Lightweight Steel Framing: Engineering Considerations

Design factors to consider for fabrication and application of lightweight steel framing members

by Irving Fader

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This is the second in a series of articles on lightweight steel framing systems. Future articles will discuss panelization, estimating, welding, how to use the manufacturers published technical data, load-bearing and non-load bearing interior and exterior wall systems as well as joists in floor, ceiling and roofing systems.

The intent here is to present some of the considerations that go into the fabrication and application of members used in light gauge metal construction to achieve a safe design within code requirements. Not every design aspect is included in codes. The designer or contractor does not have a free hand when the code is silent. Good engineering judgement based on rational approaches should be applied and documented.

Forming of Light Gauge Framing

Light gauge structural shapes are cold formed by pulling a flat width of sheet steel through a series of rollers. Each set of rollers forces an increment of shape on the metal until the final section is achieved. Obviously, the thickness of metal that can be handled in this manner is limited. The practical limit is 12 gauge (.106") material.

Channel

The framing member that dominates light gauge metal application is the channel, a singly symmetric shape. Fig. 1-symmetrical about the (x-x) axis). It is formed in the roller process as a flat plate closing in on each side. The channel is a structurally efficient shape and compares favorably with the more efficient I shape (doubly symmetric shape). The major difference is that the channel is subject to twisting as an axially loaded stud or laterally loaded joist. As illustrated in Fig. 2 when a load carrying joist twists, the cross section rotates and high stresses are introduced. There are analytic provisions and additional structural bracing elements that account for and accommodate the twisting considerations. The cost of producing and marketing a light gauge metal I shape would be too prohibitive for practical use.

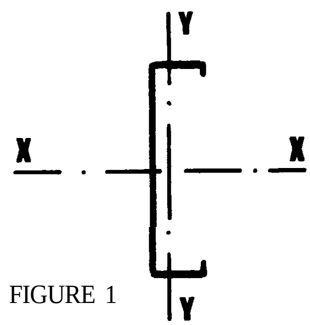

FIGURE 1

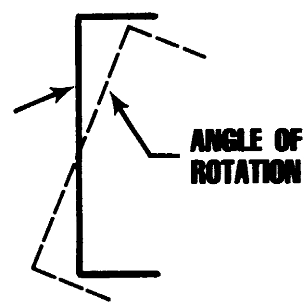

FIGURE 2

The basic channel section used as a structural member is C-shaped (Fig. 3) consisting of three elements: lip, flange, and web. For local buckling considerations, the AISI Code limits the ratios of (width/thickness) of each element than can be considered as effective in carrying the loading. The lip is by itself an unstiffened element. (It has a free edge). However, the lip provides stiffening of the flange, which can be considered as a stiffened element. This permits a larger limiting flange width. The length of the lip varies from 3/8" to 3/4" for all the ranges of flanges (1-3/8" to 2-1/2"), and thicknesses of material (20 ga. to 12 ga.). This narrow range is within the code requirements of unstiffened elements. Using a longer lip will not provide additional strength considerations.

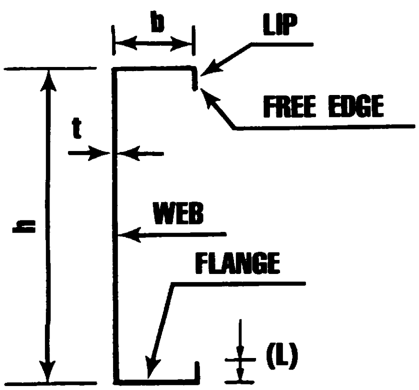

FIGURE 3

Another section that is widely used in conjunction with the channel is a track, which is a channel shape without a lip. It can be used as a joist or axially loaded stud, but due to its reduced and unstiffened flange width, a track does not have the load carrying capabilities of a C-shaped member with lips. The track is readily used in conjunction with the channel.

It should be noted that the nominal depth of the track is the inside flange dimension whereas the nominal dimension of the joist/stud channel section is the outside flange dimension. This permits nesting (fitting of one member into another). In a wall system, a track is placed horizontally on top and bottom; studs cut to length can be snapped into place vertically, nesting inside the track and connected to the flange to prevent rotation at top and bottom. With a floor joist system, a track member at the ends of the span provides a connection to prevent end rota-

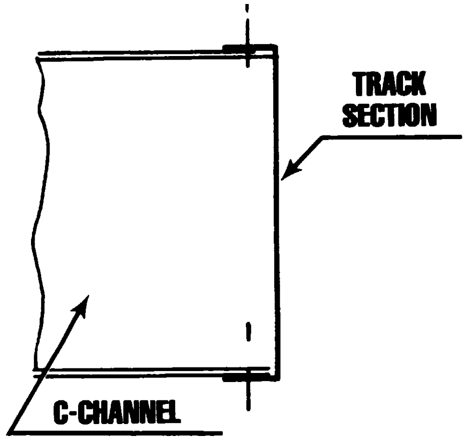

FIGURE 4

tion of the spanning joists and gives a closed exterior surface (Fig. 4).

The track section can be connected to joists/studs to produce combined sections that have greater stability and load carrying capacities than the individual units. This will be discussed later in this article.

Single Sections in Bending

Single joist members are designed to stress levels permitted by code requirements. There are reduced allowable stresses for laterally unsupported compression flanges. However, in the usual bending condition from imposed loads, (Fig. 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 by code, without bracing. There should be no need for bridging, yet bridging 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 at the ends only, and workers walk around on them in setting-up to secure the flooring. If the joists are connected to the flooring in an out of normal position, the superimposed loading will not be properly introduced and may impose 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 (Fig. 6).

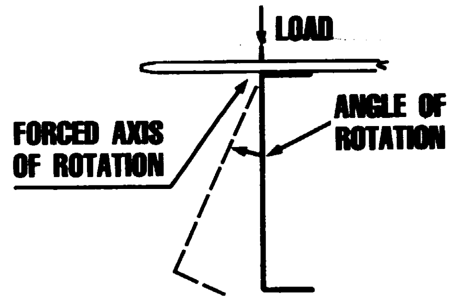

FIGURE 6

To stabilize this twisting, bridging is provided. The spacing of such bridging is not addressed in the code. The location of bridging is dependent upon seam depth, flange width, material thickness, loading, and manufacturer's recommendations.

Metal framing manufacturers publish different recommendations for the spacing of bridging. As an example, for framing members spanning 25 feet:

Manufacturer #1
recommends bridging at quarter points or 6.25 ft. intervals.

Manufacturer #2
recommends bridging at third points or 8.33 ft. intervals.

Manufacturer #3
recommends bridging at 6 ft. intervals.

The considerations that went into determining the spacing are not known. There may be different considerations by each manufacturer for a particular shape. The contractor or designer should consult with the manufacturer of the metal framing specified or used, and should certainly verify bridging requirements when substituting a supposedly equal product.

FIGURE 5

Load Bearing Studs (Axially loaded)

Single sections are designed in accordance with 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 that an axially loaded stud can be designed and installed without bridging to brace the flanges. The sheathing does provide bracing, but it has to be in-place and properly installed before any loading can be imposed. While a building is under construction, the sheathing is probably not in place and fastened, unless one floor at a time is completed, which at times may not be practical. Therefore, to carry the loading of construction (materials and workers), the studs must be designed and braced for that loading condition. Extreme care must be taken to distribute the weight of construction materials to avoid imposed loads from stacking concentrations. The engineer should be contracted to ascertain the loading limits. A properly sheathed wall can carry more load than the exposed braced wall (depending on bracing). Therefore, the minimum stud size required should be obtained by initially designing with the maximum live and dead loading for a sheathed wall condition. The same size can be checked for the exposed stud with bridging, using the construction loading. Some building codes permit a 10% increase in allowable stresses for construction loading.

A more conservative design approach considers the maximum live and dead loading for the exposed stud condition, which may result in using heavier gauge studs, and 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. As an illustration: The axially loaded channel and track sections in Fig. 7 are combined to form

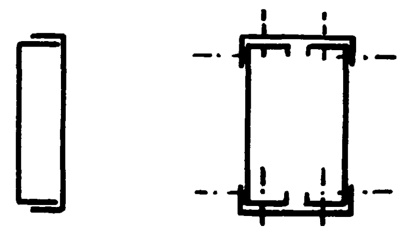

FIGURE 7

closed, doubly symmetric sections, not subject to torsional buckling and stiffened for flexural buckling. The combined members, therefore, have a higher allowable stress. 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 carrying 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 lighter gauge studs are provided and installed back to back in lieu of one heavy gauge member. Some of the reasons are:

1) The same gauge stud can be used for the entire job.

2) Multiple layers of sheet rock with staggered edges, can be attached to the double flange.

3) Combining single studs can reduce eccentric application 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 (Fig. 8).

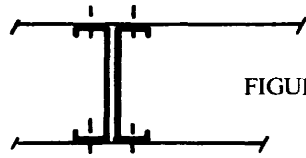

FIGURE 8

The load carrying capacity can be increased if the members are connected together (Fig.. 9) to form a composite doubly symmetric shape. There may be savings in material to offset increased labor in the extra connections. This detail should be coordinated with the manufacturer's technical staff for the particular stud loading.

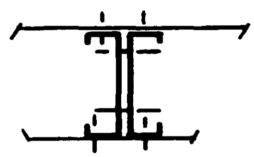

FIGURE 9

Bridging

In the design considerations of floor joists and studs, the use of bridging, (bracing the top and bottom flanges), was discussed earlier as providing additional lateral support. Strap bridging is commonly used as an effective tension member (it can take loading in one directly only, like pulling on a string). The strap member has to terminate or anchor to a solid base. In a flooring system, solid block bridging is placed at the ends of each run, and at intermediate intervals (from 20 ft. to 25 ft.).

This provides the support necessary to transfer accumulated forces. Solid bridging may be provided with joist sections that are shallower than the floor joists, or the full depth of the floor section (Fig. 10). Under certain conditions, one may be more applicable or preferable.

In wall systems, solid bridging sections are not usually provided with strap bridging. The strap bridging can

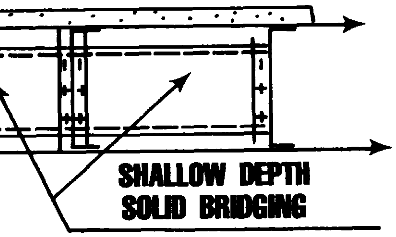

FIGURE 10(a)

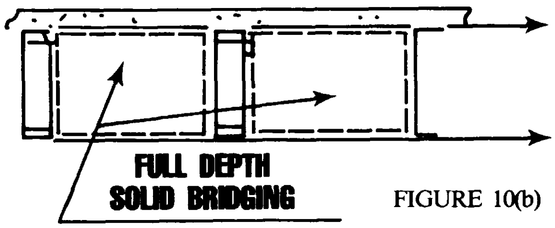

FIGURE 10(b)

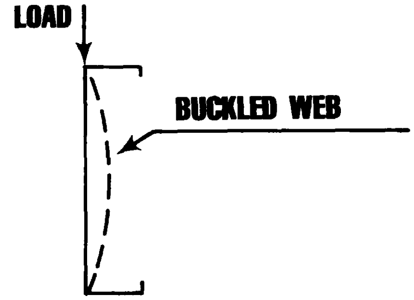

FIGURE 11

be connected to built-up sections of posts, door and window jambs, that have sufficient rigidity to provide anchoring.

Connections

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 panel acts as a column and may buckle (Fig. 11), 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, 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 Fig. 12.

The type and orientation of the stiffener is developed to suit other framing conditions.

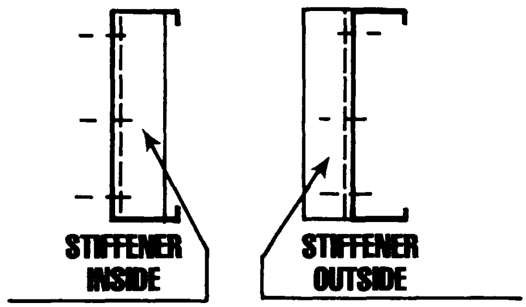

FIGURE 12(a) FIGURE 12(b)

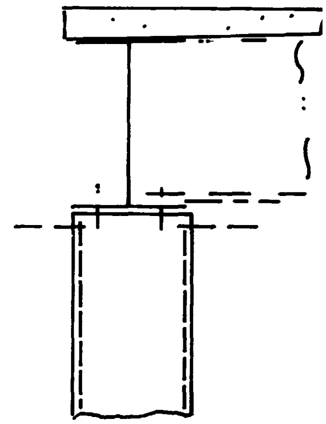
FIGURE 13

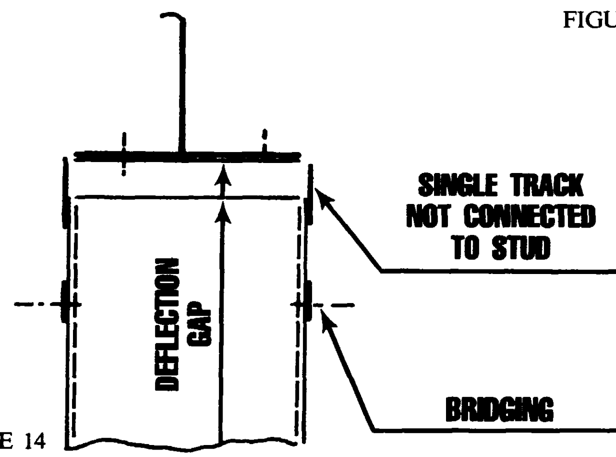

FIGURE 14

Slip Joints

Another connection that requires special attention is a slip joint, for a non-bearing wall attached to or near a load carrying 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 (Fig. 13), then accumulated loading may be directed into these studs, and down to the base foundation which were not designed or intended to support such loading.

Where a slip joint is required at a spandrel beam, a detail as shown in Figure 14 can be used. The lateral load reaction is carried by one flange of the track. The load carrying capability of the flange of a single track system is very limited.

More effective, but costly, is the double track system (Fig. 15) where tracks with special depth and flange widths are made up to effectively distribute the stud reaction over a larger area. The loading that can be accommodated is approximately eight to ten times greater than the single track system.

If a contractor is not aware of slip joint requirements, it can be a costly oversight in preparing a construction bid.

Wind Wall Bracing

With expanding applications of light

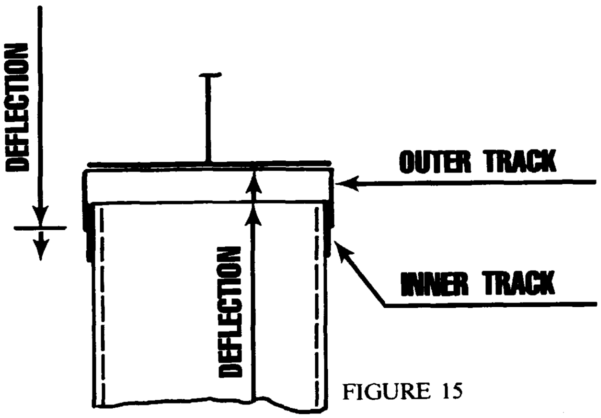

FIGURE 15

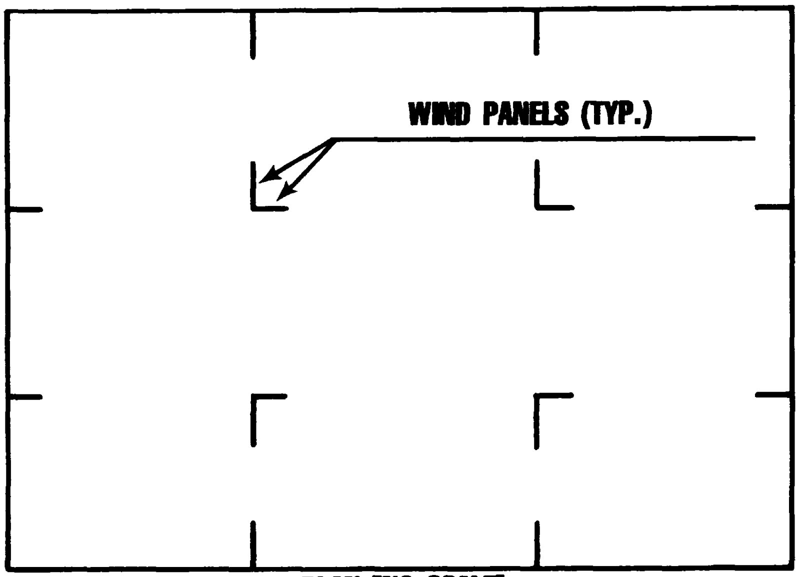

FIGURE 16 PLAN [NO SCALE]

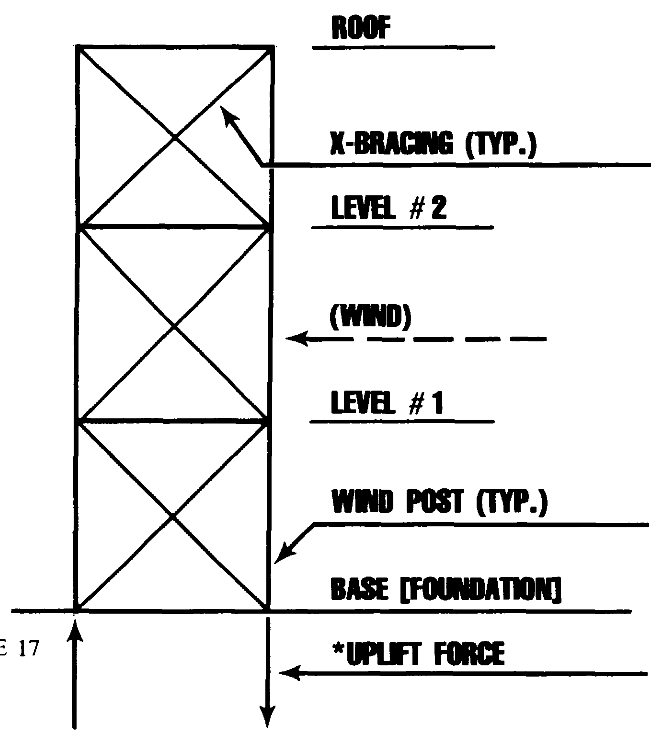

FIGURE 17

gauge structural framing, interior wind wall panels are needed (Fig. 16). They are especially required where exterior walls are decimated with openings from panoramic windows and balcony doors. 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, (Fig. 17), 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

With expanding applications of light gauge structural framing, interior wind wall panels are needed

building? Unlike heavy structural steel framing, where girders impose high load concentrations on support columns, the dead weight and floor live load in a light gauge system is carried by joists and studs that are spaced at 16" to 24" 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 light gauge structures. They claim it wasn't needed for wood. Part of the explanation is that the joint fastening details for wood are different from light gauge framing. In the light gauge typical floor/wall detail (Fig. 18), the joint detail is a pin connection and unstable in a rack frame. Figure 19 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 (Fig. 20), then it would be possible to provide rack frames at the 16" to 24" joist/stud intervals without special wind wall panels.)

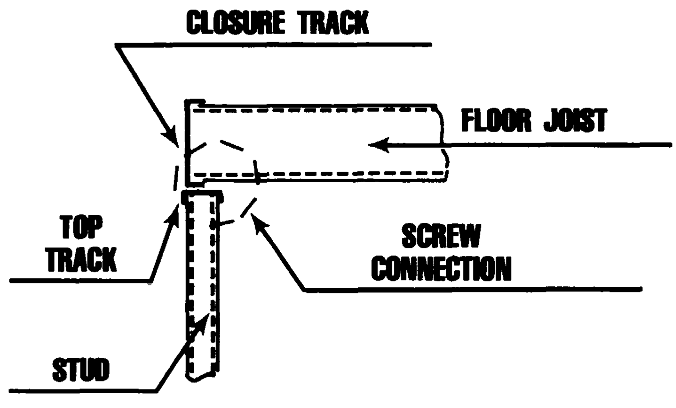

FIGURE 18

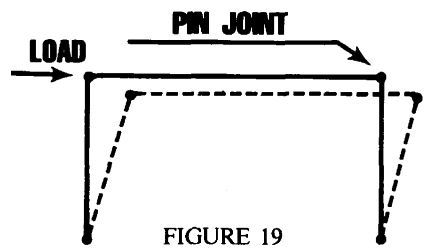

FIGURE 19

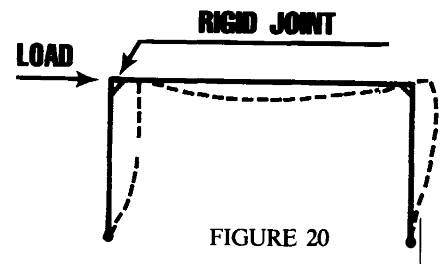

FIGURE 20

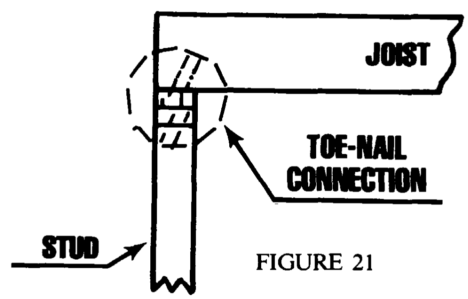

FIGURE 21

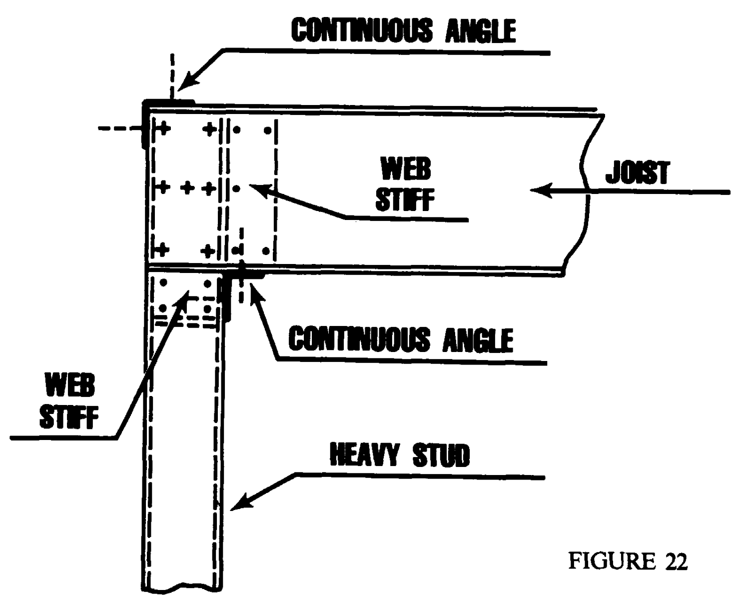

FIGURE 22

With a wood framing detail (Fig. 21), joist/stud toe-nailed to heavy sill pieces provide rigidity and can resist some racking imposed by 16" interval loading contributions. Rigid joints can be provided with light gauge metal, by using balloon framing (Fig. 22) or knee bracing (Fig. 23). They have limitations in applications and are labor intensive.

Light gauge members have versatile applications. There may be different ways of putting a job together, so the engineer has to be flexible. This writer has found the contractor to be inventive in seeking details or framing variations that are more suitable to his particular operation and resources. It is important that the contractor work with a manufacturer whose technical staff has the complete knowledge of the product and diverse exposure in design analyses and construction situations to permit evaluation and execution of particular contractor considerations.

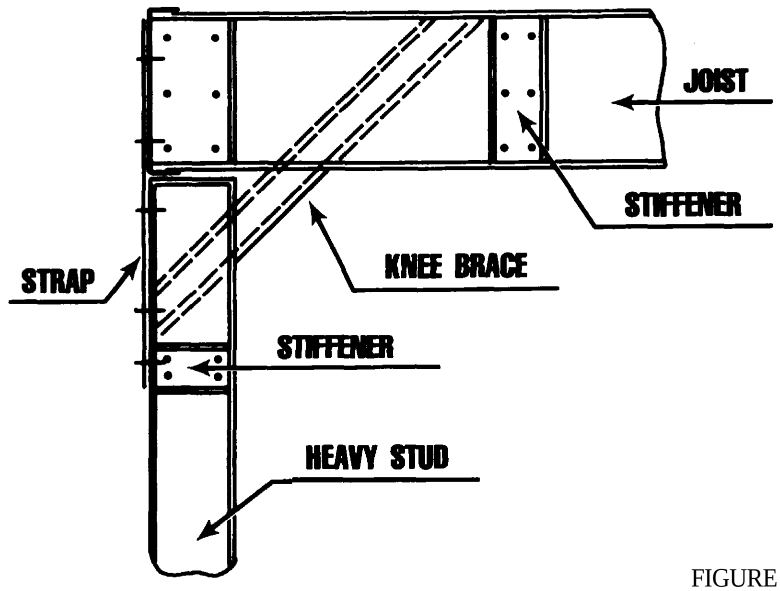

FIGURE 23