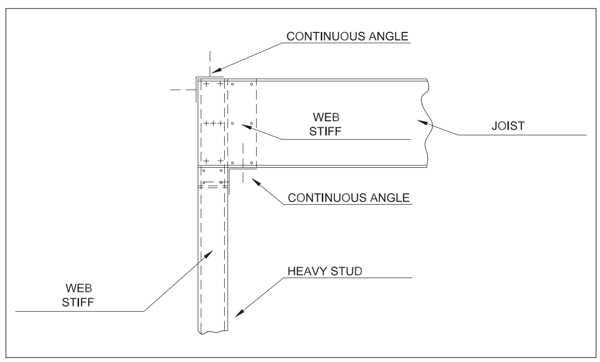


Figure 12-20

system are carried by joists and studs spaced at 16 to 24 inch intervals. At a wind wall, there is usually not enough loading at corner posts to overcome uplift.

Contractors familiar with wood framing of smaller buildings or houses often question the application of the diagonally braced wind wall systems, particularly with the smaller cold-formed structures. They claim it wasn't needed for wood. Part of the explanation is that the joint fastening details for wood are different from cold-formed framing. In the cold-formed typical floor/wall detail (Figure 12-17), the joint detail is a pin connection and unstable in a rack frame.

Figure 12-18 indicates an unstable rack frame that can collapse when subjected to a lateral load.

Such a frame has to be supported at the floor level where accumulated loading can be transferred to the specially designed wind wall panels previously described. If a rigid joint were provided (i.e., knee brace [Figure 12-19]), then it would be possible to provide rack frames at the 16 to 24 inch joist/stud intervals without special wind wall panels.

With a wood framing detail (Figure 12-20), joist studs toe-nailed to heavy sill pieces provide rigidity and can resist racking imposed by 16 inch interval loading contributions. Rigid joints can be provided with cold-formed metal by using balloon framing (Figure 12-21) or knee bracing (Figure 12-22). They have limitations in applications and are labor intensive.

Cold-formed members have versatile applications. There may be different ways of putting a job together, so the engineer must be flexible. Contractors are becoming increasingly inventive in seeking details or framing variations that are more suitable to particular operations and resources. It is important that the contractor work with a manufacturer whose technical staff has the complete knowledge of the product, plus diverse exposure in design analyses and construction situations to permit evaluation and execution of particular contractor considerations.

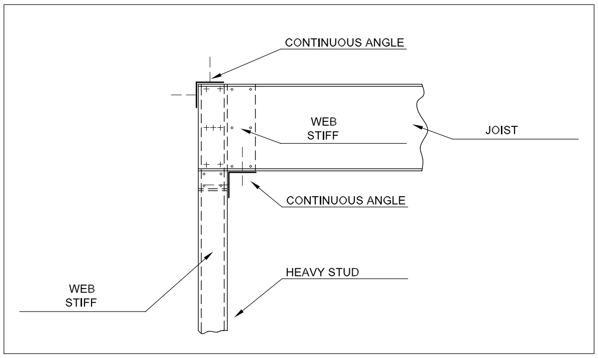


Figure 12-21

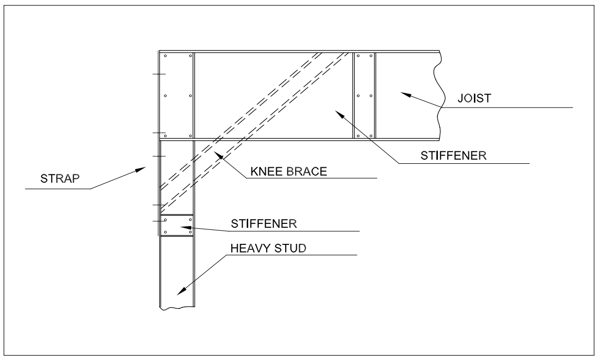


Figure 12-22

CHAPTER THIRTEEN

Panelization from Start to Finish

An analysis of today's construction market indicates, now more than ever, the need for highly engineered, quality systems that are quick yet economical to install. One solution that gained momentum throughout the 1990s is the use of prefabricated cold-formed steel framed panels. Why? The advantages are many:

Weather Factors. Panels can be fabricated off site in a controlled environment; hence, their production is unaffected by inclement weather. Construction proceeds without weather related delays.

Quality and Productivity. A good manufacturing environment, coupled with increased and efficient supervision, provides high levels of quality and productivity.

Time Savings. Panel fabrication may occur while the foundation and structural systems are being constructed on site. Construction schedules can be compressed.

Efficiency. On-site erection of prefabricated cold-formed steel framed panels is among the most efficient construction systems in terms of square footage erected per man-hour.

Reduced Equipment Needs. Scaffolding systems and job site clutter are eliminated. This allows increased project access to other trades.

Lower Labor Rates. Off-site panel fabrication can often be performed at reduced labor rates.

Varied Finish Possibilities. Prefabricated cold-formed steel framed panels can serve as the structural frames for a wide variety of interior and exterior finishes. These include gypsum drywall, plaster, stucco, EIFS, stone, brick, ceramic tile, and metal panels.

While some subcontractors get involved in panelization on a per-job basis, a few have shifted from subcontracting to manufacturing. They have made a commitment to the business. This commitment includes marketing plans, full-time facilities, and a staff of trained professionals.

Ideally, the panelization process starts in the early stages of design development. Meetings with the owner, architect, and general contractor/construction manager help to determine whether a project is suited to prefabrication. If so, getting involved with the design team on the front end allows the maximum interface with the other structural elements to optimize economy. The decision to use panel versus stick framed methods should be formally agreed to by all parties in the preliminary stages of the project. This is important so that the contract documents reflect proper engineering and detailing, thus creating an environment that fosters clear and concise bidding.

Many contract documents provide performance criteria and aesthetic concepts only, so that the panel manufacturer has some flexibility to engineer and design the most efficient system. Because of this responsibility, it is important that a panel manufacturer have either a competent structural engineer on staff or a strong working relationship with an established consulting firm. Several engineering firms throughout the nation have recognized expertise, and specialize in cold-formed steel framing design.

The key to any panelized project is extensive pre-planning. Be exacting and have a contingency plan for everything.

Starting at the bid stage and continuing to completion, the balance of this chapter will cover specific information to assist in obtaining a successful panelized construction project.

Terms of Payment. Make sure the architect, owner, and lending institution all will allow a payment schedule tailored to panelization. Specific items include front-end engineering, shop drawings, materials stored off site, and fabricated panels stored off site or in transit. Obtain specific instructions regarding required documentation, insurance, and inspection trips required to certify an Application for Payment.

Product Liability. Determine the scope of your liability exposure. For example, who is responsible for panels damaged after they have been erected in a building? Who is responsible for damage to panels stored on site prior to erection?

Insurance Coverage. Because panel manufacturing is different from subcontracting, make sure you analyze all of your insurance needs. Do you have sufficient contents' coverage at your manufacturing facility to cover the materials and fabricated panels? Who is insuring the panels while they are in transit from your plant to the job site? What about panels stored on site or at a remote off-site location?

Structural Engineering. Determine if you are responsible for providing any structural calculations. Avoid trying to replace the Engineer of Record. Provide calculations (stamped or unstamped?) for the project engineer's review and approval.

Shop Drawings. Prepare complete and thorough shop drawings to be submitted for approval to the architect/engineer. Shop drawings should include items such as the type and designation of members, accessory items, connection details complete with weld and/or mechanical fastener information, erection diagrams (elevation and plan views), size, steel thickness, spacing of framing members, and finally the relationship of framing to surrounding finish and structural members.

Some projects require all shop drawings to be stamped and sealed prior to submittal.

Embeds and Miscellaneous Connection Steel. Concrete structures generally require the inclusion of steel embeds and miscellaneous steel clips and angles for attachment of the panels. Typically, the panel manufacturer/erector is responsible for furnishing the embed items. Miscellaneous steel angles and clips that attach to the embeds are generally furnished and installed by the panel manufacturer/erector.

Material Buy Out. Provided the project schedule allows it, material quantities should be taken off from approved shop drawings. This practice eliminates costly shortages and/or waste to maximize profits.

Shop Fabrication. *Framing jigs*—The framing jig is one of the most important pieces of equipment needed to fabricate cold-formed steel panels. Your level of involvement in panelization will dictate how elaborate your jig will need to be. The effective jig is one that controls the dimensional tolerances of the finished panel. The jig also should provide for rapid adjustment for differing panel sizes. Finally, some jigs include pneumatic cylinders to properly seat the studs into the track, and to facilitate the removal of the finished panel. A jig of this type will accommodate panels up to 30 feet high or up to 30 feet wide.

Welding Equipment—Welding operations are generally isolated from the finish areas of the fabrication plant because of ventilation requirements, weld flash protection, and cleanliness. All panel connections should be welded. Some contractors recommend using 200 ampere Gas Metal-Arc (MIG) welders with constant speed wire feeders. These units typically require a 230- or 460- volt, three-phase power source.

Wire feeder units should be mounted on a swing arm with a slide rail above the jig to provide optimum access to the entire area. One or two welding units should be installed per jig, depending on jig size and use.

Welder Certification—Welders should be certified per the current AWS D1.3 Structural Welding Code – Sheet Steel, available from the American Welding Society.

Illumination—Current recommended illumination levels are 80 foot candles in the welding area and 100 foot candles in the finish space. Studies have proven that quality lighting increases production.

Quality Control—A tight quality control program is necessary for a panelization operation. While still in the jig, every panel should be checked for overall dimensions, squareness, and member spacing. Panels should be rechecked prior to the sheathing installation.

Industry tolerances for completed panels are as follows:

- Height shall not exceed +/– 1/8 inch in 10 feet.
- Width shall not exceed +/– 1/8 inch in 10 feet.
- Squareness shall be +/– 3/16 inch within the panel length.
- Spacing of studs shall not exceed +/– 1/8 inch from the designed

spacing provided the cumulative amount does not exceed the requirement of the finish materials. All welds should be primed with a zinc-rich primer.

Safety—All employees working in the welding areas should wear protective eyewear to prevent eye damage from the welding process. The welding areas should be completely screened to prevent inadvertent exposure to weld finish. Safety requirements vary from state to state, so it is advised to check local safety requirements.

Provide positive ventilation, air cleaner systems, or respirators as required to handle the fumes created from welding galvanized material.

Panel Transportation. Panels should be sized and bid with transportation requirements provided for. Most panels are transported by truck to the job site. Wide load and excessive height loads will require the purchase of special permits for each state entered during shipment, and travel hours may be restricted. Extreme oversized loads will require single or double escorts. Check with each state's department of transportation for specific information regarding regulation and permits. Panels can be loaded flat or vertically, one-by-one, in unitized bundles. Care should be taken to protect the finished surfaces and securely tie the panels to the trailer. Finished panels should be wrapped to protect them from diesel exhaust and road dirt.

Panel Erection. Factors affecting panel erection include the following:

- Field measurements and building survey.
- Connection alignment and installation.
- Crew size.
- Vertical travel of crew and panels.
- Site accessibility.
- Type of connection details.
- Erection sequence.
- Leave-out areas (for buck hoist or material stocking).
- Trueness of building structure.
- Weather conditions (high winds, rain, and extreme cold).
- Type of crane or hoist.

Crane service can have the greatest impact on erection costs and productivity. On a small to medium height building, a dedicated crane for panel erection is desirable. Cranes can be furnished by the erector or the general contractor. When negotiating a tower crane service on a high-rise building, carefully define the hours it will be provided. Often the crane is promised, but the erection is interrupted for concrete hoisting, material stocking, etc.

CHAPTER FOURTEEN Energy Codes and Cold-Formed Steel Framing

Energy code requirements are forcing the industry to reevaluate exterior wall systems. This is challenging designers to come up with systems that provide more insulation and less air leakage. Architects and contractors now view the exterior wall, or envelope, as a complete system, not as a series of fragmented building materials that are installed adjacent to each other. The impact on the use of cold-formed steel framing is the necessity for greater compatibility of materials and collaboration of the construction team.

The energy codes were first drafted in the late 1970s. They had little impact on the design and installation of cold-formed steel framing. However, that is rapidly changing. The U.S. Department of Energy enacted federal policy that mandates each individual state must adopt and enforce a State Energy Code. This code must follow the strict guidelines that are established by the U.S. Department of Energy. The empowerment stems from Section 304 of the Energy Policy and Conservation Act, or EPCA, Public Law 94-163.

This federal law establishes that each state follow the guidelines found in ASHRAE 90.1 Energy Standard for Buildings Except Low Rise Residential Buildings. This standard is not a consensus document, nor is it written in what is termed mandatory language. This makes it difficult for local building officials to enforce.

To meet the need for enforceable requirements, the International Code Council (ICC) published the International Energy Conservation Code (IECC). The standard and the code focus directly on reducing the amount of energy that is consumed during the day-to-day operation of a structure. They force the designer to pay attention to energy consumption related to heating, ventilation, and air conditioning. Other targeted items include service water heating, power, lighting, other equipment, and the exterior envelope. The last item is the one that impacts the design and installation of cold-formed steel framing.

Building Thermal Envelope

The IECC defines the Building Thermal Envelope as the "basement walls, exterior walls, floor, roof, and any other building elements that enclose conditioned space or provides a boundary between conditioned space and exempt or unconditioned space" (IECC 2012). Several important concepts that impact the design and installation of cold-formed steel framing are embedded in that simple definition.

Exterior Envelope as a System

The codes do not differentiate between individual components that make up the boundary between conditioned and unconditioned space. From the wall standpoint, code enforcement will not limit inspection to individual elements of an exterior wall. The inspector, or commissioning authority, will require that the components that comprise a wall work together as a system. System design will require that all exterior wall components to be compatible. System installation requires greater collaboration between all the trades that touch the exterior wall.

Exterior Envelope as a Boundary

Implied in the definition is the seamless transition between foundation to wall, and wall to roof. There can be no gaps in the design and installation of the exterior envelope. A common disconnect in the seamless boundary sometimes occurs in the soffit area. This is where the wall team completes their work, and the roofing team starts theirs. If that area is not insulated or there is a break in what is called the air/water barrier, it can lead to catastrophic failure of one of the boundary components. Energy efficiency requires tighter controls on insulation and air// water barrier. The tighter the building, the greater the impact that the smallest leak has in the thermal envelope.

Commercial and Residential Applications

Both the IECC and the ASHRAE standard differentiate between commercial and residential construction. This means that cold-formed steel framing will need to meet energy requirements in all construction types.

Design Driven by Eight Climate Zones

The United States (including Guam, Puerto Rico, and the Virgin Islands) is divided into eight climate zones. That means that the design of cold-formed steel framing will vary with the location of the project itself.

Prescriptive or Performance Options

The IECC states that it is a design guide for architects. Therefore, it allows several options that architects can follow, all with the same goal of reducing the amount of energy that will be consumed during the life of the building. Two primary options are prescriptive or performance based.

In the prescriptive case, the designer is told how to design the exterior thermal envelope. It will prescribe the required amount of insulation that an exterior thermal envelope (walls, roofs, and foundations) must have, based on its geographical location.

Within the prescriptive case are several options. Looking at the exterior wall, the designers can either call out the amount of insulation that is specified in the code (see Table 14-1) or meet a U-factor requirement for the entire exterior wall system. In the science of heat transfer, the thermal resistance of individual materials is called its Thermal Resistance, or R Value. Building insulation, for example, is sold by its respective R-Value, which is determined by a combination of material properties and thickness. Glass fiber batt insulation has an R-value of 13 for a 3 1/2 inch batt. Extruded polystyrene at a thickness of 1 inch has an R-value of 5. Units of R-Value are h*ft2*oF/Btu.

The second option under the prescriptive path allows the designer to look at the entire exterior wall. Each wall has a unique thermal transmittance factor, or U-factor. This factor analytically combines the individual thermal resistance values of the wall components. Its units are Btu/h*ft2*oF. The code establishes minimum performance levels, U-factors, of the wall. The designer then is free to manipulate the individual wall components as long as the overall U-factor is met.

The performance based design starts with a code-required energy budget for the entire building. Then, using computer generated energy modeling, the designer can balance all energy-consuming elements (exterior walls, heating, and lighting systems) and develop an entire building that stays within that energy budget.

Continuous Insulation

The result of either the prescriptive of performance path will be the requirement for continuous insulation on the exterior envelope. Continuous insulation is defined in IECC as "Insulation that is continuous across all structural members without thermal bridges except fasteners and service openings. It is installed on the interior or exterior or is integral to any opaque surface of a building envelope." The most common solution is to add insulation on the outside flange of the exterior wall stud. This insulation can either be expanded polystyrene, extruded polystyrene, polyisocyanurate, or even mineral wool in composition. Based on where the project is geographically, the thickness of the insulation can range from one to four inches.

Climate Zone	Wood Framing	Steel Framing
1	13	13 + 4.2
2	13	13 + 4.2
3	20 or 13 + 5	13 + 8.9
4	20 or 13 + 5	13 + 8.9
5	20 or 13 + 5	13 + 8.9

Table 1

The table above reflects amount of cavity and continuous insulation that is required in residential construction based on the 2012 IECC. For example, in climate zone 5 for wood framing, there is a requirement for R-20 insulation in the cavity. As an option the designer can use R-13 insulation in the cavity, and a continuous insulation of R-5 over the stud. Cold-formed steel framing is penalized for its perceived thermal conductance. It requires an R-8.9 continuous insulation.

Air/Water Barrier

The IECC stipulates that there will be an air/water barrier system included in the exterior wall design. The IECC definition of an air barrier system is "Material(s) assembled and joined together to provide a barrier to air leakage through the building envelope. An air barrier may be a single material or a combination of materials." There are eight different types of air barriers, and each type has its benefits.

The types are:

Interior membranes: These would include polyethylene sheets and proprietary membranes especially designed for this application

Mechanically attached membranes: This type of material is usually installed on the exterior side of the wall. The most common type is polymeric in nature and the joints are taped with a special tape.

Self-adhering, non-foaming membranes: This is a rubberized material and is typically referred to as "peel and stick." It, too, is installed on the exterior side of the wall.

Non-insulating sheathing: Generally this is gypsum sheathing installed over the exterior flange of the cold-formed steel stud. The joints must be sealed with tape.

Insulating sheathing: This is an option that allows the contractor to use the already required continuous insulation as the air barrier. As with gypsum sheathing, the joints must be taped.

Sealants: Some manufacturers have developed spray-in materials that can be used as an air barrier.

Spray applied foams: Spray-in insulation can also be considered as an air barrier.

Grandfathered materials: The IECC allows some common building materials to be used as air barriers. The list includes gypsum panels and plywood.

Performance tested as installed.

The final item, and possibly most important in the code, is the requirement for testing installed assemblies. There are several test protocols including one called the "blower door test" that allows for the testing of buildings for air leakage. This puts increased pressure on the design and installation of the exterior thermal envelope to function as required.

The Green Codes

There are also green codes in the industry that may need to be met. The most recognized one is called LEED (Leadership in Energy and Environmental Design). Although this is purely voluntary, its use does have an impact on cold-formed steel framing. Under LEED, points are awarded based on material selected and design. From a cold-formed steel framing perspective, the point system tends to focus on a material's recycled content, and whether the material is considered regional. Version 4 of the program was recently released. It calls for greater transparency and performance. How that impacts cold-formed steel is yet to be determined.

The ICC and ASHRAE have both published what are considered stretch goal codes and standards as it relates to sustainability and energy. The ICC code is entitled The International Green Construction Code (IgCC). It uses the IECC as a basis, then broadens the scope to include sustainability. What is important here is that it requires acoustical performance on interior cold-formed steel framed systems. The California Green Code required acoustical performance on exterior walls as well.

The cold-formed steel framing contractor should be aware of these requirements. Although the required sound performance requirements are not highly restrictive, they must be met.

Another requirement within the IgCC is a process known as "commissioning." This is a process where a construction professional is hired by the owner to provide oversight over the entire life of the project and structure. Ideally, this professional is hired before the architect, and helps mold the need, function, and operational requirements for a building. This culminates with drafting the "basis of design." While the building is under construction, there will be a team of specialists. Impacting the cold-formed steel contractor will be an exterior envelope specialist and one for interior acoustics. These specialists will make sure that the exterior envelope and any interior acoustical wall systems meet the required performance.

Reference Documents and Standards

AISI, S100 "*North American Specification for the Cold-formed Steel Structural Members*"

AISI, "*Commentary on the Specification*"

AISI, "*North American Standard for Cold-Formed Steel Framing – Floor and Roof System Design*"

AISI, "*North American Standard for Cold-Formed Steel Framing – Wall Stud Design*"

AISI, "*North American Standard for Cold-Formed Steel Framing – Header Design*"

AISI, "*North American Standard for Cold-Formed Steel Framing – Lateral Design*"

AISI, "*North American Standard for Cold-Formed Steel Framing – Truss Design*"

AISI, "*North American Standard for Cold-Formed Steel Framing – Prescriptive Method for One and Two Family Dwellings*"

AISI, "*North American Standard for Cold-Formed Steel Framing –Nonstructural Members*"

AISI, "*North American Standard for Cold-Formed Steel Framing – General Provisions*"

AISI, "North American Standard for Cold-Formed Steel Framing- Product Data"

ANSI/AWS D1.3-98 "Structural Welding Code: Sheet Steel"

ASHRAE 90.1 , "Energy Standard for Buildings Except Low-Rise Residential Buildings"

ASTM C645 "Standard Specification for Nonstructural Steel Framing Members"

ASTM C 754 "*Standard Specification for Installation of Steel Framing Members to Receive Screw-Attached Gypsum Panel Products.*"

ASTM A1003 "*Standard Specification for Steel Sheet, Carbon, Metallic- and Nonmetallic-Coated for Cold-Formed Framing Members*"

ASTM C1007 "*Standard Specification for Installation of Load Bearing (Transverse and Axial) Steel Studs and Related Accessories*"

International Code Congress, "*International Building Code*"

International Code Congress, "*International Green Construction Code*"

International Code Congress, "*International Residential Code*"

International Code Congress, "*International Energy Conservation Code*"

R. S. Means, "*Building Construction Cost Data*"

Steel Framing Industry Association, "*Technical Guides for Cold-Formed Steel Framing Products*"

Steel Stud Manufacturer Association, "*The SSMA Technical Product Guide*"

Underwriter's Laboratories, "*Fire Resistance Directory*"

U.S. Green Building Council (USGBC), "*Leadership in Energy and Environmental Design (LEED)*"

USG, "*The Gypsum Construction Handbook*"

Associations

The American Institute of Architects (AIA)

The American Iron and Steel Institute (AISI)

The American Welding Society (AWS)

The Association of the Wall and Ceiling Industry (AWCI)

The Ceiling Interiors Systems Construction Association (CISCA)

The Certified Steel Stud Association (CSSA)

The Construction Specifications Institute (CSI)

The Foam Sheathing Committee (FSC)

The Gypsum Association (GA)

The International Code Congress (ICC)

The Steel Framing Alliance (SFA)

The Steel Framing Industry Association (SFIA)

The Steel Recycling Institute (SRI)

The Steel Stud Manufacturer's Association (SSMA)