What's on the Horizon for Steel

New Design Developments

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Recent developments in steel design and construction offer the promise of reducing costs and construction time.

• **Snug-tight bolts in tension applications.** The economic benefits of snug-tight bolts can currently be realized in the majority of shear/bearing connections in building structures. However, the current RCSC and AISC *Specifications* require all bolts in tension applications to be pretensioned. Recent research, though, shows that pretension is not critical to performance for ASTM A325 bolts in applications involving tension but not fatigue or impact. Accordingly, it is anticipated that both the RCSC and AISC *Specifications* will permit snug-tight ASTM A325 bolts in such applications.

• **Use of one-sided shear connections.** The recent development of detailed design procedures for one-sided connections, coupled with erection safety considerations, has led to a more widespread usage of one-sided shear connections, such as single-plate, single-angle and tee shear connections.

• **Extended end-plate moment connections for seismic loading.** With all welding done in the shop with better quality control and lower cost and only bolting in the field, the advantages of extended end-plate moment connections have long been known. However, these connections have historically been limited to use in static loading applications and non- and low-seismic applications.

Recent research, however, shows that, if the design procedure is modified slightly to account for the effects of prying action and weld access holes are not used to make the beam-flange-to-end-plate welds, extended end-plate moment connections are suitable for high-seismic loading. The use of weld access holes causes an increase in the strain rate in the beam flange under load and results in a premature flange fracture.

At the same time, improvements in cutting and drilling equipment have made large moment end-plate connections an increasingly viable alternative for moment resisting frames. Current cutting methods can produce an acceptably square beam end without milling. Additionally, computer-controlled drilling equipment can produce accurate hole placement in both the end plates and the column flanges, resulting in excellent alignment for field assembly.

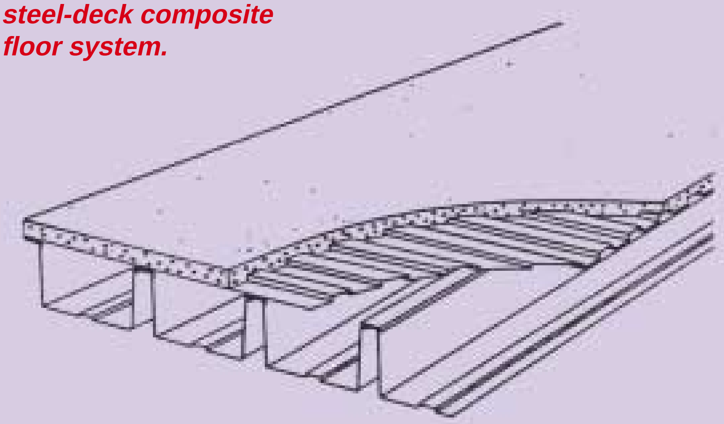
• **Other Seismic Moment Connections.** Tremendous advancements have also been made in the inelastic deformation capabilities of welded beam-to-column moment connections for seismic applications. At the same time, more stringent performance requirements have been implemented in the AISC *Seismic Provisions*. Several connection alternatives that can withstand inelastic rotations of at least 3 percent have been developed using reinforcement, including cover plates, ribs and haunches. Additionally, the reduced beam section (dogbone) approach has also demonstrated excellent inelastic performance. At the same time, bolted solutions, such as extended end-plates, flange tees and flange plates are being investigated further. Some proprietary alternatives also have been developed.

• **Framing for Reduced Floor-to-floor Heights.** In the past, designing for reduced floor-to-floor heights has led designers to reinforced concrete, new steel systems are available that accommodate this requirement. Some layouts have utilized conventional framing to achieve a floor-to-floor height as small as 8'-8" with the structure well integrated into the partitions and other architectural features. Other framing system, such as the staggered truss system have also been used to achieve such a reduction.

A new proprietary system recently introduced in the United States is Flex-Frame. It nests the floor deck and slab within the depth of a castellated beam, resulting in a more compact sandwich.

In the United Kingdom, a system called Slimflor has been developed, wherein the infill beams are nested inside and supported by the wider bottom flange of an asymmetrical girder. Spans in the range of 20' to 30' are practical for very shallow framing depths. Additionally, in the United States, a preliminary study on a two-way composite floor system spanning 30' to 40' between similar asymmetrical girders indicates the potential for a very competitive system. The two-way composite floor system illustrated in Figure 1 is constructed with deep metal deck spanning one direction, a very shallow form deck spanning the other direction, and double-headed self-tapping screws, which interconnect the two plies of metal deck and achieve composite action with the topping concrete.

Figure 1. A two-way steel-deck composite floor system.



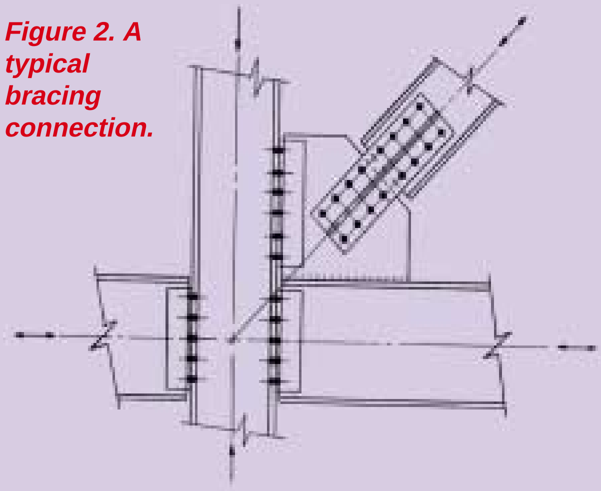


Figure 2. A typical bracing connection.

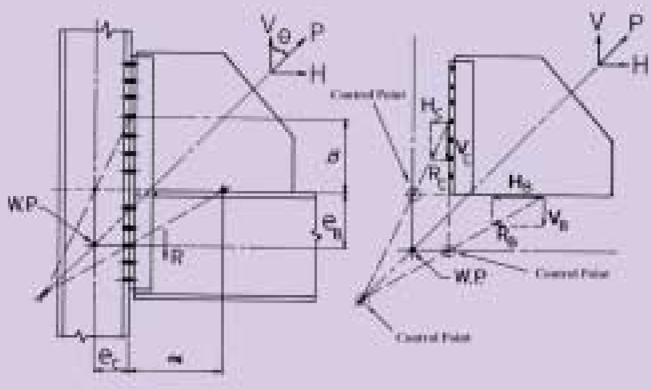


Figure 3. Force distributions in gusset plates per the Uniform Force Method.

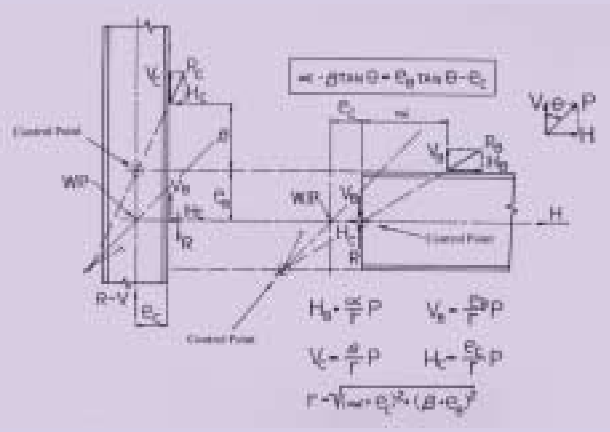


Figure 4. Force distributions in the beam and column per the Uniform Force Method.

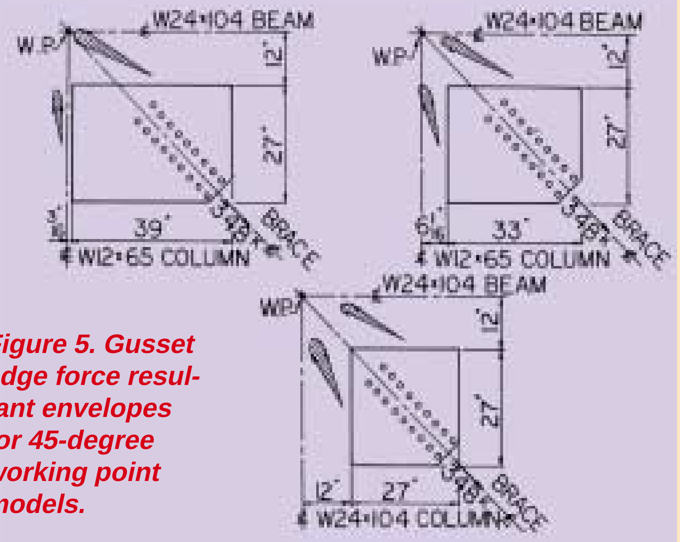


Figure 5. Gusset edge force resultant envelopes for 45-degree working point models.

• **Composite Trusses.** Composite "joists", which are actually light trusses with composite action, have recently been introduced. This type of construction allows for economical ultra-clear span construction, and has been used in applications with spans from 45' to 120'. Ductwork and other mechanical system components can pass through the open-web trusses, allowing for reduced building height without the need to create web penetrations as for solid-web members. In-service measurements of floor accelerations have shown that floor vibrations are not a significant problem in these systems.

• **The Uniform Force Method for Bracing Connections.** Until recently, there has not been a systematic approach to the analysis and design of bracing connections, such as the connection shown in *Figure 2*. There is now available just such a method which is based on analytical and experimental results and not on the usual simple beam and strut formulas applied to various cut sections. The method is called the Uniform Force Method and has been adopted by AISC for use in the AISC *Manual*.

The admissible force distribution for this method is shown in Figures 3 and 4. The force distribution is called admissible in the sense of the lower bound theorem of limit analysis because it satisfies equilibrium for the free body diagrams shown in Figures 5 and 6, i.e., the gusset in Figure 2 and the beam and column and Figure 3, with absolutely no additional forces required anywhere.

Research shows that the force resultants on the gusset edges fall within the regions shown cross-hatched in Figure 5. Each cross-hatched region of Figure 5 contains the resultants for six cases in which the connections of the gusset to the beam and column were varied from bolted to welded.

Other new developments are discussed on various web sites, including **www.aisc.org**, **www.steelstuff.com** *and* **www.seaint.org**. *In addition, the latest technical information is available in AISC's* Engineering Journal.