FUNDAMENTALS OF

STEEL CONSTRUCTION

By Lyle D. Hogan

Figure 1—The sides of a structure need stiffening to resist tortional stresses. Here box section members are positioned with an alignment rod and welded all around.

ABSTRACT:

Rarely does a roofing design/consulting firm also design and specify the structural steel. Indeed, many firms resolutely avoid any service that would be associated with "structural engineering." Part of this attitude may even be justified in light of the direction that litigation can take.

However, ignorance is rarely a valuable trait. The relationships of modern roof construction with structural matters are ultimately inescapable. Consultants retained to review a roof installation would benefit from a fundamental knowledge of how structures behave.

This article will focus on structural steel framing and how it interacts with roof performance. It is not intended to be a detailed study of structural engineering, and no empirical formulas are included. Methods for testing the various components are also beyond the intent of the article. Instead, it is an overview of matters of likely interest to the roof consultant.

Structural steel provides a framing system for many commercial and industrial buildings. Although it can be the support system for various types of roof decks, it is commonly matched with a fluted steel deck. During some recent steel inspections, our firm has observed a number of features that do not inspire confidence.

Diagonal Bracing

Strength is gained from triangulation of structural members. A bar joist is a lightweight structural element and gains its load-carrying properties by triangulation. The sides of a structure need similar stiffening to resist tortional stresses. *Figure 1* shows diagonal members positioned by an alignment rod and welded all around.

Joists need to be linked together to perform as a system. Rotation of the joists out of the vertical plane may result in rapid crippling under quite moderate loads. Small angle shapes are commonly used in this work, bolted together or tack-welded.

Figure 2 depicts a pair of failed bar joists from a collapse that resulted in serious personal injury. Substandard diagonal bracing was a significant contributor to the event. Linking the joists together with diagonal bracing keeps everything working as a system.

Framed Openings

When two or more corrugations are cut from a fluted steel deck, things start getting soft quickly. Roof drain openings should have iron framing along the underside, although this type of bracing is not always provided. Neither the below-deck clamp nor the stamped receiver pan is intended to restore the load-carrying compromise brought about by the opening (*Figure 3*).

For the same reasons, curbed openings for HVAC equipment must be framed underneath. The curb that will eventually support the unit is not intended to serve as a structural element. Even when treated wood nailers are provided at the deck, the stiffness afforded is well short of that which underside iron framing will provide. *Figure 4* shows an ideal arrangement of below-deck framing for a curbed mechanical unit.

Figure 2—At right, a pair of failed bar joists from a collapse that resulted in serious personal injury. Substandard diagonal bracing was a significant contributor to the event. The lateral deformation of the members prompted the collapse. Linking the joists with diagonal bracing keeps everything working as a system.

Bolted Connections

The bolt holes provided by the steel fabrication mill are there for a reason. If all holes are not filled, there is a valid reason to inquire. Omission of one bolt in a high-strength connection may overstress remaining bolts.

It should be noted that not all bolts in a steel structure are torqued. Indeed, many bolts are merely snugged down and do not require torquing in order to perform. The accepted definition of "snug-tight" is …

> *the tightness that exists when all plies in a joint are in firm contact. This may be attained by a few impacts of an impact wrench or the full effort of a man using an ordinary spud wrench*[1].

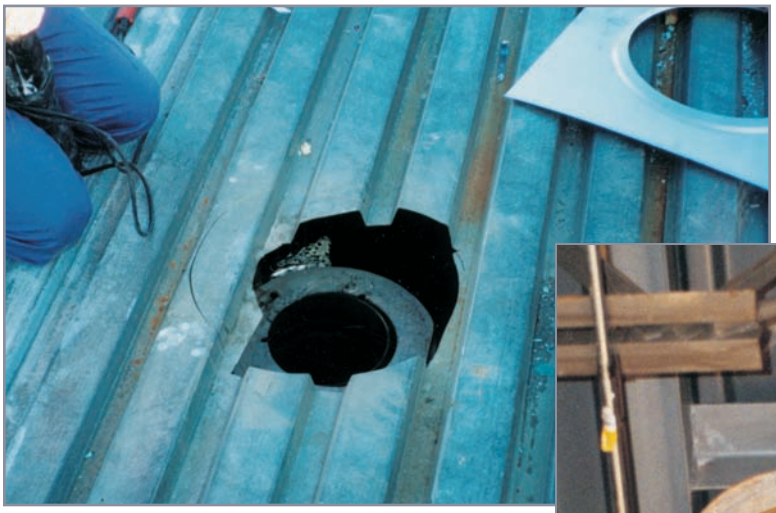

Figure 3—When two or more corrugations are cut from a fluted steel deck, things start getting soft quickly. Openings for a roof drain (above) require bracing along the underside of the deck (right). The below-deck clamp (even when coupled against the receiver pan) is not intended to restore the load-carrying capacity.

The importance of inspecting snug-tight work is to verify that framing members come together in a flush, square fit without gaps or diverging contact surfaces. On the other hand, slip-critical connections may be present in the work (and should be indicated as such in the erection drawings). These connections are more crucial in the performance of the structure and virtually always have moment (or bending) reactions imposed in addition to shear forces.

There will be instances where some holes do not align well enough to bolt as intended. Blowing out new holes with a torch is not recommended, particularly around high-strength connections. For "snug-tight" connections only, a continuous fillet weld may sometimes serve as the remedy. This matter is discussed later.

Figure 4—An ideal arrangement of below-deck framing for a curbed mechanical unit. The curb that will eventually support the unit is not intended to serve as a structural element.

Members at a slip-critical connection are usually configured for ease of construction. Most slip-critical connections are matched and fitted in the fabrication shop. There may even be a trial fit in the shop to verify alignment of holes prior to shipment. Identification marks may also be applied for use during field assembly. So, when mismatching of bolt patterns occurs, it is usually the result of structural members being in the wrong place.

Welded Connections

In a bearing arrangement, the fillet weld should make optimum use of the available contact surfaces. For instance, the entire heel of a truss should be welded all around onto the bearing surface. Most welding of this nature is minimum 1/4-inch and is "full penetration." *Figure 5* depicts substandard weld length where a girder was merely tack-welded to a column capital. The expected rotation at the heel can fracture a tack weld such as this.

In some instances, welding may be used to substitute for a bolted arrangement where bolt hole alignment was not favorable. Blowing out larger bolt holes with a torch is not recommended. When change of this nature is implemented, the overall weld used must replace the equivalent cross-sectional area of the bolts intended. This, however, is a sizing procedure best left to the structural designer.

The Steel Roof Deck

Project specifications routinely indicate that commencement of work over a steel deck will be construed as acceptance of that

Figure 5—Substandard weld length where a truss was merely tack-welded to a column capital. The entire heel of the truss should have been welded all around onto the bearing surface.

surface. If the deck is later found to be lacking, the roofing contractor as well as the consultant may experience impeached credibility (and all the trappings that go with it).

If the deck is to be arc-welded, some "burn-through" is going to occur. The occurrence can be seen from the ground, and it is sometimes the source of concern. Burn-through stems from the inherent difficulty in arc-welding a thin gauge sheet to a heavier framing member. Welding washers have been used in the past to help match the thicknesses being joined, but the practice is now virtually obsolete. Notice that shorts in the welding leads (cables) will certainly vary the amperage available at the stick. The resulting variation in current will produce a similar variation in weld fusion quality. Badly scarred and pock-marked roof decks are likely to exhibit poor weld fusion (*Figure 6*).

A steel deck, when properly fastened, will serve as a horizontal shear diaphragm[2]. However, the diaphragm is not functional until the side lap stitching screws are installed (*Figure 7*). At least one screw is required between any pair of bar joists, although two or three are commonly found, and up to ten may be used in seismic zones. The approved shop drawings should indicate the required frequency of stitching.

Meandering deck sheets (*Figure 8*) are a real frustration for the roofing contractor, and the condition can be avoided. Acceptable deviation from a true line has been established by the National Roofing Contractors Association (NRCA). The limit put forth is that deck sheets should align to within 1/4-inch per hundred feet of length[3]. This tolerance is attainable with very little trouble.

Figure 6—Burn-through stems from the inherent difficulty in arc-welding a thin gauge sheet to a heavy gauge member. Shorts in the welding leads (cables) will certainly complicate the amperage available at the stick.

Bond Beams

Bond beams are the connecting link at the top of block and cavity wall construction. It is the feature at which three distinct trades converge, and there is routinely something omitted from

Right: Figure 7—A steel deck, when properly fastened, will serve as a horizontal shear diaphragm. However, the diaphragm is not functional until the side lap stitching screws are installed.

Figure 8—Meandering deck sheets (above) are a real frustration for the roofing contractor. Deck sheets should align to within 1/4-inch per hundred feet of length.

the detail. Bond beams are built by the masonry contractor and appear to have little to do with steel construction. However, the leading edge of the deck will integrate into the wall in some manner, and a number of steel framing arrangements may be encountered.

Figure 9 depicts a shelf angle to which plates have been welded. Rock anchors will eventually secure the plates, and the concrete within the block units will be the sole medium determining strength of the connection. A preferred arrangement would have been to use threaded J-stirrups that extend lower into the wall construction, particularly in a location where high winds are expected.

Expansion Joints

The summary nature of this article does not permit thorough review of expansion joint design. However, there are fundamental concepts that should be understood.

By definition, expansion joints provide interruption of structural framing to accommodate anticipated movement (whether thermal, load-induced, or whatever). Rigid framing that crosses the void region will violate the movement otherwise available. Accordingly, it is necessary to "line-up" the hardware[4].

Figure 9—Bond beams are the connecting link at the top of block and cavity wall construction. A number of framing and attachment methods may be encountered.

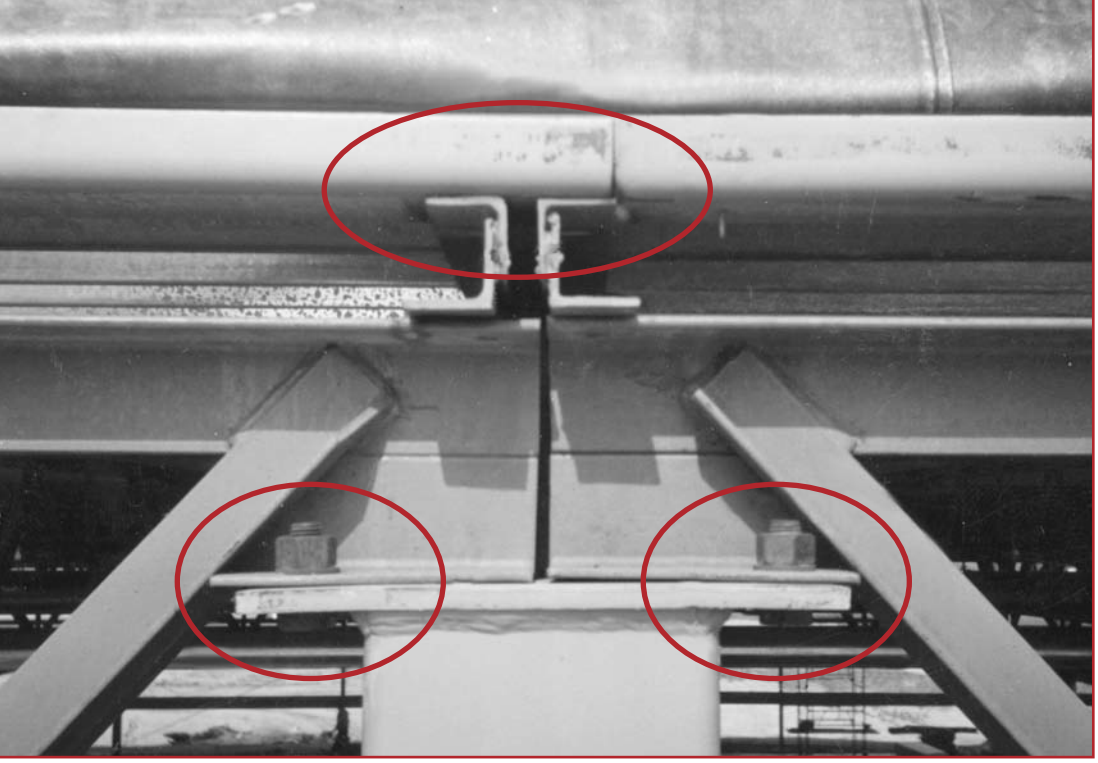

Figure 10—Expansion joints should be continuous through the edge carpentry and the wall construction, terminating at the footing. Rigid framing that traverses the opening violates the movement available.

Ideally, the interruption of the structure should be continuous through the edge carpentry and wall construction, terminating at the footing (*Figure 10*). Expansion joints that magically terminate into a wall are of questionable utility.

Summary Comments

Remaining silent about structural shortcomings is a disservice to the owner/developer/client. This article is to inform quality control representatives about conditions that may be encountered during routine site visits. While these structural issues may seem too peripheral to merit involvement, these matters will surely come under sharp scrutiny following a collapse or other episode of nonperformance. ■

References

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