Modern Steel Construction

April 2022

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April 2022

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ON THE COVER: Exposed steel is front and center at Kiewit's new Omaha headquarters, p. 26. (Photo: © HDR/Dan Schwalm)

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editor's note

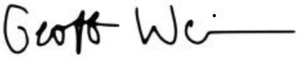
I've always said that I don't love Las Vegas, but I always have a good time there.

That held true for my most recent Vegas trip (in February). And honestly, I left this time loving it just a bit. Perhaps it was the reason for the trip—a wedding—which meant that I got to spend some quality time with several good friends that I don't see too often anymore (also, the officiant was a David Bowie impersonator, which was pretty fun). Perhaps it was the fact that I saw more than just the Strip this time around and paid visits to the (really cool!) Arts District, the Neon Museum, and a (reputedly) haunted tiki bar (bonus points since it was happy hour). Perhaps it was the weather—much cooler than the blast furnace temperatures I'm accustomed to on most of my trips to Sin City. Perhaps it was because my wife was with me this time (my last several visits have been for work). And perhaps it was that, instead of scoffing at the fact that so many of the well-known buildings there try to replicate other places or themes, I let that mentality go and just enjoyed myself and appreciated those grandiose edifices for their function and scale. Perhaps (definitely) it was a combination of all the above.

It also didn't hurt that we stayed at what I consider to be a very nice hotel: the Venetian. While our room didn't face the Strip (that would have cost extra), our windows allowed a very clear view to the east of a large, round structure rising roughly a half-mile away. My first thought was of the Death Star being constructed in *Return of the Jedi*. Luckily, the building's function is much less sinister than that of a planet-destroying battle station. When completed (and fully operational), the project, MSG Sphere, will serve as a signature music and entertainment venue with a seating capacity of 17,500 and a standing-room-only capacity of 20,000. (In this case, MSG stands for Madison Square Garden, not monosodium glutamate).

This building isn't replicating anything. It's its own thing, a massive orb that will be wrapped in an equally massive LED screen. Designed by architect Populous and structural engineer Severud, the building will be 365 ft tall and 516 ft wide at its widest point (the "equator"), with 875,000 sq. ft of interior space, when it's completed. The steel package was equally massive. The framing system, including a steel geosphere exoskeleton, comprises more than 29,000 tons of structural steel fabricated by W&W|AFCO Steel and erected by W&W Steel Erectors. The exoskeleton is made up of more than 4,300 tons of round hollow structural sections (HSS), ranging in outer diameter from 8 in. to 24 in., as well as nearly 370 steel castings from Cast Connex. This system will support an outer trellis, also using round HSS (nearly 22 miles of it), that will in turn support the exterior LED screen components.

Construction was put on hold in April 2020 (due, of course, to COVID) and resumed that August, and the venue is scheduled to open next year. It's one of countless reminders that, despite setbacks like pandemics, economic downturns, or even wars, our industry will persevere and continue to think—and build—big. It's also a testament to how amazing steel structures can transform cities, not to mention hotel room views. In fact, I'd say it's entirely possible that some future guests might turn down a Strip view for a better one looking east.



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If you've ever asked yourself "Why?" about something related to structural steel design or construction, *Modern Steel*'s monthly Steel Interchange is for you! Send your questions or comments to **solutions@aisc.org**.

Welded Stiffened Seat Eccentricity

The recommended design procedure for a welded stiffened seat connection (see Figure 1) provided in Part 10 of the 15th Edition AISC *Steel Construction Manual* states: "The stiffening element is assumed to carry the entire end reaction of the supported beam applied at a distance equal to 0.8*W*, where *W* is the dimension of the stiffening element parallel to the beam web." Why not use ½ l_b instead?

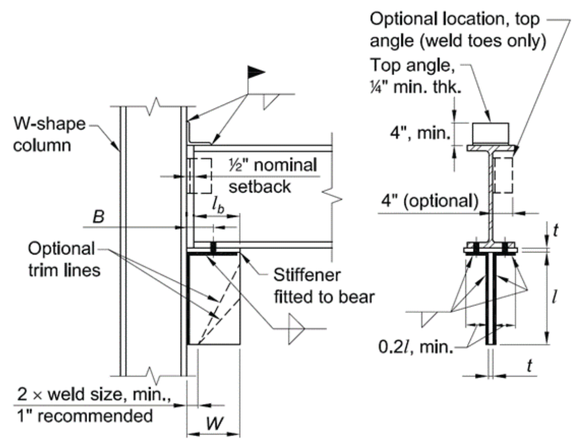


Fig. 1.

Because stiffened seated connections are rotationally stiff, the beam end rotation under load causes the initial contact point between the seat and the beam flange to be located at the edge of the seat. When the load is small, the eccentricity equals the seat width, *W*. However, this is not a critical condition. Larger loads cause yielding at the seat plate and/or beam web, which reduces the eccentricity based on the yielded length. If the beam web yields at the same load as the bracket design load, the eccentricity can be determined using the center of the bearing length as the load point (as discussed in your inquiry). Because this condition is rare, the Manuals Committee determined that an eccentricity equal to 0.8*W* is appropriate.

Bo Dowswell, PE, PhD

Slip-Critical in Bolted Moment Connections

Does the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360) require bolted moment connections to be made slip-critical?

The AISC *Specification* does not require the use of slip-critical connections for moment connections, and the AISC 15th Edition *Steel Construction Manual* does not recommend using slip-critical connections for moment connections.

One typical configuration of field-bolted moment connections is the bolted flange plate. Due to the flange tilt tolerance on the column, it is common (in my experience) for fabricators and erectors to prefer oversized holes for these connections, and using oversized holes would lead to the use of slip-critical connections. However, note that there is no requirement to use oversized holes for bolted flange plate moment connections; it is only a common preference in our industry.

Larry Muir, PE

Slip-Critical in Welded Moment Connections

I am designing a moment connection where the beam flanges are welded to the support. Does the bolted connection to the beam web need to be made slip-critical?

The May 2012 *Modern Steel* SteelWise article "Developing M_p" states: "A common misconception is that slip-critical joints are necessary at the web connection to limit the vertical movement of the beam after the flanges have been welded. This would presumably prevent secondary bending and shear stresses in the beam flange in the area between the column flange and the weld access hole. However, the tests showed no decrease in strength when bearing joints were used. Furthermore, most of the tests with slip-critical joints had slip occur at some point in the testing, effectively rendering the web connection a bearing joint anyway."

There is no requirement or recommendation in the AISC *Specification* or *Manual* to use a slip-critical connection at the web of a moment connection.

Larry Muir, PE

All mentioned AISC codes, standards, or manuals, unless noted otherwise, refer to the current version and are available at **aisc.org/specifications**. Any mentioned *Modern Steel* articles can be found at **www.modernsteel.com**.

Steel Bridge Design Handbook

We cannot figure out how to download the new *Steel Bridge Design Handbook* as one PDF. Is there such a way? Is this handbook also available for purchase as a hard copy?

The handbook is only available in PDF format. However, you can download the entire document at once (as a .zip file) by using the link near the bottom of the *Steel Bridge Design Handbook* webpage (**aisc.org/bridgehandbook**).

Devin Altman, PE

Fillet Weld Directional Strength Increase

Would it be good design practice for me to apply the fillet weld directional strength increase for the fillet welds shown in Figures 2 and 3?

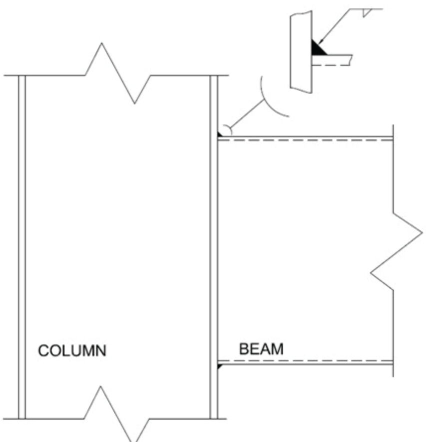


Fig. 2.

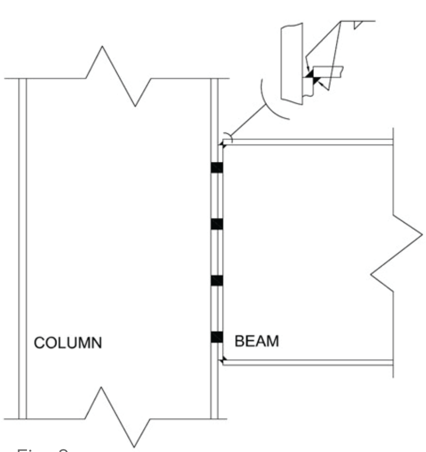


Fig. 3.

Currently, the *Specification* does not explicitly prohibit consideration of the directional strength increase relative to either condition. However, it is generally considered a bad idea to load single-sided welds in "tension"—unless the weld is somehow restrained against rotation about its longitudinal axis (sometimes described as about its root or toe). Therefore, it would seem to be reasonable to question whether one should consider the directional strength increase when a single-sided weld may only be partially restrained.

This topic has seen a lot of discussion in the AISC Committee on Specifications for the last decade or so. In the 2022 *Specification*, which will be published later this year, Section J2.4 will generally permit the directional strength increase "for fillet welds where strain compatibility of the various weld elements is considered" but will explicitly prohibit it "for fillet welds to the ends of rectangular HSS loaded in tension." The Commentary will read:

"Welds to HSS are inherently single-sided. Experimental testing and numerical studies have been performed on fillet-welded joints to the ends of HSS members, where the HSS end is connected to a thick, rigid plate and the HSS is subjected to axial tension (Packer et al., 2016; Tousignant and Packer, 2016; 2017). In such situations, the entire weld length is effective due to the rigid base material. This research has shown that single-sided welds to a tension-loaded HSS wall element are partially unrestrained and are prone to local bending about the axis of the weld, as shown in Figure C-J2.12, leading to opening of the weld root. The restraint provided to the fillet weld depends on the connected element thickness and shape (linear versus curved), as well as the weld size and amount of penetration."

"It was found that the HSS welded joints in the above research did not achieve the expected target safety (reliability) index of $\beta \geq 4.0$ (*Specification* Commentary B3.3) at failure, if the directional strength increase factor, kds, was applied. Thus, this factor of $(1.00 + 0.5\sin1.5\theta)$ should be set to unity (i.e., θ taken as zero) for fillet welds at the ends of rectangular, tension-loaded HSS wall elements. The single-sided weld effect was more severe for square and rectangular HSS than for round HSS. Since recent numerical research (Tousignant and Packer, 2017) found that round HSS-to-rigid plate connections generated $\beta = 3.6$, which is only marginally lower than the target of $\beta \geq 4.0$, fillet welds to the ends of tension-loaded round HSS have been excluded from the prohibition on the use of the directional strength increase factor."

In the 2022 *Specification*, the directional strength increase will be explicitly prohibited at the ends of rectangular, tension-loaded HSS members but implicitly permitted at the ends of round, tension-loaded HSS members.

The condition in Figure 3 will not be explicitly addressed in the *Specification*. The detail shown is not common in my experience. It is a detail I would likely avoid using. However, the detail does not seem to suffer from single-sided loading.

Larry Muir, PE

Devin Altman (altman@aisc.org) is a bridge steel specialist with AISC. **Bo Dowswell**, principal with ARC International, LLC, and **Larry Muir** are consultants to AISC.

STEEL SOLUTIONS CENTER

Steel Interchange is a forum to exchange useful and practical professional ideas and information on all phases of steel building and bridge construction. Contact Steel Interchange with questions or responses via AISC's Steel Solutions Center: 866.ASK.AISC | **solutions@aisc.org**

The complete collection of Steel Interchange questions and answers is available online at **www.modernsteel.com**.

This month's questions and answers were developed by Michael Desch, an AISC intern and current graduate student at the Illinois Institute of Technology. Thanks, Michael!

This month's steel quiz looks at curved member design. You can refer to Design Guide 33: *Curved Member Design* (available at **aisc.org/dg**) for guidance.

And if you need advice on designing with curved members, consider reaching out to one of our AISC member bender-rollers: **aisc.org/benders**.

1 Parabolic, elliptical, and other non-circular bends are all examples of:
a. Variable-radius bends
b. Compound bends
c. Spiral bends
d. Ogee bends

2 Members are bent by the careful use of plastic deformation. Several bending processes can be used to accomplish this. This hot-bending method can produce small-radius bends with high dimensional accuracy and low cross-sectional distortion.
a. Pyramid roll bending
b. Induction bending
c. Rotary draw bending
d. Gas pressing

3 **True or False:** When detailing multi-axis curves, a separate view is required for each plane of curvature, with each curved segment dimensioned separately, providing all the dimensions needed for standard circular curves.

4 **True or False:** When designing statically loaded curved members in typical building construction, the loss of ductility and toughness due to cold-bending strains must always be accounted for.

5 **True or False:** To calculate the required loads in a curved beam, the finite-element method is generally used for preliminary design in cases where complicated geometry and loadings are required.

6 When determining the flexural strength of a curved member, if the angle between torsional restraints $\theta_b \leq$ ___, AISC *Specification* chapter F applies without modification.
a. $\pi/4 = 45°$
b. $\pi/6 = 30°$
c. $\pi/8 = 22.5°$
d. $\pi/12 = 15°$

7 **True or False:** When designing curved beam connections, the primary difference as compared to designing straight beam connections is the need to provide the required torsional resistance.

TURN TO PAGE 14 FOR THE ANSWERS

1 **a.** Variable-radius bends. Parabolic, elliptical, and other non-circular bends are all variable-radius bends. These are also known as multi-radius bends.

2 **b.** Induction bending. This bending method can produce small-radius bends with high dimensional accuracy and low cross-sectional distortion. Heavy shapes that exceed the capacity of cold-bending machines can often be bent with this method.

3 **True.** A separate view is required for each plane of curvature. Additionally, any straight segments between tangent points of the multi-axis curves must be dimensioned. Some bender-roller companies may also prefer to work from the detailer's 3D model.

4 **False.** Under normal conditions with static loading in building construction, any ductility and toughness reductions caused by bending can be neglected in design. However, the effects of bending may need to be addressed to ensure the proper performance of structures with unfavorable loading, fabrication, or service conditions.

5 **False.** Section 7.3 of Design Guide 33 states that while they are accurate enough for use in final design, both the M/R and eccentric-load methods may be more appropriate for preliminary design in cases where complicated geometry and loadings are required. The finite-element method is generally used for final design.

6 **c.** $\pi/8 = 22.5°$. If the angle between torsional restraints $\theta_b \leq \pi/8 = 22.5°$, AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360, **aisc.org/specifications**) Chapter F applies without modification. Otherwise, Chapter F may be used with a revised lateral-torsional buckling modification factor.

7 **True.** In addition to moment and shear, the connections must provide the required torsional resistance. If single-plane shear connections cannot provide the required torsional resistance, the use of flange plates (beam to beam) or end plate connections (beam to column) may be a good solution.

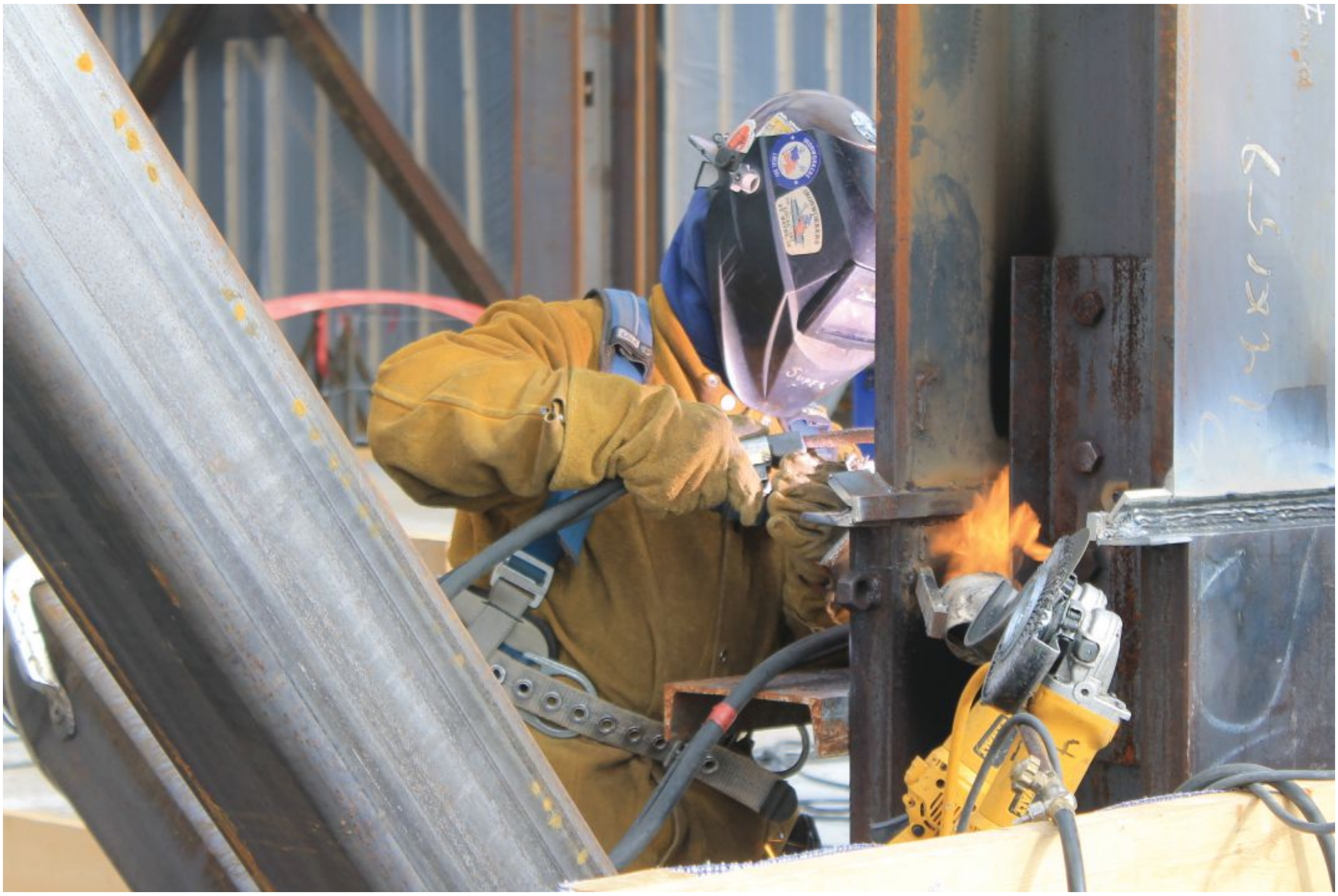
STEEL SOLUTIONS CENTER

Everyone is welcome to submit questions and answers for the Steel Quiz. If you are interested in submitting one question or an entire quiz, contact AISC's Steel Solutions Center at 866.ASK.AISC or **solutions@aisc.org**.

Welded Connection Basics

BY RICHARD M. DRAKE, SE, JENNIFER A. MEMMOTT, PE, AND MOHAMMED BALA, PE

Welding is a fairly straightforward concept in theory. But in practice, there are a lot of nuances, and understanding them can result in better welding design.



WE ALL KNOW how welding works—or at least we think we do.

While we may know the overall concept and basics, taking that knowledge to a higher level can help engineers understand why and how welding is beneficial and thus make better-informed welding decisions when creating framing designs.

Here, we'll highlight the fundamental principles and limit states necessary for designing welded connections in accordance with the provisions of the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360-16, **aisc.org/specifications**).

Structural Arc Welding

Welding is the localized joining of metals by heating the base materials to above their melting points, with or without the addition of filler metals. Almost all structural steel welding is arc welding (see Figure 1).

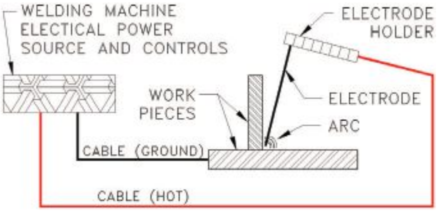


Fig. 1. A basic arc welding circuit.

The electrical power source is connected by a ground cable to the workpiece and a "hot" cable to an electrode. When the circuit is energized and the electrode tip touches the workpiece, the circuit is completed. An arc is created across the gap when the electrode tip is withdrawn from but held close to the workpiece.

The arc produces a temperature of about 6,500 °F, which melts the base metal and any filler metal. The pool of molten metal can hold atmospheric gases in solution, but if the pool is not shielded from the surrounding atmosphere, it will chemically combine with the free oxygen and nitrogen, resulting in a relatively brittle, nonductile weld. As a result, arc welds are typically shielded using either a specially coated electrode, gas, or granular flux (flux is a chemical purifying agent, flowing agent, or cleaning agent). When heated by the arc, the shielding releases inert gasses that protect the molten metal. After the melted metals cool and solidify, a solid piece of bonded metal is left—the completed weld.

There are two types of arc welding that are common in structural applications. The first is shielded metal arc welding (SMAW), which is commonly called stick welding or manual welding. Welds can be made in all positions and many difficult-to-reach areas. The coated electrode is consumed and transferred to the base metal during the welding process. The electrode coating produces a gaseous shield to exclude air and stabilize the arc.

The electrode coating introduces materials to refine the grain structure of the metal and produces a blanket of slag over the molten metal and solidified weld. The slag protects the weld from nitrogen and oxygen that would otherwise react with the hot metals. The slag also serves to slow down the cooling process of the weld, reducing potential brittleness.

A controlled environment is essential. The work area must be kept dry to preclude the introduction of hydrogen and oxygen into the molten material, and wind speeds must be fairly low to prevent the dissipation of the protective shielding gasses. Note that constant replacement of consumed electrodes with new electrodes decreases the time spent welding and adds to the overall labor cost.

The second arc welding type is flux-cored arc welding (FCAW), which is similar to SMAW except that the electrode is a continuous tubular wire fed from a coil through the electrode holder. The shielding is provided by a gas fed through the tubular wire, and additional shielding may be provided by externally supplied CO_2 gas. FCAW replaces SMAW as the field welding process of choice because it is faster, as time is not lost changing electrodes.

Common Structural Weld Types

There are two common weld types for structural steel applications. The first type is a fillet weld, which is principally used to connect structural members (workpieces) not aligned in the same plane. These welds are made on the "outside" of the pieces and are usually chosen for overall economy and ease of fabrication and fit-up, with about 80% of structural welds being fillet welds (see Figure 2 for basic fillet components).

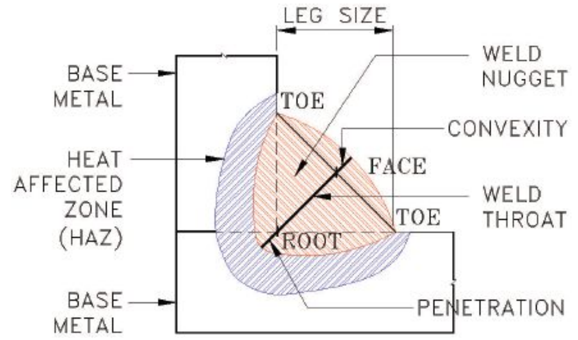


Fig. 2. Fillet weld components.

- **Base metal** refers to the workpieces being joined by the weld.
- **Weld nugget** is the melted filler metal and base metal joining the workpieces.
- **Heat-affected zone (HAZ)** is the base metal whose mechanical properties or microstructure have been altered by the heat of welding and subsequent cooling. The HAZ is stronger but more brittle than other base metals. Preheating the base metal will slow down the HAZ cooling rate, reducing the cooling rate and allowing absorbed hydrogen to escape.
- **Weld throat** is the shortest distance from the root to the weld face, used in strength calculations.
- **Convexity** is the weld metal area not used in strength calculations. A good fillet weld has a convex surface that shrinks into compression.
- **Penetration** is the weld metal not used in strength calculations.
- **Leg** size is the dimension specified on design drawings.
- **Face** is the exposed weld surface on the side from which the welding was done.
- **Toe** is the junction of the weld face and base metal.

The second weld type, the groove weld, fills a gap (or groove) between two pieces of steel and is often used to connect workpieces aligned in the same plane. Some of the workpieces have beveled or machined edges to facilitate making the weld. Each variation of groove weld is classified according to its shape or groove preparation, such as flare, bevel, or vee. About 20% of structural joints are made with groove welds (see Figure 3 for groove weld components).

- **Root opening** is the separation of the base metal at the root.
- **Groove face** is the base metal included in the groove.
- **Root face** is the base metal included in the root.

The other terms shown are the same as defined for fillet welds.

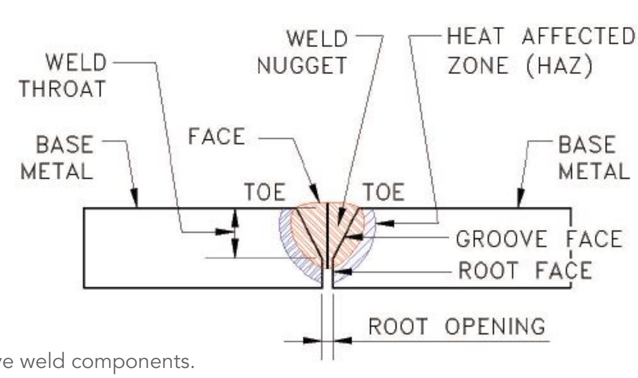


Fig. 3. Groove weld components.

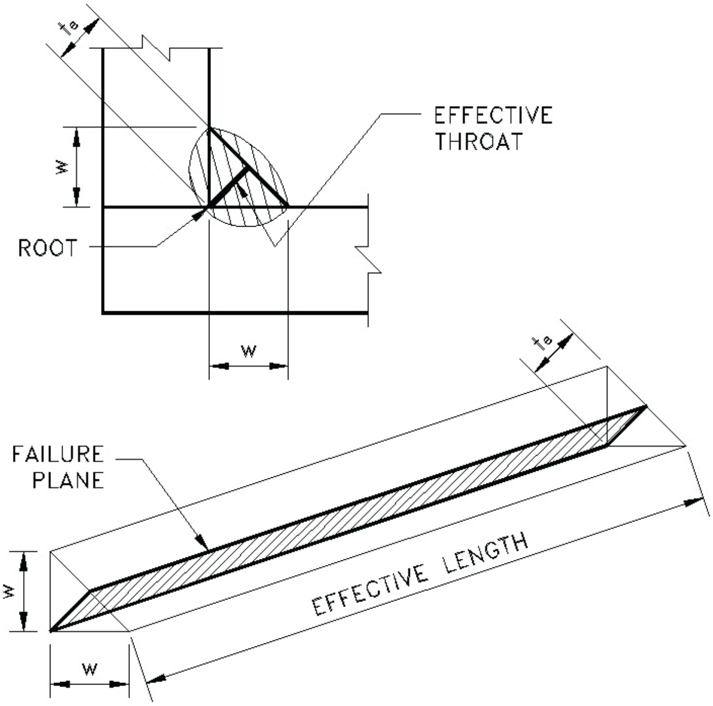


Fig. 4. Fillet weld effective area.

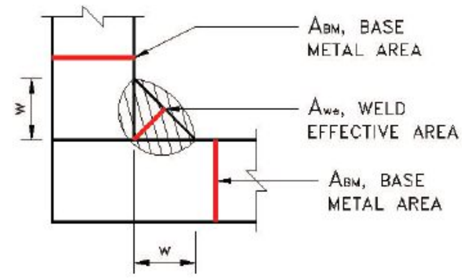


Fig. 5. Locations to evaluate weld strength.

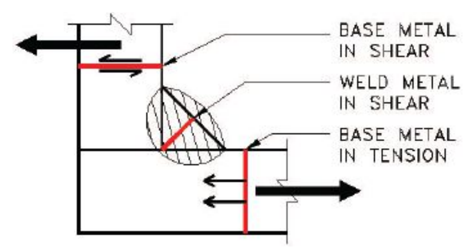


Fig. 6. Example fillet weld force transfer.

Fillet Weld Strength

Several factors help determine a fillet weld's strength.

Base metal nominal stress. *Specification* Table J2.5 directs the user to *Specification* Section J4 for the base metal nominal stress (F_{nBM}) for base metals loaded in tension, shear, combined tension, and shear (block shear), or compression. Depending on the limit state, the base metal nominal stress will be the material specified minimum yield stress (F_y) or the material specified minimum tensile strength (F_u).

Base metal area. *Specification* Table J2.5 directs the user to Section J4 for the base metal cross-sectional area (A_{BM}) for base metals loaded in tension, shear (block shear), or compression. Depending on the limit state, the base metal cross-sectional area may be the gross area (A_g), effective area (A_e), gross shear area (A_{gv}), net shear area (A_{nv}), or net tensile area (A_{nt}).

Fillet weld nominal stress. Table J2.5 defines the weld metal nominal stress (F_{nw}) as 0.60 times the weld filler metal classification tensile strength (F_{EXX}).

$$F_{nw} = 0.60F_{EXX}$$

Fillet weld effective area. *Specification* Section J2.2.2a defines the fillet weld effective area (A_{we}) as the effective length multiplied (L_e) by the effective throat (t_e).

$$A_{we} = L_e t_e$$

Figure 4 illustrates the fillet weld effective area.

Fillet weld sizes (w) are given in increments of $^1\!/_{16}$ in. For a properly placed fillet weld, the effective throat equals 0.707 times the weld size (0.707 is the COS 45°).

$$t_e = 0.707w$$

A properly prepared fillet weld will have a convex shape. When the weld cools and shrinks, the convex shape will place the weld surface in compression. Conversely, a concave weld will put the weld surface in tension when it cools, often resulting in unacceptable weld cracking.

For most fillet welds, the effective length is equal to the actual length.

Evaluation of Fillet weld strength. Fillet welds are intended to transfer forces from one base metal element to another, which requires a check for the applicable limit state at multiple locations for one weld. *Specification* Section J2.4 defines the fillet weld strength as the lower of the strength of the base metals and the weld metal.

$$R_n = F_{nBM}A_{BM}$$
$$R_n = F_{nw}A_{we}$$

See Figure 5 for an example fillet weld and the locations of these strength evaluations. The two base metal elements are evaluated at a slight distance away from the weld toe, and the weld metal strength is evaluated at the effective throat.

Figure 6 provides an example of how the tension force in one base metal element is transferred to the other base metal element as a shear force.

Linear fillet weld groups. Research has shown that fillet welds loaded at an angle (θ) from the weld longitudinal axis have more strength than welds loaded along their longitudinal axis, a condition of pure shear. This relationship can be expressed as follows:

$$F_{nw} = F_{nw(shear)}(1.0 + 0.5sin^{1.5}\theta)$$

Where θ is the angle between the line of force and the weld longitudinal axis (see Figure 7).

The directionality strength increase applies to both the weld metal and the base metal.

Specification Section J2.4(b)(1) provides an alternative to Table J2.5 for fillet weld strength that takes advantage of this increase in fillet weld strength for linear weld groups. Linear weld groups are defined as a single line of weld, or parallel lines of welds, loaded through its center of gravity at an angle θ relative to the weld longitudinal axis (Figure 7 shows a linear weld group consisting of two parallel fillet welds).

$$F_{nw} = 0.60F_{EXX}\,(1.0 + 0.5\sin^{1.5}\theta)$$

For a loading angle of 0°, which is pure shear loading, $\sin\theta = 0.0$, and $F_{nw} = 0.60F_{EXX}$, the same value provided in Table J2.5 for fillet welds loaded in shear.

For a loading angle of 90°, which is pure tension loading, $\sin\theta = 1.0$, and $F_{nw} = 0.90F_{EXX}$, an increase in strength of 50% with respect to pure shear loading. Using this *Specification* alternate is encouraged and may result in a more economical selection of weld size.

Concentrically loaded weld groups. Section J2.4(b)(2) provides an additional alternative to Table J2.5 for fillet weld strength that also takes advantage of the increase in fillet weld strength for concentrically loaded weld groups. Concentrically loaded weld groups combine welds in tension and shear, with the resisting welds concentric with, and in the same plane with the applied force (see Figure 8).

In the Figure 8 example, the channel tension member is welded to the gusset plate with a concentrically loaded weld group, the longitudinal welds between the channel flanges and the gusset plate are loaded in pure shear, and the transverse weld between the channel web and the gusset plate is loaded in pure tension.

In this *Specification* section, AISC defines the strength of both the longitudinal (R_{nwl}) and transverse (R_{nwt}) welds in terms of the Table J2.5 shear strength.

$$R_{nwl} = (0.60F_{EXX})(0.707w)(L_{longitudinal})$$
$$R_{nwt} = (0.60F_{EXX})(0.707w)(L_{transverse})$$

The *Specification* then permits the strength of the concentrically loaded weld group using the *larger* of the following:

$$R_n = R_{nwl} + R_{nwt}$$
$$R_n = 0.85R_{nwl} + 1.5R_{nwt}$$

The first equation is conservative because it underestimates the strength of weld with a tension component. The second equation indicates that for concentrically loaded weld groups, it is acceptable to increase the tension weld strength by 50% as long as you also reduce the shear weld strength by 15%. Again, using this *Specification* alternate is encouraged and may result in a more economical selection of weld size.

A better understanding of welding basics will result in better, more economical weld designs. See AISC Design Guide 21: *Welded Connections–A Primer for Engineers* (**aisc.org/dg**) for a more in-depth treatment.

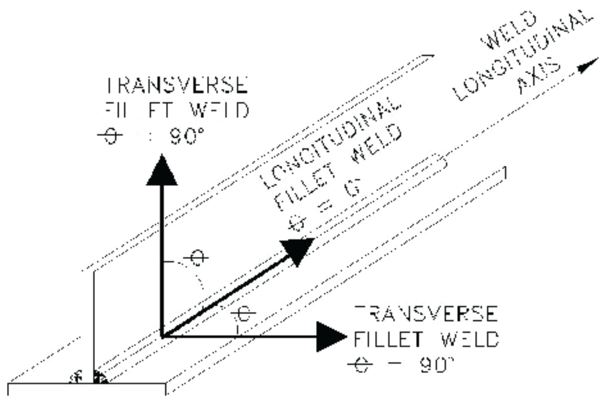


Fig. 7. Directionality of force action on a fillet weld.

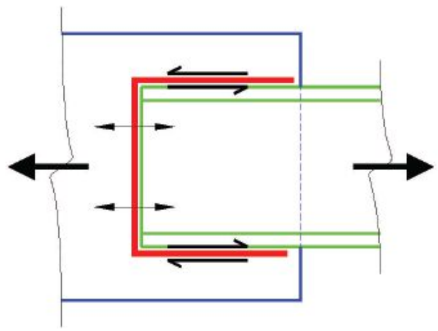


Fig. 8. Concentrically loaded weld group example.

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State by State

BY JOE DARDIS

Construction starts are expected to increase this year, though the situation varies on a state-by-state basis.

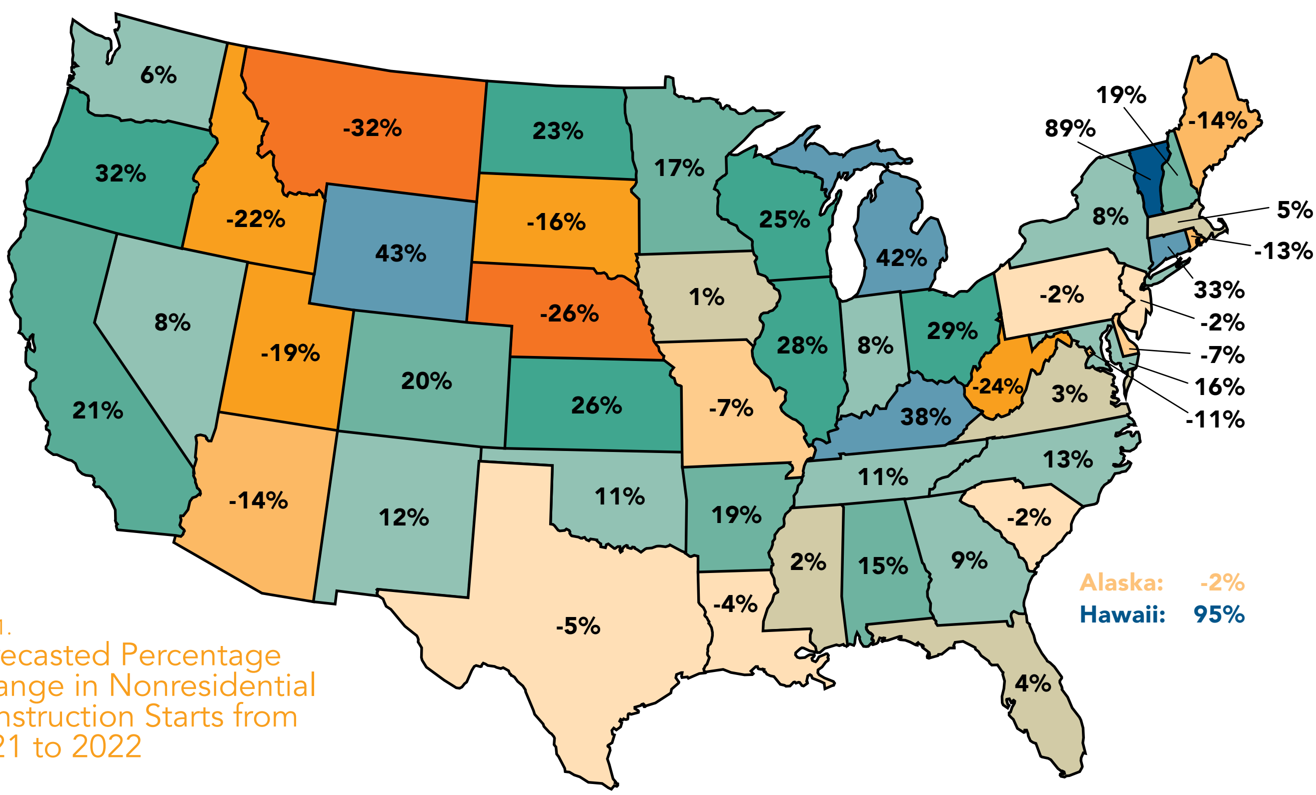


Fig. 1.
Forecasted Percentage Change in Nonresidential Construction Starts from 2021 to 2022

THE BIG PICTURE is very telling, but zooming in on the various sections provides insight as well.

Take construction starts, for example. In total, nonresidential construction starts are expected to rise roughly 7% nationwide in 2022—but as Figure 1 shows, this can vary quite dramatically depending on which region or state you're in.

The first thing you may be asking is, "Why are the swings so drastic from state to state?" This is actually typical in any year, particularly in rural states or states with a low overall volume of construction activity. Because of this low overall volume, one more or one fewer big project can greatly affect year-to-year changes as opposed to states with larger cities and more overall construction activity.

It's also important to understand that the forecast is changing not just by state but also by region, since fabricators typically bid work not only in their own state but also in surrounding states (see Figure 2 for projected annual regional changes through 2026 as compared to 2021). If a fabricator is located in a state that is projected to see a downturn this year, it may find opportunities in nearby states or even other regions.

Fig. 2.
Projected Change in Nonresidential Construction Starts Relative to 2021

	2022	2023	2024	2025	2026
South Central	1.6%	-3.0%	-6.3%	-7.5%	-10.4%
West	9.1%	4.6%	1.5%	1.0%	-1.6%
Northeast	3.4%	-0.5%	-3.4%	-4.4%	-7.6%
South Atlantic	5.7%	3.8%	1.1%	0.4%	-2.5%
Midwest	15.4%	10.9%	7.9%	7.0%	3.9%

In the short term, all regions are expected to see growth through the rest of this year, with the Midwest (particularly Michigan) leading the pack. In fact, warehouse construction starts (the largest project sector) are expected to nearly double in Michigan from 2021 to 2022. Warehouse starts are also expected to increase far above the national average in Ohio, Wisconsin, Illinois, and Kansas.

Despite sharp declines in the mountain states, the forecast for the west is also very healthy for 2022. This is largely due to California, which is expected to see a 21% increase in starts and accounts for roughly 42% of the region's construction volume. The warehouse, hotel, and office markets are all expected to see significant increases in California in 2022.

The Northeast, South Atlantic, and South Central regions are all expected to see modest growth through 2022, roughly 2% to 5%. The largest volume of growth is expected to happen in Kentucky, followed by Georgia, Florida, and North Carolina, while Texas is expected to see the largest volume decline (Texas' warehouse surge came in 2021 and is expected to contract in 2022).

In the long run, all regions are expected to see construction starts decline beyond 2022, which is largely due to the fact that warehouse starts are expected to peak in 2022, then fall year over year until 2026. While that may sound like bad news, it's important to consider that 2022 construction starts are expected to be at their highest level since 2007. So, a modest decline beginning next year may not necessarily point to a slowdown but rather a typical, modest "valley" and not a steep one following 2022's "peak." ■

Joe Dardis (dardis@aisc.org) is AISC's senior structural steel specialist for the Chicago market.

Wise Welder

INTERVIEW BY GEOFF WEISENBERGER

To Mary Jo Emrick, welding is an art, a science, an opportunity, and a lifelong skill that she is teaching to the next generation.

MARY JO EMRICK has been involved with welding for decades, first as a professional welder and now as a welding instructor at Austin Community College. She's also a certified welding inspector (CWI). In this month's Field Notes column, she discusses her experience in the profession, her philosophy on teaching welding, recruiting the next generation into the trades, and what she loves most about Austin.

Tell me a little bit about where you're from and where you've lived.

I was born outside of Chicago, in a suburb called Elmhurst, and moved to Stamford, Conn., when I was young, and then I moved to Texas when I was 13 and have been here ever since. I started out in Houston and stayed there until 1981, when I moved to Austin. And then eight years ago, I moved to Georgetown, which is north of Austin, and that's where I am now.

How did you get into welding? I know you teach it now, but I understand that you were a welder for a while before that.

I went to school for art at the University of Houston, and I took an art metal class and learned stick welding, and I really fell in love with metal. I was offered a job as a welder in a shop, making double what I was making working in a grocery store at the time, and that was in 1976. It was a large structural steel shop, and I worked there for a number of years. And then when there was a layoff, I went into pipe shops and started really learning specialty welding and chamber welding, and I really was fond of that. Like most welders, whoever would pay me more, I'd hop over and work for them. We eventually moved to Austin, and because of my experience in chamber welding and titanium, I was able to get a job with the University of Texas in an applied research lab. During that time period, I started going to school and got my associate's degree in art metal. Then I got a second associate's degree in blacksmithing. I eventually retired from UT, and Austin Community College convinced me to come and teach for them part-time, and that's what I'm doing today: teaching and doing CWI work.

When it comes to teaching welding, is it a situation where you can get anybody to be able to learn it, or can you tell right away if welding isn't for a particular person?

I don't believe just anybody can learn it. I think to be successful as a welder, you have to have a love for the metal. There are also a lot of aspects of welding that people don't like, such as grinding or working in the heat. It wasn't until I worked in Austin that I actually got to work in an air-conditioned shop! But I used to also be a long-distance cyclist, so I like the heat. Some students don't get it, and they get flustered. And if they can't get past that, it might not be the best choice for them. I'm constantly having to tell students not to drink Monster drinks or a lot of caffeine. If they have a lot of shake, that makes things difficult, though I've also had welders that have learned to work with their shake, so it really depends on their determination at that point.

Field Notes is *Modern Steel Construction*'s **podcast series**, where we interview people from all corners of the structural steel industry with interesting stories to tell. Listen in at **modernsteel.com/podcasts**.

There's a very different level of skill between a welder that's welded for six months compared to someone that's been doing it for five years. You can take that five-year welder and put them into a blind situation, and they're still going to pull it off, where a new welder won't have that motor memory to be able to do the work well. People say it's like riding a bicycle in the sense that if you're an active cyclist and you walk away from cycling, you can get back into it pretty easily. But if you're a beginner and you walk away from it for a while, when you come back to it, it's like going back to square one.

Speaking of beginners, it's common knowledge that getting young people to start careers in manufacturing jobs, like welding, has been difficult. What's your take on that?

I think a lot of the difficulty is the fact that we've gone through a couple of generations where we all told our kids they should go to college, and we weren't encouraging the trades at all. When I was in high school, we still had trade schools tied to our schools, and that all went away. But now we're starting to see trades introduced into the high schools again. The hardest part is getting kids to understand the work ethic part of it and being persistent and getting past their difficulties.

I came from a white-collar family, and nobody in my family did anything like welding until I did—and my brother also went into the field. I'm guilty, too, because I encouraged my daughter to go into engineering instead of welding and really kind of kept her away from the welding world, but now she actually manages a machine shop. She got her degree in engineering, but she did go get into my field in a sense. I think that in order to get more kids to consider careers like welding, parents have to change their attitudes about manufacturing and the trades.

On the topic of changing attitudes, welding has traditionally been a male-dominated profession. Has it been difficult recruiting women?

I have been the only woman in some jobs and went through several years of that. But I think people started realizing that 50% of the workforce is women and that in order to get more people back to the trades, we should attract women. And I'm seeing more of that happening. We're trying to approach kids more at the high school level and, really, we actually need to go younger than that and start at the middle school level to show girls that a career in welding is a possibility. We did that during World War II, and there's no reason why we couldn't do it again. And a lot of women are stepping up to the plate and hanging in there with it.

Switching gears, what are some of the things you love about Austin and its vicinity?

One thing I love about Austin is that it has more than 200 public parks. It's a very green area. I live in Georgetown now, but when we first moved to Austin, we took a big pay cut, and one thing we made a goal of was biking to the different parks with the kids because it wasn't costly. There are a lot of beautiful places to go in and around Austin, like Barton Springs, Enchanted Rock west of town in Hill Country, and also Devil's Backbone southwest of town. There's also Hamilton Pool, which is a natural swimming hole with a waterfall, and I'd consider it a top ten place to go in Texas. The area surrounding Austin is just beautiful, especially to somebody coming from the flatlands of Houston. ■

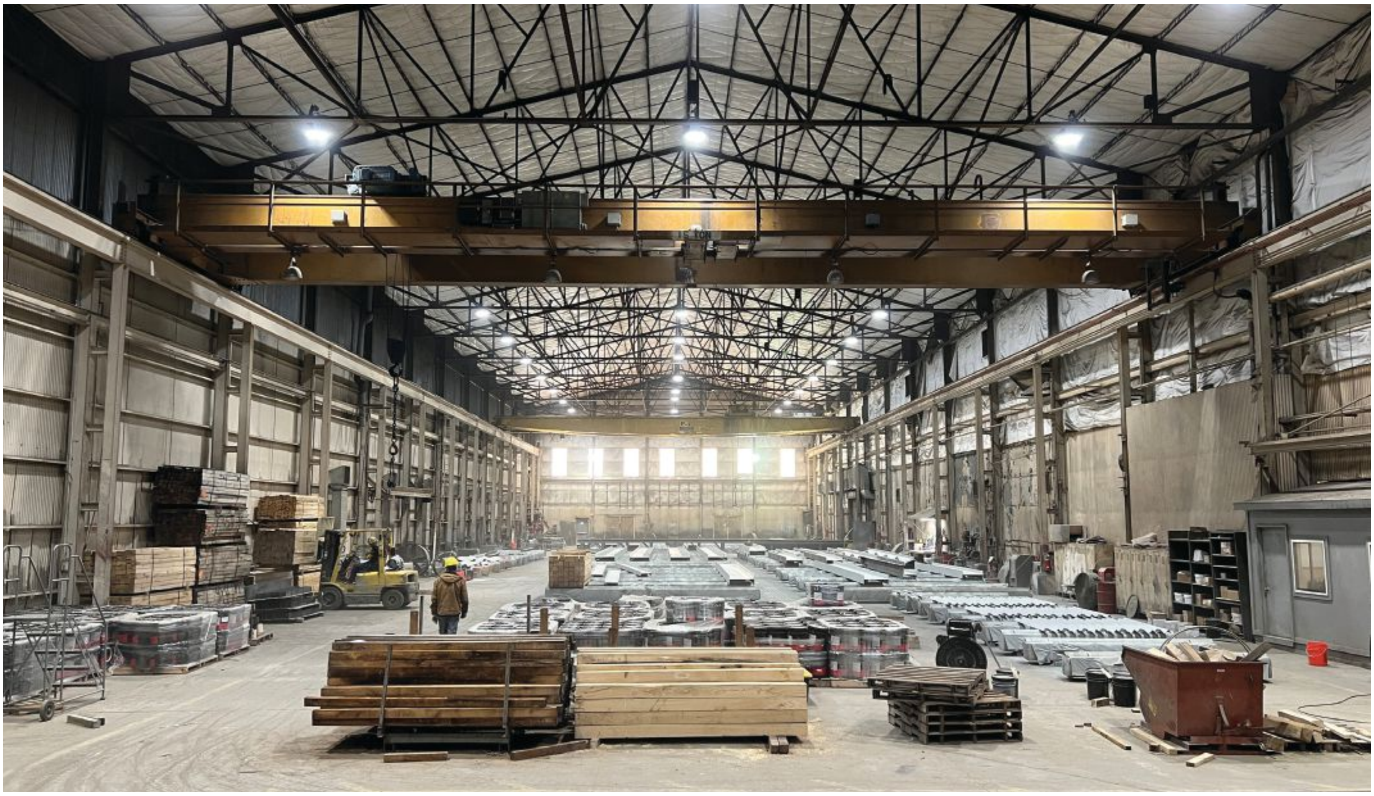
This column was excerpted from my conversation with Mary Jo. To hear more from her, including her thoughts on barbeque, blacksmithing, and cycling, check out the April Field Notes podcast at ***modernsteel.com/podcasts****.*

Geoff Weisenberger
(**weisenberger@aisc.org**) is chief editor of *Modern Steel Construction.*

Push and Pull

BY DERRICK FITTON AND JUSTIN JENSEN

Implementing an internal resource management system to "pull" rather than "push" work through your shop will result in better shop efficiency and fewer headaches.



LIFE AS A STRUCTURAL STEEL FABRICATOR is anything but simple and certainly never boring.

If you're not dealing with unprecedented challenges resulting from a pandemic, there are continuous design and schedule changes to keep things interesting. All these challenges beg questions like "How am I supposed to plan my work with so many things uncertain and out of my control?" and "Would mowing lawns be a better career choice?"

While it's easy to let those external challenges impact your shop schedule, Drake-Williams Steel has intentionally built a structure where the lean principle of "flow" drives our shop schedule. When you create tools and processes to steady the production flow, you can effectively schedule and use your number one resource: your shop. Then, and only then, will you be able to optimize your performance through the best and worst of times.

This may seem like a no-brainer, but the reality is that too often, fabricators are "pushing" the work through instead of "pulling" it. This often results in an uneven workflow and underused resources. We have identified two key areas that, when managed correctly, can positively impact the flow and productivity of your shop resources: backlog management and daily resource management.

Backlog Management

Shop resources and flow can be hard to manage if you don't accurately track your existing and potential backlogs. To avert any issues, a team of our employees spends hours each week discussing and managing our current and potential backlogs.

We use an internally developed shop schedule in Excel that summarizes all our current projects. Each project is scheduled at the sequence/phase level based on the most current customer delivery requirements. While this spreadsheet is managed by each division individually, the data is combined to give an accurate picture of the total company backlog. This allows us to manage our overall workload and determine if work needs to be shifted between divisions to ensure all our resources are used to their fullest extent. As potential or existing project schedule changes arise, we modify this file to evaluate any impact on our overall schedule. In addition, our sales and production leaders meet weekly to review the backlog schedules as well as any potential bid opportunities, which are managed through our bid and sales program, Access.

It's critical that we understand and evaluate the shop hours associated with each opportunity as well as the impact on the overall production schedule. The crystal ball tends to get a little fuzzy when you start talking about potential projects that might be early in the design process, but we do our best to estimate each project's size and schedule.

The reality is that we must evaluate and respond to at least one schedule change during most of our projects. With that in mind, we expect our project managers to provide weekly schedule updates so we can adjust our priorities as needed and minimize schedule changes to our overall production flow. These efforts also allow us to provide commitments, with a high level of confidence, to our customers.

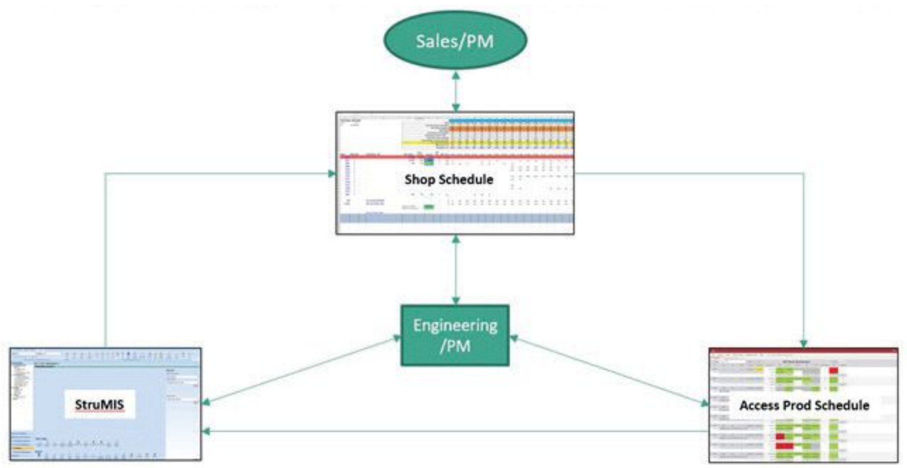


Fig. 1. Shop schedule—productive flow summary. This diagram represents a defined path of information between all our tools, which enables a productive flow of data and resources throughout the entire process.

Daily Resource Management

Most fabricators have been involved in building information modeling (BIM) discussions to review the Level of Detail (LOD) in their steel models, and the same mindset should be applied to shop resources as well. The focus should be on the question, "To what level of detail should we manage our daily shop resources?" Should we manage our resources at the department level, equipment level, or maybe down to the individual? There is not a right or wrong answer, but that decision can affect your ability to support the desired production flow.

A good place to start is with your estimating capabilities. It's hard to manage your shop resources at the equipment level if you are only breaking down your estimated hours to the department level. No matter what level you manage these resources at, it's important that the two are aligned so you can effectively schedule and evaluate your production.

If the Excel backlog tool we mentioned is the 30,000-ft view of our shop schedule, our Access production schedule provides us with a 1,000-ft view. We created this tool to allow us to schedule each respective sequence/lot to the corresponding departments in our shop: processing, fabrication, finishing, and loading. Each department is then broken into more detail by workstations. For example, processing is broken down by each piece of equipment, while we will split fabrication into our four different fab bays.

The internal production schedule is prioritized by workstation start dates rather than customer delivery dates. These start dates inherently create a pull system as each department helps to define the priorities of the preceding department. At the end of the day, to sustain the desired flow of work, we need to balance the requirements of our external customers with the needs of our internal "customers" or departments. Once work is prioritized for each respective department, we can produce workstation-specific priority reports to help operators and other employees map out their workloads.

While the Access production schedule helps us map out each sequence/lot by workstation, it does not give us specific piece tracking. We use the program StruMIS to give us the final 10-ft view and to track individual pieces throughout production. Each department/function can produce outstanding work reports that show what specific pieces are currently ready for them to work on. Once each individual process is complete, production floor employees move the piece forward to the next function in StruMIS to track their workload in real time (see Figure 1). By using our Access production schedule and the tools of StruMIS, we have been successful at implementing a "pull" rather than "push" mindset in our shop. And in doing so, we've streamlined our workflow, used our resources to their full potential, and made customers, both internal and external, happier. ■

*This article was excerpted from the 2022 NASCC: The Steel Conference session "Scheduling Shop Resources to Create Productive Flow." A recording of the presentation will be posted at **aisc.org/educationarchives** in early May.*

Derrick Fitton (**dfitton@dwsteel.com**) is the director of operations for the structural division and **Justin Jensen** (**jjensen@dwsteel.com**) is the production office manager, both with Drake-Williams Steel in Omaha.

Homage to Omaha

One of the world's largest general contractors reaffirms its commitment to its hometown with a new HQ that incorporates some clever cantilevers and trusses.

BY JOHN M. SAVAGE, SE, PE

FROM ITS EXPOSED STEEL to its long spans, Kiewit's new corporate headquarters is a reflection of the company's values: honesty, strength, and flexibility. The seven-story, 180,000-sq.-ft steel-framed building in downtown Omaha was intentionally designed to foster collaboration and interaction.

Based in Omaha since 1884, Kiewit has grown to become one of the largest general contractors in the world. When it came time to build a new headquarters, company leadership wanted to reaffirm its commitment to the city and encourage neighborhood redevelopment, choosing a north downtown location adjacent to their recently completed training center, Kiewit University. The design for the new headquarters expresses the company's values, history, and brand in three dimensions: It is honest and strong, flexible yet enduring, and also tells a story.

The new headquarters building (with a connected parking structure) houses 650 employees in a progressive work environment that fosters collaboration and interaction to support Kiewit's global operations. The ground floor is clad in brick, enlivening the streetscape and evoking the turn-of-the-century warehouses that once filled downtown Omaha. The glass-clad office tower above features an enclosed, elevated walkway connecting to the training center, and the south- and east-facing curtain walls feature dark bronzed or black anodized aluminum frames with low-iron and clear vision glass.

The project is an urban insertion that accomplishes two significant elements to the revitalization of downtown Omaha. First, it connects the Creighton University campus to the west with downtown Omaha's entertainment and sports district to the east. The building itself is a strong anchor point that enables the site's periphery to extend and help reconnect industrial North Omaha and the central business district of downtown Omaha to the south. It also serves as the cornerstone for a new Builders District, an essential component of a greater downtown development strategy.

Maximum Flexibility

Inside the building, the owner wanted a "loft" aesthetic to help recruit and retain younger employees and left the steel framing exposed throughout most of the structure. The design intent was to create as open a floor plan as possible. By shifting the core elements to the building's north side, the design team, led by architect and structural engineer HDR, provided a 60-ft-wide, 250-ft-long, uninterrupted bay on the south side of the building, allowing for maximum flexibility in laying out the office space. In a sense, HDR returned the favor to Kiewit on this project, as Kiewit served as the general contractor for HDR's new headquarters facility, which is also located in Omaha (for more on that project, see "Inside Job" in the March 2020 issue, available in the Archives section at **www.modernsteel.com**).

The team paid special attention to the use and control of natural light inside the building by means of low-e reflective coatings, shading devices, and operable interior roller shades, and the facility configuration incorporates covered pedestrian plazas and provisions for a future elevated exterior patio. The project also incorporates a modular wall system configured in a pod layout with an open ceiling to preserve flexibility for future changes. This resulted in a compressed construction schedule, with entire floors being fit out much faster than normal stick-built construction. In addition to the neighborhood concept, acoustic baffles, white noise system, and extra sound insulation in the modular wall system promoted a more private open office setting for staff.

opposite page: Structural engineer HDR designed Kiewit's new headquarters, and Kiewit was the general contractor for HDR's new headquarters (see "Inside Job" in the March 2020 issue).

above: A cutaway view of the building, showing the various sections.

All photography: © HDR/Dan Schwalm

A site plan showing the new office tower and attached parking garage.

Based on the desired long-span, open floor plates, and aggressive construction schedule, steel was the only material seriously considered for this project. Due to the aggressive schedule, Kiewit brought fabricator Drake Wiliams Steel and erector Davis Erection onto the team early to assist with pricing, scheduling, and constructability. The project incorporates approximately 1,200 tons of structural steel.

On the ground floor, the building includes eight bays facing east-west and two bays in the north-south direction. The typical bay size on the south end is 30 ft by 60 ft and 30 ft by 37 ft on the north end. Although not impossible, achieving the 60-ft span in concrete would be difficult and heavy. Mass timber was also suggested during design development but would have resulted in tighter column spacing, which was not conducive to the desired open plan. In addition, the structural team upgraded part of the eighth level roof for a potential future patio late in the project, and steel made it easier to increase the capacity of the beams to carry the added load from the patio.

To achieve the 60-ft spans, the design incorporates 36-in.-deep girders while W16×26 purlins, spaced 12 ft on center, span the 30-ft bays; the 36-in. depth fit within HDR's desired floor-to-floor height of 15 ft, and the system met AISC vibration requirements using the design criteria for an electronic office (HDR consulted AISC Design Guide 11: *Vibrations of Steel-Framed Structural Systems Due to Human Activity*, available at **aisc.org/dg**). The floor slab comprises 3-in. metal deck topped by 4½-in.-thick normal-weight concrete, a configuration that helped reduce steel tonnage. With the long spans, floor deflection was a concern. HDR calculated the camber using 80% of the pre-composite dead load deflection based on previous experience.

The girder depth was closely coordinated with the mechanical team. The north bay was only 37 ft wide, resulting in shallower framing, and the main HVAC ducts were placed east-west in this bay, with the supply/return ducts running into the 60-ft bay along the sides of the girders. As the bottom of the girder and duct nearly match, the girder depth visually disappears.

V is for Value

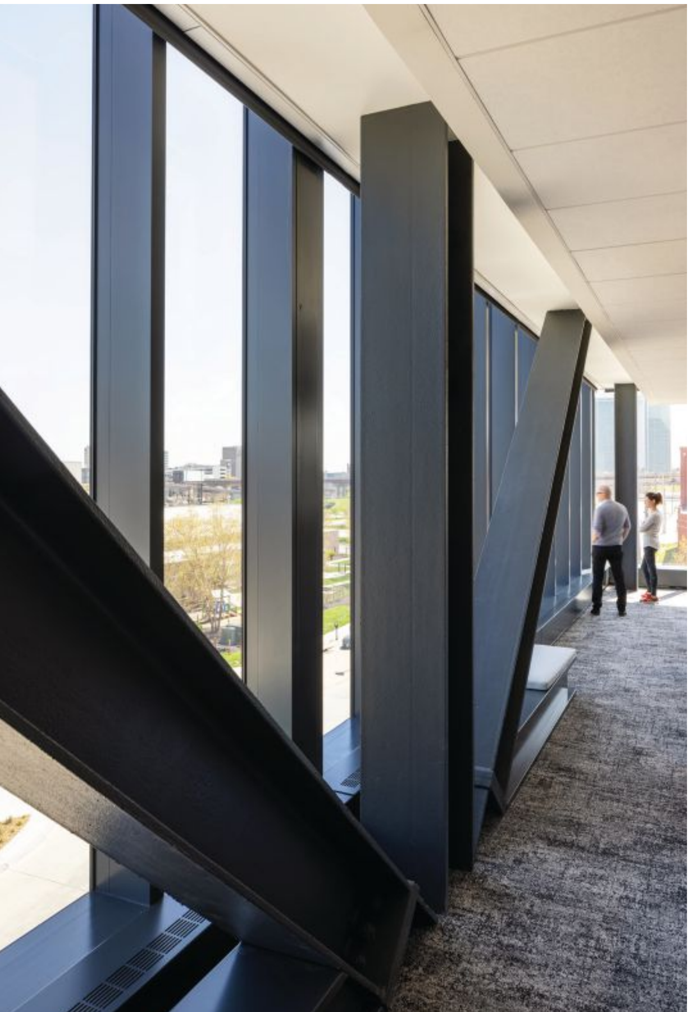
The team faced another major challenge when the decision was made to open the entry plaza by removing the southeast corner column between the ground and level three of the building. This meant the upper four stories of the tower would cantilever 30 ft over the entry plaza. The structural team considered many solutions, including a plate girder below the third floor and story-deep trusses at level three or seven. The chosen solution was to use two stacked V-shaped cantilever trusses, with each half of the V being one bay wide—30 ft for the cantilever and 30 ft for the back span. Each truss was two stories tall, starting at level three and extending up to level seven. These trusses echo the V shapes of the diagonals in the adjacent skywalk.

These trusses act as part of the braced-frame lateral load-resisting system between levels three and seven. On these levels, the stiffness of the trusses moves the center of rigidity east, resulting in significant lateral load redistribution in the braced frames at levels three and seven, which were accounted for in the floor diaphragm design.

Initially, the structural team designed the V truss diagonals so they would be in tension, which would have involved smaller member sizes. However, as the team reviewed the design, they realized that the tension diagonals would place gusset plates at the floor line in the corners of the building. Corner spaces are highly coveted, whether for offices or for meeting rooms, and gusset plates would have made them less usable. As a result, the team flipped the braces, placing the diagonal members in compression and moving the gusset plates from the floor to the ceiling. This added steel weight but opened the corners for usable space.

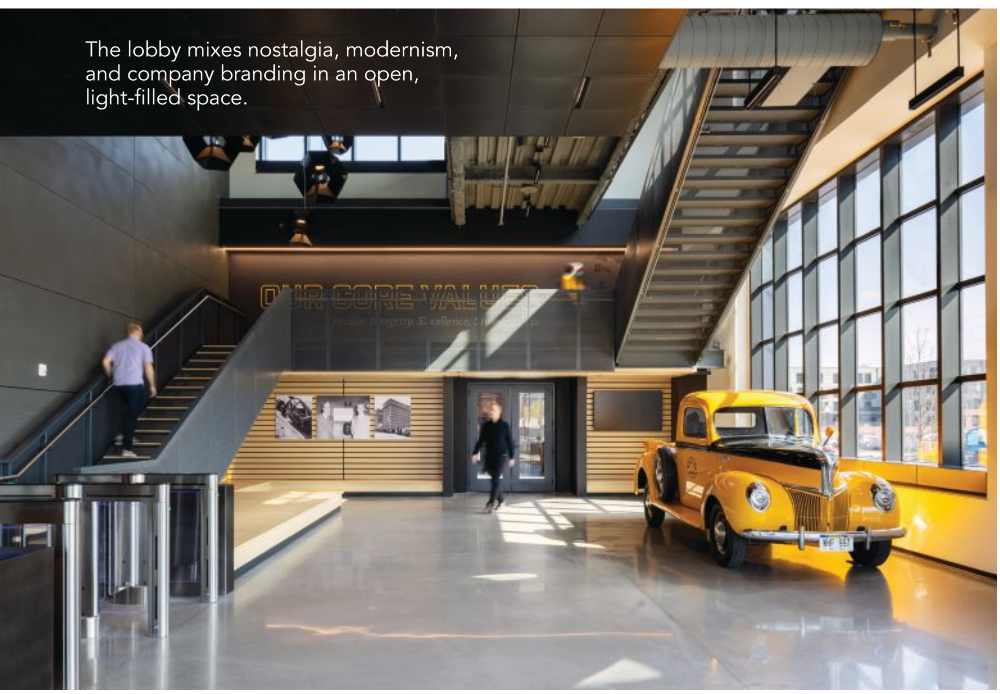
The structural team designed the V trusses so that the cantilevered corner of the building could be built without shoring. However, Davis Erection preferred to use shoring, so a temporary

above and below: A section of one of the two-story V-shaped trusses during construction and following project completion.



above and below: The seven-story, 180,000-sq.-ft steel-framed building houses 650 employees in a progressive work environment that fosters collaboration and interaction to support Kiewit's global operations.

The building's framing system uses 1,200 tons of steel. All columns of 90 lb per linear ft or more were made from Nucor's Aeos ASTM A913 Grade 65 steel, whose preheat requirements are substantially less than that of A992; see **nucor.com/aeos** for more.



The lobby mixes nostalgia, modernism, and company branding in an open, light-filled space.

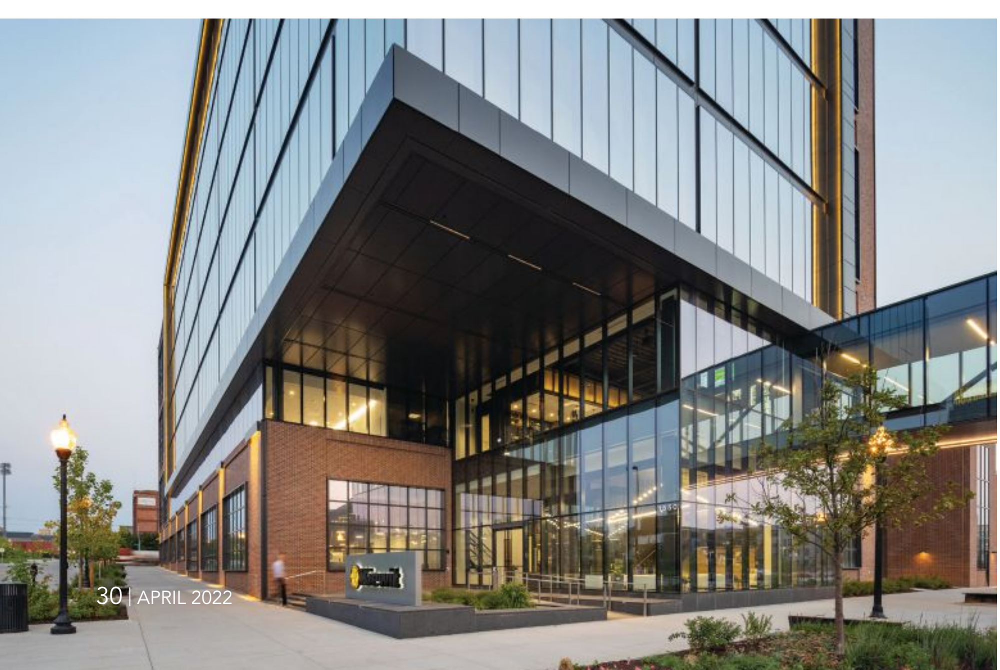
column was placed between the ground level and level three until level five was poured and the concrete reached its design strength. When the architects first proposed this cantilever, the universal response from the rest of the team was that the budget could not allow for it. However, implementing the V trusses resulted in the cantilever requiring less than 10 tons of steel—and the team liked the look of these trusses so much that they left them exposed. Since they are part of the primary structure, the diagonals are coated with intumescent paint.

All columns of 90 lb per linear ft or more were made from Nucor's Aeos ASTM A913 Grade 65 steel, and the building is only the second in Nebraska to incorporate this grade (and one of the first anywhere to use Aeos, whose preheat requirements are substantially less than that of A992). During the design phase, the HDR team checked steel prices with Drake Williams. At the time, the cost difference between Grade 50 and Grade 65 steel was negligible, but changing the yield strength reduced the overall steel package by more than 20 tons. Despite the building's 60-ft bays, relatively narrow and less efficient braced frames for north-south lateral load resistance, a 30-ft cantilever at a corner of the building, and a relatively tall 15-ft floor-to-floor height, the total amount of steel used for the structure is still less than 13.5 psf.

Steel Skywalk

The steel-framed pedestrian skywalk between the headquarters building and the adjacent existing training facility spans 94 ft over a city street. It also slopes down 4 ft from the former to the latter to accommodate differences in floor elevations. To maintain clearances above the street, the team turned to WT12 chords, with the top of the chord matching the top of the slab.

The skywalk floor slab did not require a fire rating, so it is topped with 3 in. of normal-weight concrete on 3-in. composite metal deck for a 6-in. total floor thickness, which places the bottom of

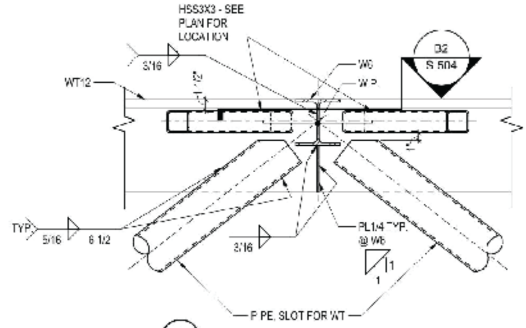


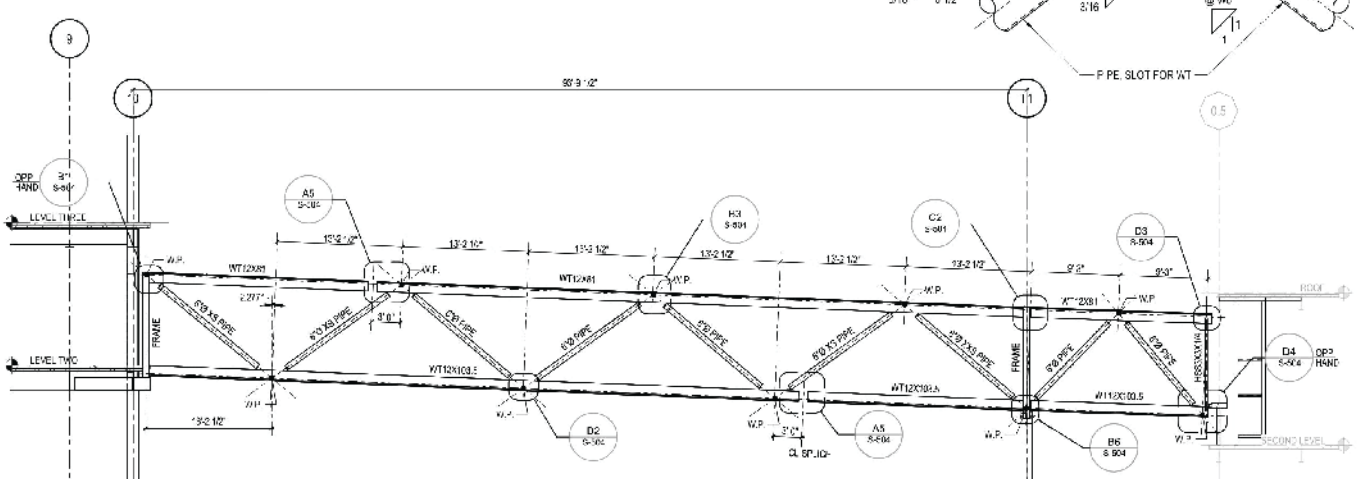
The upper four stories of the building cantilever 30 ft over the entry plaza.

above: The steel-framed pedestrian skywalk between the headquarters building and the adjacent training facility spans 94 ft over a city street.

right: A detail of a framing section for the bridge.

below: The bridge navigates a 4-ft elevation change between the two buildings.





the WTs only 6 in. below the bottom of the slab. With the WT chords, the round hollow structural section (HSS) diagonals could be slotted and welded directly to the WT webs, and gusset plates were not necessary for the diagonal members in the vertical trusses.

Kiewit's new headquarters building literally and figuratively expands the contractor's footprint in Omaha. With a nod to the past and an eye on the future, the facility will enhance the company's ability to attract staff to continue building exemplary projects locally and globally. ■

Owner
Kiewit Real Estate, Omaha

General Contractor
Kiewit Building Group, Omaha

Architect and Structural Engineer
HDR, Omaha

Steel Team

Fabricator
Drake Williams Steel, Inc. (AISC Certified Fabricator), Omaha

Erector
Davis Erection/Topping Out, Inc. (AISC Associate, AISC Certified Erector), Omaha

John Savage
(john.savage@hdrinc.com) is a senior structural engineer with HDR.

Bridge to the Future

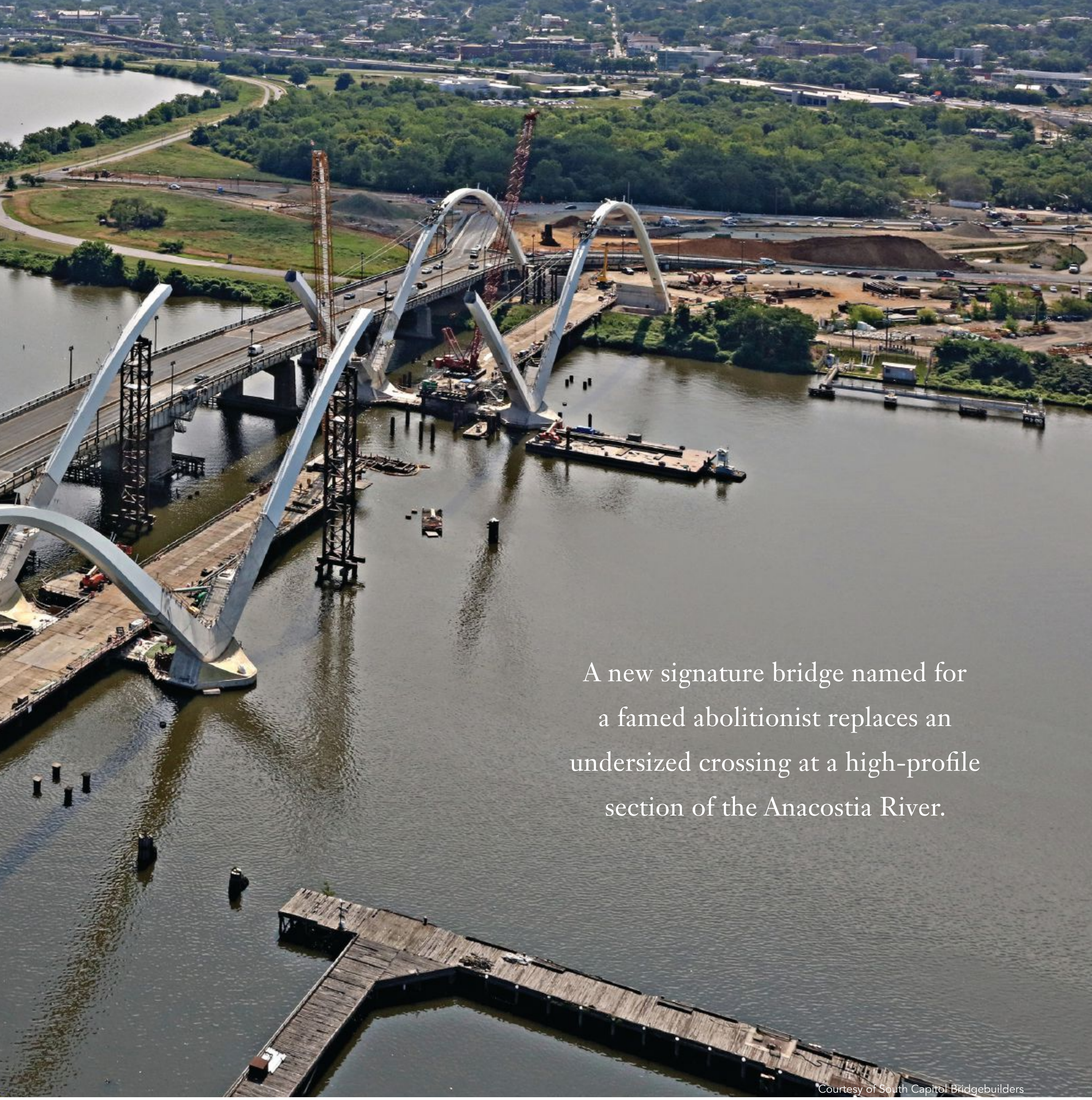
BY KEVIN BIRD

WASHINGTON, D.C.'S new Frederick Douglass Memorial Bridge connects not only the two sides of the Anacostia River but also the region's past with its future.

Named for one of the area's most esteemed abolitionists and residents, the $480 million three-span bridge opened this past fall and stretches 1,445 ft over the river between D.C.'s Anacostia neighborhood and Navy Yard district, with the approaches landing just a stone's (or baseball's) throw from Nationals Park. Built to accommodate traffic over the river, it carries six traffic lanes flanked by 18-ft-wide paths on both sides for pedestrians and cyclists.

At the bridge's dedication, Kenneth B. Morris, Jr., the great-great-great-grandson of Frederick Douglass, stated, "We are thrilled that this magnificent bridge will serve to educate the public about [Douglass'] legacy, connect D.C. to the neighborhoods where he worked and lived, and inspire future generations to agitate for change," according to *Washingtonian* magazine.

The new steel crossing replaces its predecessor, which was built in 1950 and named the South Capitol Street Bridge and was recently demolished. It was renamed the Frederick Douglass Memorial Bridge in 1965 and underwent some renovations at that time, but even then, it remained a traffic headache and only offered 5 ft of cramped concrete for pedestrians and cyclists to cross the river. Over the years, it also began to deteriorate, with its old, narrow walkways losing large chunks of concrete. And with more than



Courtesy of South Capitol Bridgebuilders

77,000 commuters driving across the bridge each day, it experienced the inevitable wear and tear. It became clear that a larger, more accommodating, and safer bridge was needed.

Also, a more attractive one. In addition to helping relieve the area's traffic burden, the new bridge also offers pedestrian overlooks and is defined by six steel arches, three on each side. These signature elements echo the vision of Pierre L'Enfant, the French-American military engineer who designed the basic layout for the nation's capital and visualized the South Capitol Street Corridor as a resplendent boulevard leading into the heart of the district. The arches are comprised of 56 arch rib sections that were shipped via truck to the site from two of fabricator Veritas Steel's locations, one in Eau Claire, Wis., and the other in Palatka, Fla. The arch ribs are hexagonal in shape, fabricated from flat plate steel, and vary in depth and width from the base to the top arch section. Veritas fabricated more than 7,100 tons of steel for the bridge in all, including the arches and superstructure elements, and the bridge also incorporates 12,000 linear ft of steel piles. Each center arch is made up of 12 sections, and each end arch is made up of eight sections, with all sections varying in length from 28 ft to 65 ft and weight from 20 tons to 75 tons.

Planning for the bridge took over a decade before construction started in the summer of 2017. The project employed approximately 200 local residents, and at least 45 minority- and

above: A temporary bridge was built for the cranes to work from and was progressively removed as the arch floor system was being erected.

left: Looking up at the superstructure beams.

women-owned businesses contributed to the bridge's erection, amounting to $91 million in contracting jobs.

Steel was chosen as the structural material thanks to its lower maintenance requirements and the fact that it offered a 100-year-plus lifespan. The steel superstructure is supported by a system of cable-stay hangers, which was chosen because it was lighter and more cost-effective than a concrete superstructure would have been, and also provided superior fatigue resistance, corrosion protection, and ease of replacement. There are 14 hangers for each side arch and 16 hangers for the two center arches (88 in all). There are 18 to 29 strands per hanger, each 0.62 in. in diameter. The design incorporated a repetitive steel grid sequence, using longitudinal edge girders and transverse floor beams, coupled with

The arches are comprised of 56 arch rib sections that were shipped via truck to the site from two of fabricator Veritas Steel's locations, one in Eau Claire, Wis., and the other in Palatka, Fla.

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13. **Tee Stem Up** — MEAN DIA. — 22" x 142$^1/_2$# Tee
14. **Angle Heel In** — INSIDE DIA. — 8" x 8" x 1" Angle
15. **Angle Heel Out** — OUTSIDE DIA. — 8" x 8" x 1" Angle
16. **Angle Heel Up** — MEAN DIA. — 8" x 8"x1" Angle
17. **Square Tube** — INSIDE DIA. — 24" x $^1/_2$" Tube
18. **Rectangular Tube The Easy Way (Y-Y Axis)** — INSIDE DIA. — 20" x 12" x $^5/_8$" Tube
19. **Rectangular Tube The Hard Way (X-X Axis)** — INSIDE DIA. — 20" x 12" x $^5/_8$" Tube
20. **Square Tube Diagonally** — MEAN DIA. — 12" x $^5/_8$" Square Tube
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precast concrete deck panels, which made for relatively simple erection. A temporary bridge was built for the cranes to work from and was progressively removed as the arch floor system was being erected.

In addition to the new bridge, other project elements include a new traffic oval that connects South Capitol Street, Suitland Parkway, and Howard Road SE. This new scenic boulevard will showcase landscaping on both sides. By later this spring, the new traffic ovals should be completed, and there will also be space for community activities on either side.

The bridge opened to the public on September 10th with a community celebration that included a 5K race attended by around 4,000 people, a walk led by Washington Mayor Muriel E. Bowser, and a ribbon-cutting ceremony. Descendants of the abolitionist Frederick Douglass, the bridge's namesake, spoke at the event, as did Congresswoman Eleanor Holmes Norton and Majority Leader Steny Hoyer.

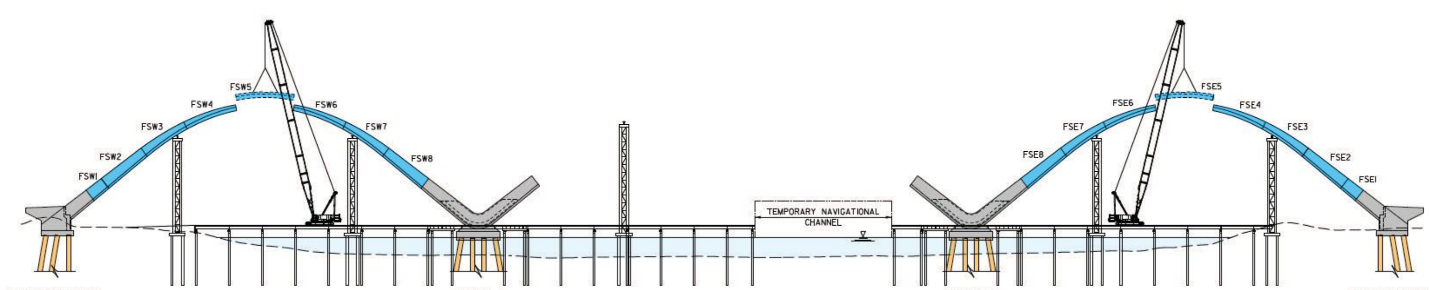
A symbol of Washington's past and future, the 100-plus-year bridge is just one of several projects under the Anacostia Waterfront Initiative Program, whose goal is to revamp the river into a thriving waterfront that can enrich its surrounding communities for generations to come. And with this significant piece of

Courtesy of AECOM

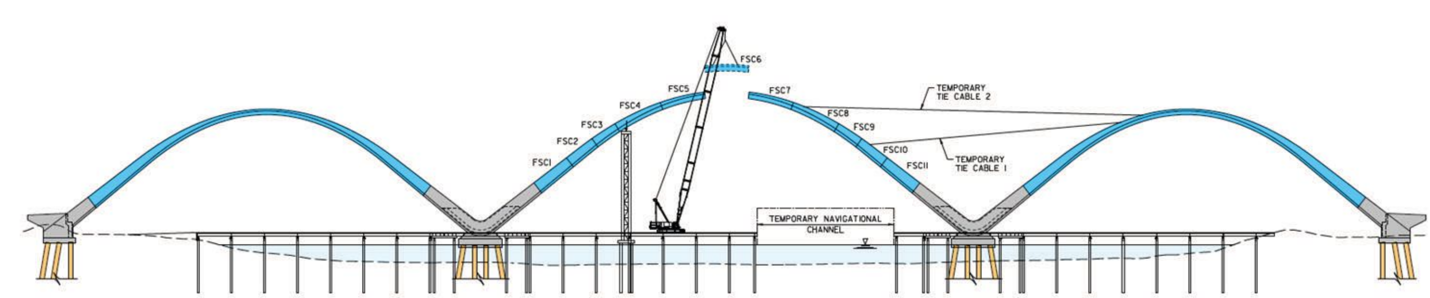
above and below: The arch ribs are hexagonal in shape, are fabricated from flat plate steel, and vary in depth and width from the base to the top arch section.

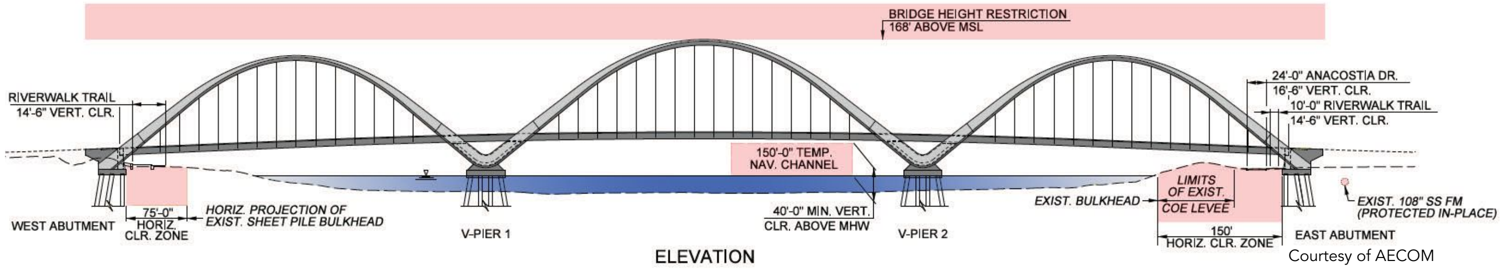
Courtesy of AECOM

below: The erection sequence for the arches.



Courtesy of AECOM



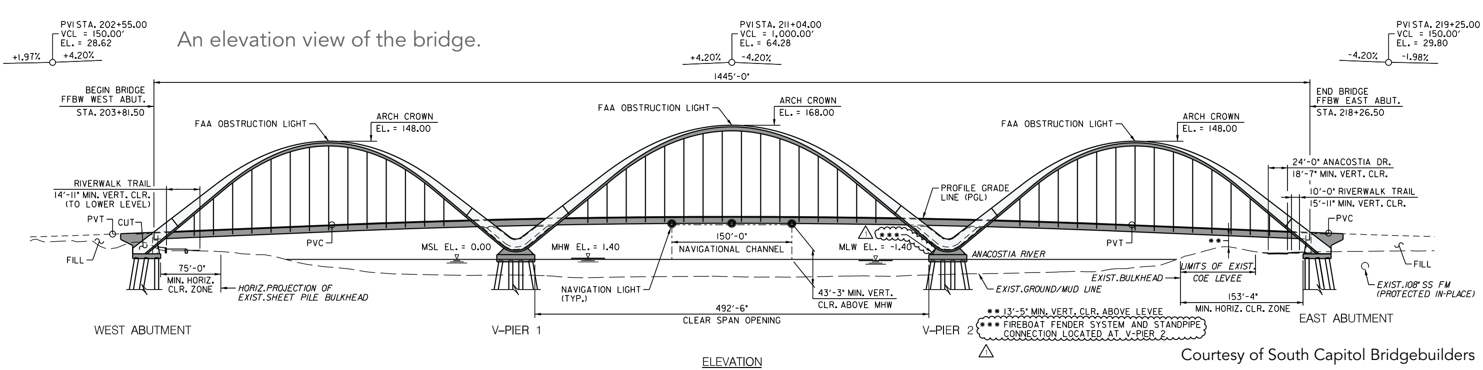


Courtesy of AECOM

Clearance requirements for the bridge.

Shoring assemblies for the arches.

Courtesy of AECOM

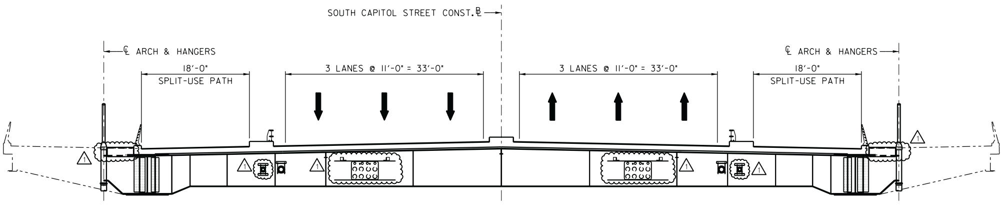


An elevation view of the bridge.

Courtesy of South Capitol Bridgebuilders

The bridge spans the Anacostia River between D.C.'s Anacostia neighborhood and the Navy Yard district, with the approaches landing near Nationals Park on the Navy Yard side.

Courtesy of South Capitol Bridgebuilders



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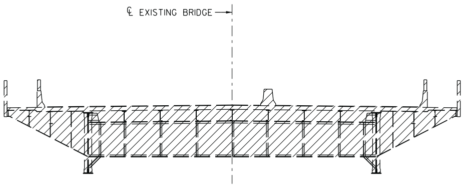


The new bridge's width as compared to that of the existing bridge.

Courtesy of South Capitol Bridgebuilders

Placing floor beams following completion of arch erection.

the puzzle now in place, the initiative is off to a great start. ■

Owner
District of Columbia Department of Transportation

Construction Manager
HNTB

General Contractor
South Capitol Bridgebuilders (a joint venture of Walsh Construction and Granite Construction Co.)

Architect
BeAM

Structural Engineer
AECOM

Erection Engineer
McNary Bergeron

Steel Team

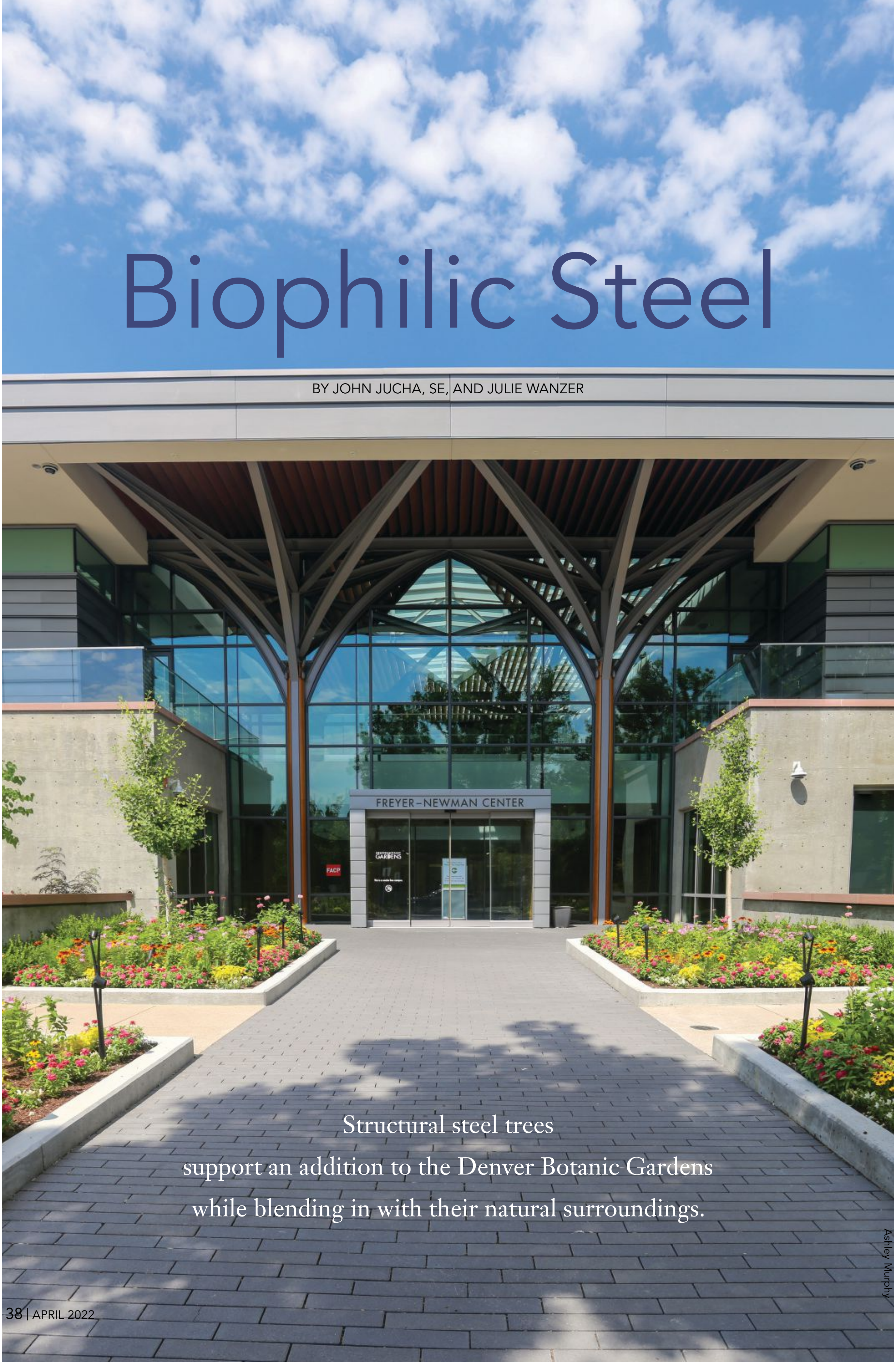
Fabricator
Veritas Steel, LLC (AISC Certified Fabricator)
Eau Claire, Wis., and Palatka, Fla.

Detailer
Tensor Engineering Co. (AISC Detailer),
Indian Harbour Beach, Fla.

Kevin Bird (kbird@veritassteel.com) is vice president of sales and marketing with Veritas Steel.

Biophilic Steel

BY JOHN JUCHA, SE, AND JULIE WANZER



Structural steel trees support an addition to the Denver Botanic Gardens while blending in with their natural surroundings.

Ashley Murphy


Ashley Murphy

THE DENVER BOTANIC GARDENS complex is a colorful icon for the Mile High City—and its recent expansion prominently showcases several new (steel) trees.

Founded in 1951, the facility has since blossomed into a popular attraction for citizens and visitors alike and recently completed the final phase of a ten-year master plan to enhance and grow its offerings. The five-year project commenced with the Gardens awarding a complex architectural design to Davis Partnership Architects for a steel-framed addition to the sprawling indoor-outdoor facility (which incorporated nearly 400 tons of steel), where necessary structural elements also served as some of the main aesthetic components to the building's entrance and interior. In addition, the design needed to intricately connect the past with the future, as this 50,000 sq. ft of new construction also included a renovation of the Gardens' Boettcher Memorial Center, completed in 1966, with the need for a seamless, structural bridge connecting to the new building. This renovation mainly involved cutting new openings in existing concrete walls and concrete waffle slab floors, with the only steel in this portion being new channel headers above the new wall openings.

The new building, the Freyer-Newman Center, is a celebration of the fusion of science and art and includes four art galleries, six classrooms, a library, an auditorium, research labs, and other amenities. One of the most important aspects of the architectural design was the appearance of a light structure with the ability for light to transmit through windows at the building's entrance and also in a skylight reminiscent of the diamond-patterned roof of the existing tropical conservatory located on the Gardens' grounds. Out of any materials considered, steel provided the most flexibility to attain this light and airy structure and was the best material to attain the complex geometry of the marquee "tree" structures located in the atrium and at the entrance—especially considering that these elements were left completely exposed. Architecturally exposed structural steel (AESS) requirements weren't specified since the majority of the exposed connections were elevated far enough overhead. Davis Partnership Architects specified a surface preparation level of SSPC-SP 11 for the exposed steel, which is protected with primer and a high-performance coating.

opposite page: Visitors to the Denver Botanic Gardens' new Freyer-Newman Center are greeted by steel trees.

above: The gardens were founded in 1951, and the new building is the final phase of a ten-year master plan to expand the facility.

The new building, the Freyer-Newman Center, is a celebration of the fusion of science and art and includes four art galleries, six classrooms, a library, an auditorium, research labs, and other amenities.

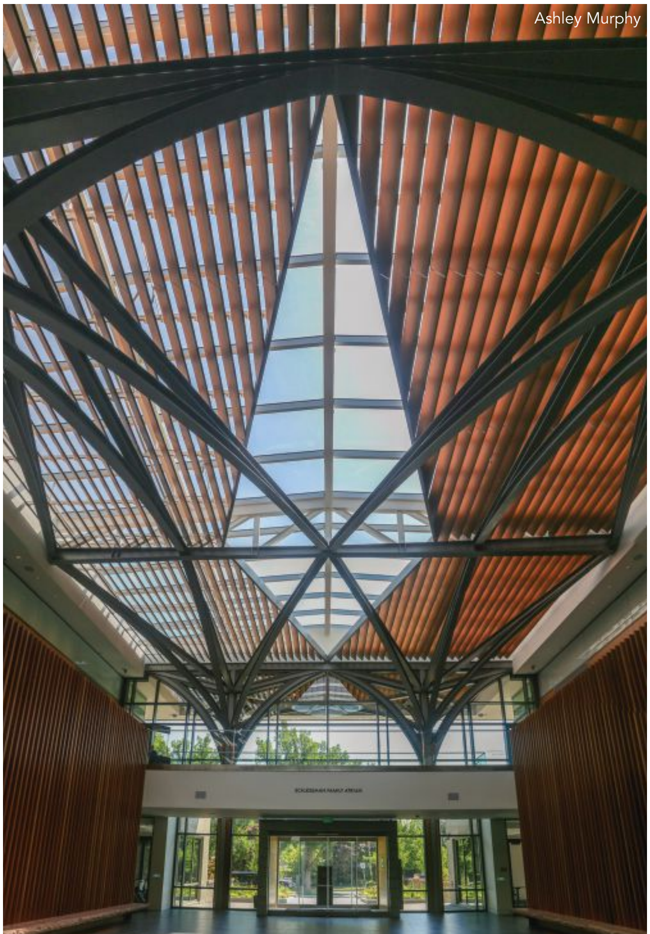
From the ground up, the Freyer-Newman Center embodied complex design criteria, and structural engineer KL&A's design expertise significantly contributed to the successful completion of the project and fulfillment of the owner's goals. One of the first challenges that the KL&A design team had to overcome centered on the complexities of the site itself, where the main structure of the building foundation floats atop a high water table. The foundation is 30 ft below grade with a 12-ft water table, resulting in about 18 ft of water buoyancy that needed to be structurally accounted for. KL&A had to consider the calculation of the water buoyancy times the water's density, which resulted in over 1,000 lb per sq. ft of uplift (or buoyancy pressure) that needed to be accounted for since the self-weight of the structure wasn't enough to overcome this issue on its own (the design was limited to only two stories above ground, with steel framing being the best choice to achieve the architectural vision). This required the design team anchor the building in the bedrock with drilled pier deep foundations to resist the uplift pressure from the high water table.

Another challenge arose from the owner's main goal of infusing the botanical landscape into the actual structure of the Freyer-Newman Center. Brian Vought, CEO of the Denver Botanic Gardens, described this goal as a means to "celebrate natural life within the built space." In a virtual tour of the building, Davis Partnership emphasized that the atrium design was inspired by the archways of the historic Botanic Gardens Conservatory and existing tulip light structures throughout the Gardens. The resulting design manifested a biophilic-inspired archway entrance to the building that was supported by steel tree-like columns and curved steel "branches." KL&A spearheaded the efforts to bring these tree columns to life to balance the constructability of the steel trees with the overall aesthetic.

The design of the tree columns themselves served as one of the unique applications of structural engineering design techniques, where select portions of the steel trees are structural in nature but other components are not. KL&A developed several design solutions to accommodate both the steel tree columns on the front façade curtain wall and the connecting elliptical branch-like shapes where the steel-tolerances proved very tight for curved members. This process required the team to consider more simplistic solutions to make the tree branches less structural in nature so that the branches were lighter in weight and could allow for easier constructability. In the interior atrium, KL&A also designed the tree branches to serve as bracing members for the main structural truss to simplify the gravity load path, with conventional truss members eventually painted over to match the overall biophilic aesthetic.

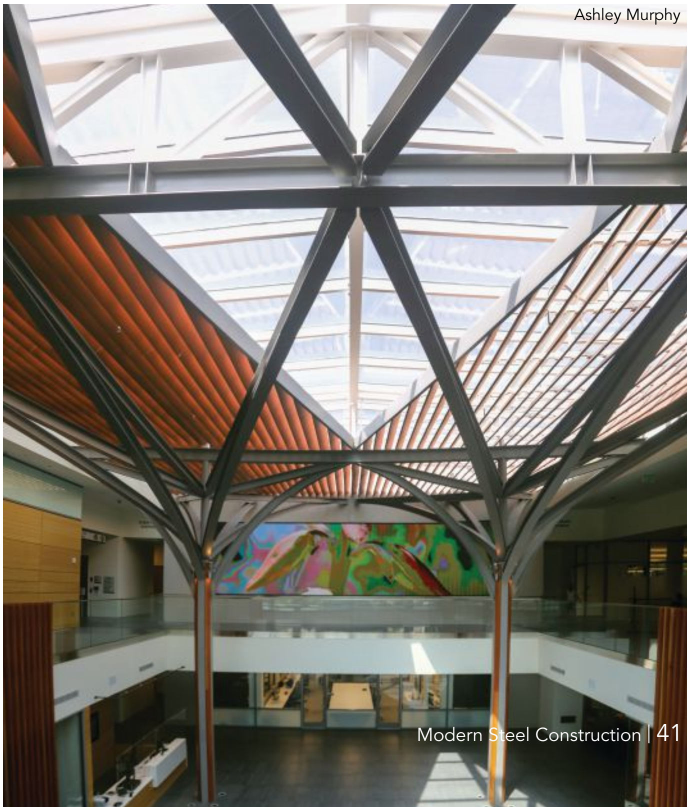
The structural design of the tree columns focused on the steel's ability to maintain its shape through shipping all the way through to the final erection of the branches, with several connection points that could accommodate a range of tolerances. This focus on constructability proved invaluable as KL&A coordinated heavily with Davis Partnership and steel fabricator Zimmerman Metals to economize the design details to allow for a smooth fabrication and erection process. KL&A tested several design solutions for the elliptical tree branches for critical field adjustability and used slotted bolt connections to achieve the desired constructability. Bender-roller Albina Co., Inc., curved 20 tons of steel for the trees and branches, including 57 pieces of W8×31.

Ashley Murphy



Ashley Murphy

The structural design of the tree columns focused on the steel's ability to maintain its shape through shipping all the way through to the final erection of the branches, with several connection points that could accommodate a range of tolerances.



Ashley Murphy

Davis Partnership Architects

A rendering of the new 50,000-sq.-ft building.

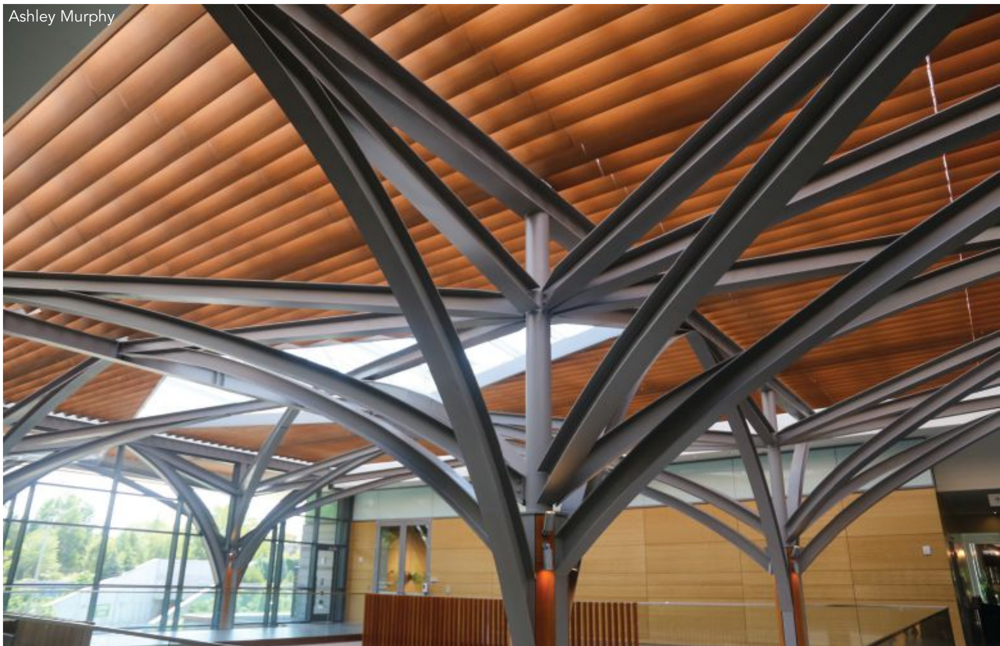
The tree columns in the front façade are unique compared to the interior tree columns in that they not only support the atrium roof but also accommodate a thermal break and provide wind load bracing to the curtain wall that infills the branches. The thermal break was necessary to prevent condensation and improve the efficiency of the HVAC system. The tree columns and branches in the plane of the glass curtain wall were built up using a combination of hollow structural sections (HSS), channels, and WT shapes with an air gap in between for insulation. The solutions to this complex design criteria are invisible to the naked eye and are hidden within the width of the storefront mullions where they attach to the steel tree columns and branches that act like girts.

Another unique application of structural design techniques includes the theater-style auditorium on the second floor. The composite steel structural slab was depressed and sloped towards the main stage, while the raised stage and tiered seating platforms were built using reinforced concrete on geofoam over framing. The programing below the auditorium included the research labs and the Herbarium, and KL&A coordinated with the mechanical/electrical/plumbing (MEP) consultants (using Revit) to ensure that the MEP systems supporting these climate-controlled zones were raised properly into the structural framing and ran through carefully coordinated beam penetrations—the largest of which were 19 in. by 29 in. through W30×90 beams—to allow for a usable finished ceiling height.

The biggest success for this project stemmed from the collaborative process, which helped achieve the owner's architectural vision. From the beginning, there was a lot of "whiteboard time" between the engineer, owner, architect, and general contractor to ensure that the concept could be constructable, and these teams would meet weekly to ensure that there were no tolerance issues that needed to be

The tree columns at the front façade are unique compared to the interior tree columns in that they not only support the atrium roof but also accommodate a thermal break and provide wind load bracing to the curtain wall that infills the branches.

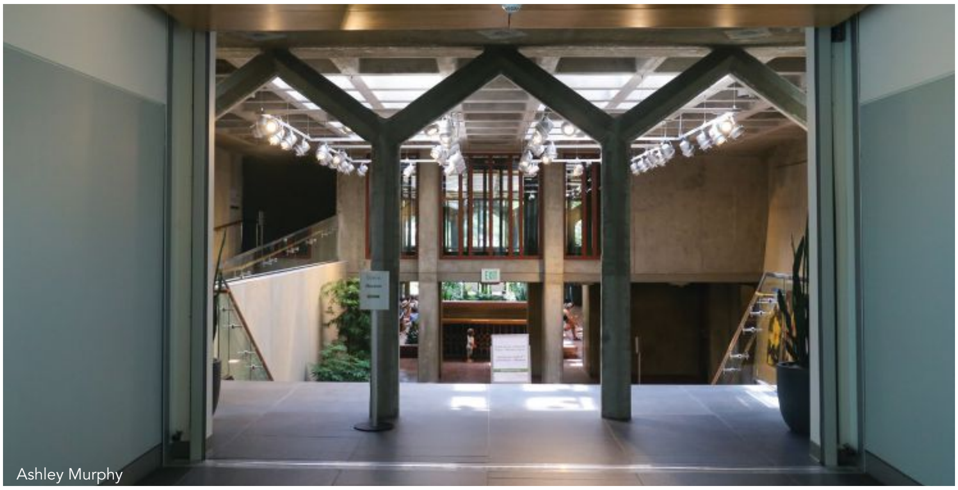
Ashley Murphy



Ashley Murphy

The project incorporated approximately 400 tons of structural steel.

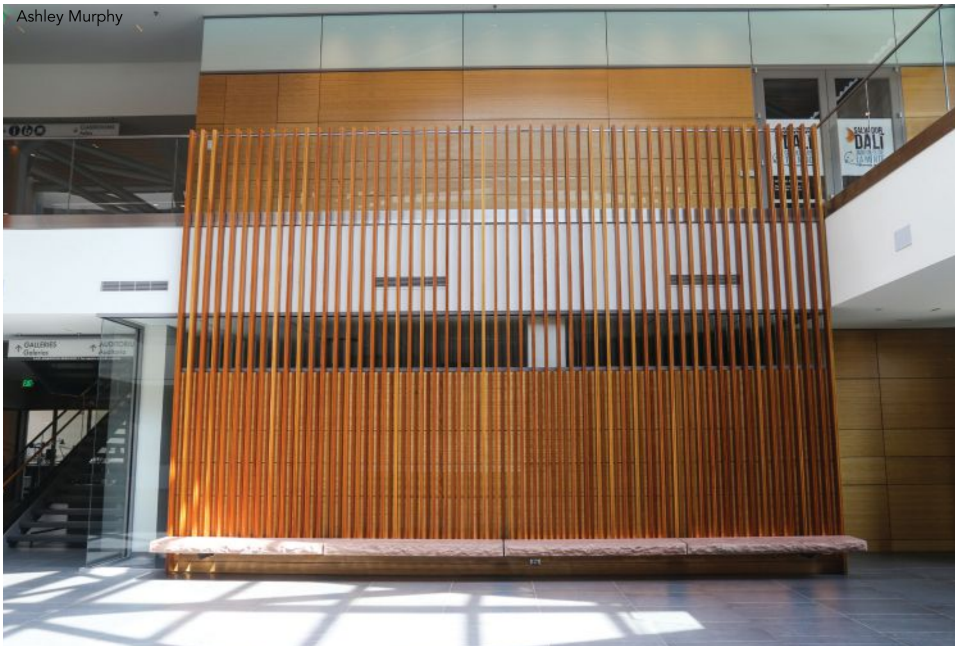
Ashley Murphy



Ashley Murphy

above: A new pedestrian bridge connects the Freyer-Newman Center with the existing Boettcher Memorial Center.

below: Decorative wood elements complement the steel "trees" as part of the project's biophilic design approach.



Ashley Murphy

Bender-roller Albina Co., Inc., curved 20 tons of steel for the trees and branches, including 57 pieces of W8×31.

solved in the field. The result is a beautiful new bloom on a botanic facility whose 70-plus-year story will continue to blossom into the future. ■

Owner
Denver Botanic Gardens

General Contractor
GH Phipps, Greenwood Village, Colo.

Architect
Davis Partnership Architects

Structural Engineer
KL&A, Engineers & Builders, Golden, Colo.

Steel Team

Fabricator
Zimmerman Metals (AISC Certified Fabricator), Denver

Erector
SNS Iron Works, Inc. (AISC Associate, AISC Certified Erector), Frederick, Colo.

Detailer
Tectonix Steel, Inc. (AISC Detailer), Mesa, Ariz.

Bender-Roller
Albina Co., Inc. (AISC Associate), Tualatin, Ore.

John Jucha (jjucha@klaa.com) is an associate and project manager with KL&A, and **Julie Wanzer** is with Business Rewritten.

A ship-in-a-bottle structural renovation demonstrates how industrial facilities can be successfully modified for new use.

Super-Trusses to the Rescue!

BY SCOTT A. COLLINS, SE, PE

Collins Structural

TALK ABOUT A QUICK CHANGE!

The new owner of an industrial facility in Greenville, N.C., needed to adapt the building—formerly used for pharmaceutical manufacturing and now serving as a filming space for YouTube videos—in just 13 weeks.

To meet the needs of its new role, the building required a large, high-ceilinged, open space that would allow for maximum flexibility and minimal obstruction. The renovation required removing 15 interior columns and replacing them with eight super-trusses up to 206 ft long bearing on enlarged footings and columns along the perimeter. The final plan created 39,400 sq. ft of clear space with a 29-ft-high acoustic ceiling grid. Given the need for high ceilings and the large depth of these trusses (6.5 ft)—as well as the industrial nature of the building—the trusses were left exposed.

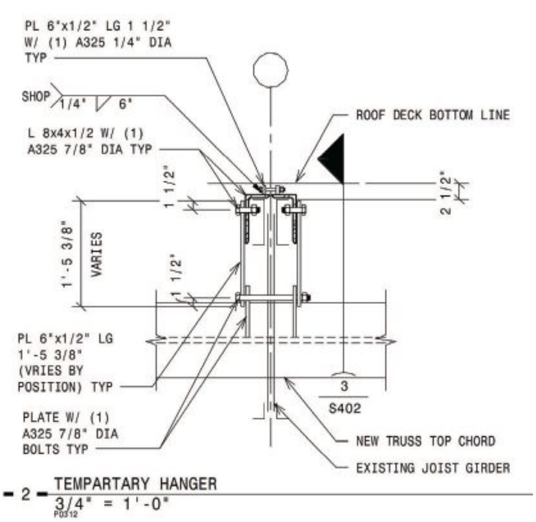
Due to the time constraints, the renovation had to be accomplished without major deconstruction, and every step from design to installation had to consider the timing of construction, the phasing of material arrival, and the order and processes of installation. Additional coordination was required between structural engineer Collins Structural Consulting and steel fabricator North State Steel to ensure continuous support of the existing structure throughout every stage of the installation. Given the required clear spans, as well as the fact that the existing framing was made of steel elements, structural steel was the only viable option for the project—which used 340 tons of steel in all.

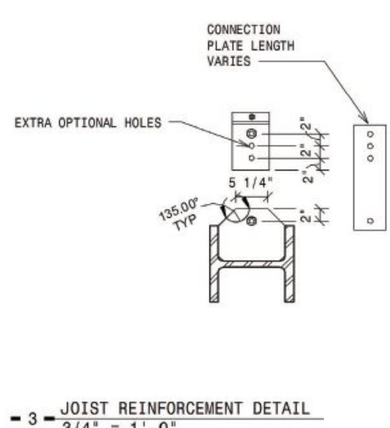
Collins Structural

opposite page: The building prior to the addition of the new roof trusses.

above: Putting a new truss in place.

below: A detail of a temporary hanging bracket.





Collins Structural

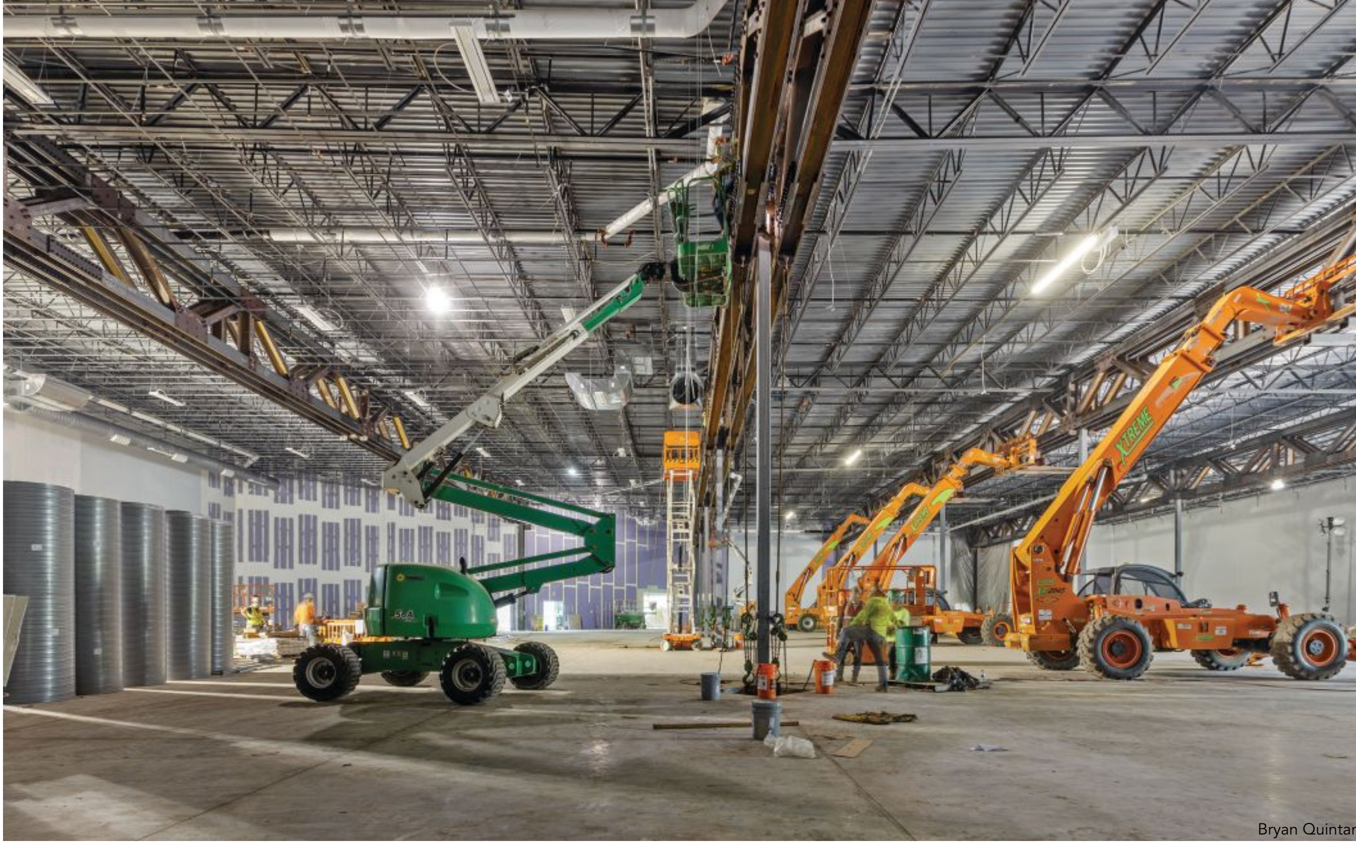
Staying on Course

The project's timing affected one of steel's inherent advantages: ready availability. Construction took place during the spring of 2021, a period when pandemic shutdowns created material shortages and pricing fluctuation, which in turn led to an iterative process with multiple rounds of design. The original design incorporated steel that was readily available to North State Steel at the time. Unfortunately, due to high demand and pandemic-related availability issues, some member sizes were no longer available just a few weeks later. Luckily, steel's flexibility came to the rescue, and the team worked together to revise the design and replace the "missing" shapes with ones that were available while still using as much of the purchased steel as possible. Each iteration of this process required Collins, North State Steel, and the steel detailer (Cistron Technologies) to work in close collaboration to keep the process moving forward while staying on schedule.

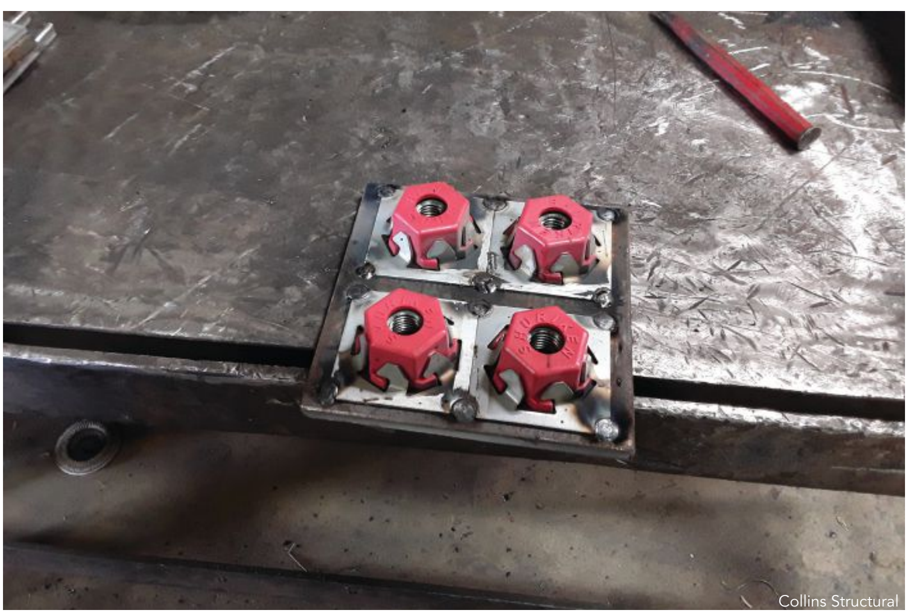
In order to reduce time downstream in the construction process, the team designed identical connections wherever possible to allow for automated fabrication and chose bolted connections to increase the installation speed. The bolt holes were generated using automated, high-throughput drill lines (specifically, Peddinghaus PCD-1100), reducing production time and avoiding potential manual manufacturing errors. Additionally, North State Steel ran its machinery around the clock to meet the schedule, such that beams were drilled and plates were fabricated simultaneously. The fabrication was also carefully sequenced by truss to allow installation of some trusses to begin while steel was still in the fabrication process. Proper phasing also addressed the lack of storage at the project site.

Super-Trusses

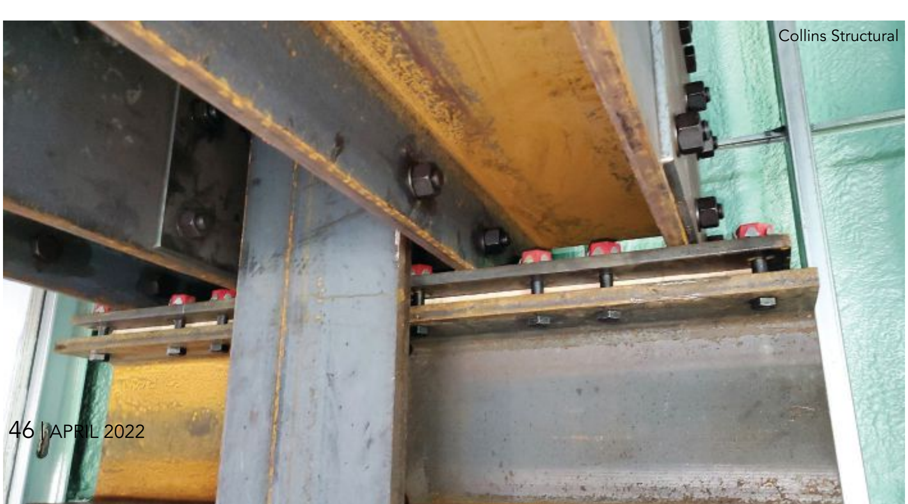
The trusses ranged in length from 164 ft to 206 ft and were 6.5 ft tall, making it tricky to install them in an existing building. As it wasn't possible to bring a fully assembled truss into the building or lift an entire truss using a crane, only one truss' worth of materials was transported to the site at a time, and the pieces were brought into the building shell through an existing garage door. These pieces were assembled into 40-ft- to 50-ft-long sections using bolted connections, with each section being small enough to be lifted with


Bryan Quintard

A pair of super-trusses was used for each column line, with the identical trusses being placed flush with a row of columns to be removed—one on each side.


Collins Structural

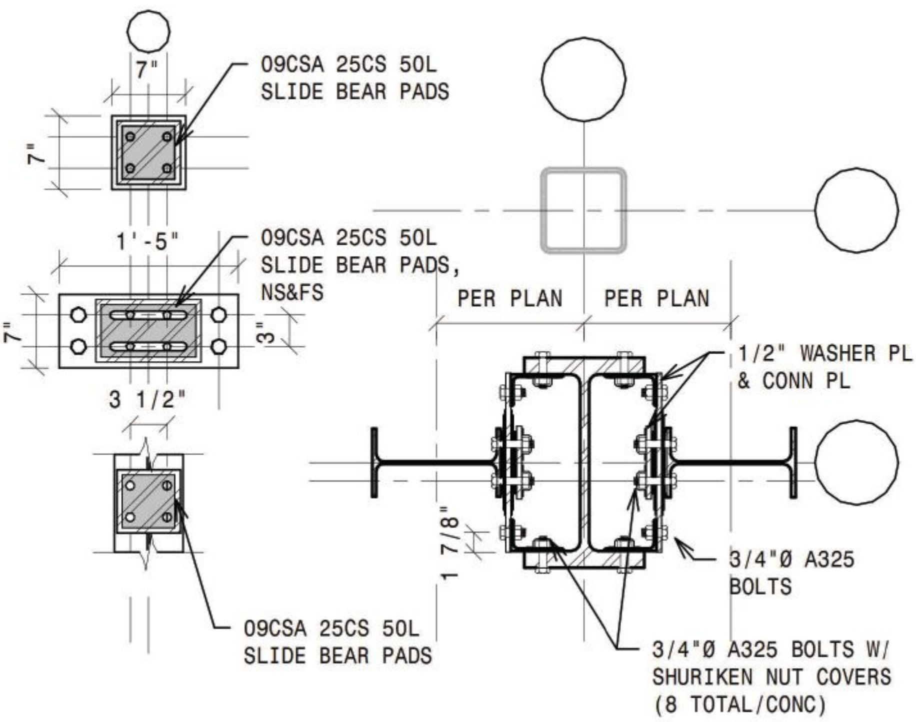
above and below: The design team took advantage of Atlas Tube's Shuriken system, which allowed bolted connections at any location where a connection plate using the system could be slid into place (see **atlastube.com/products/shuriken** for more on the product).


Collins Structural

forklifts and suspended from the existing bar joist girders using temporary brackets that were specifically designed to allow enough movement for alignment of the connections with other segments and also to allow eventual disconnection from the roof by the removal of a pin. The height of suspension was carefully determined using construction simulations that allowed the needed camber to be introduced during the in-air assembly. Once the sections were bolted together, assembly was complete, with the truss supported by the roof and therefore not taking additional loading. This left the floor below clear to assemble the next super-truss.

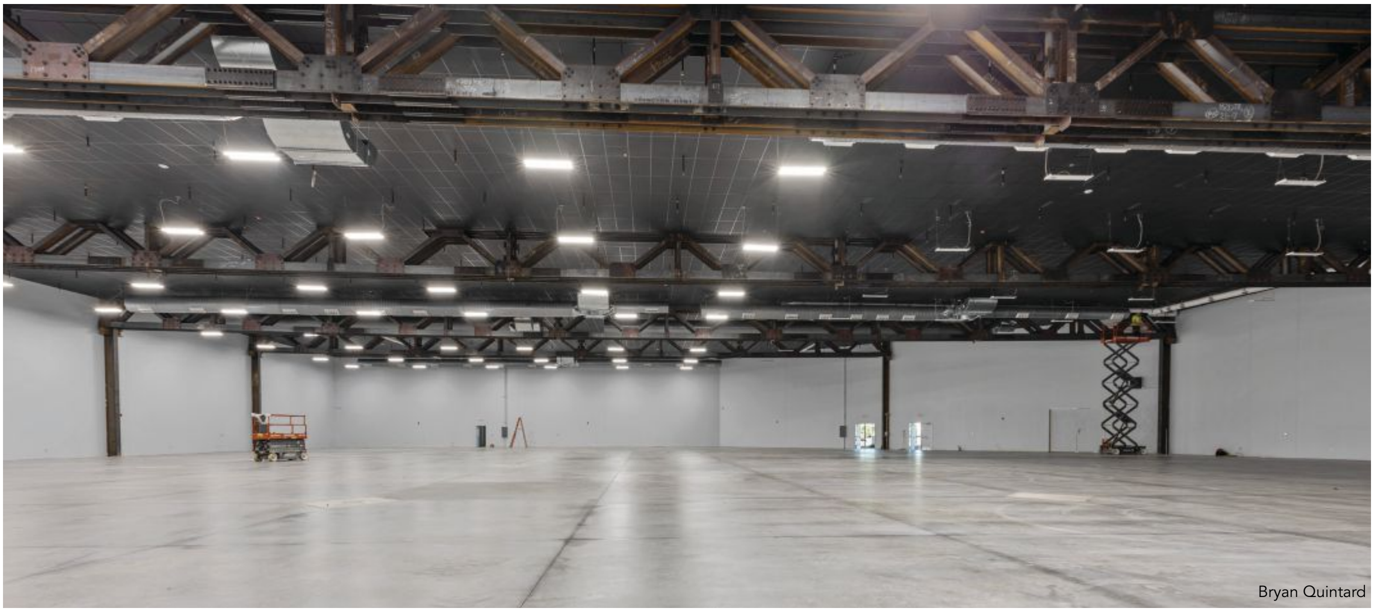
The next step was to release the hanging super-truss from the roof support and allow it to bear on the new large perimeter columns. To accomplish this, forklifts provided temporary support for the trusses, which prevented sudden displacement as the pins were removed from the brackets. As the forklifts were lowered, the super-truss settled onto the perimeter columns and deflected under its own weight, partially removing the initial camber.

The super-trusses could not be placed exactly in line with the existing columns, as the columns had to remain in place to support the roof during the super-truss installation. But situating them to one side of the existing column lines would have resulted in uneven loading and a torsional force. Therefore, a pair of super-trusses was used for each column line, with the identical trusses being placed flush with a row of columns to be removed—one on each side. The design called for the paired trusses to be connected to the sides of the columns to create the load path for the roof loads to be supported by the trusses. However, if this were to be done prior to loading the trusses, the subsequent addition of the roof loads would have deflected the trusses, resulting in a sagging roof. Therefore, prior to bolting the super-trusses to the columns, chain hoists were used to connect each truss pair to the bottom of each unwanted column. The column's foundation bolts were loosened to provide room for the columns to lift without lateral displacement. The chain hoists were gradually tightened, which initially created a downward force to pull the camber out of the trusses. Once the force required to further deflect the trusses exceeded the forces generated on the column by the roof's weight, the trusses

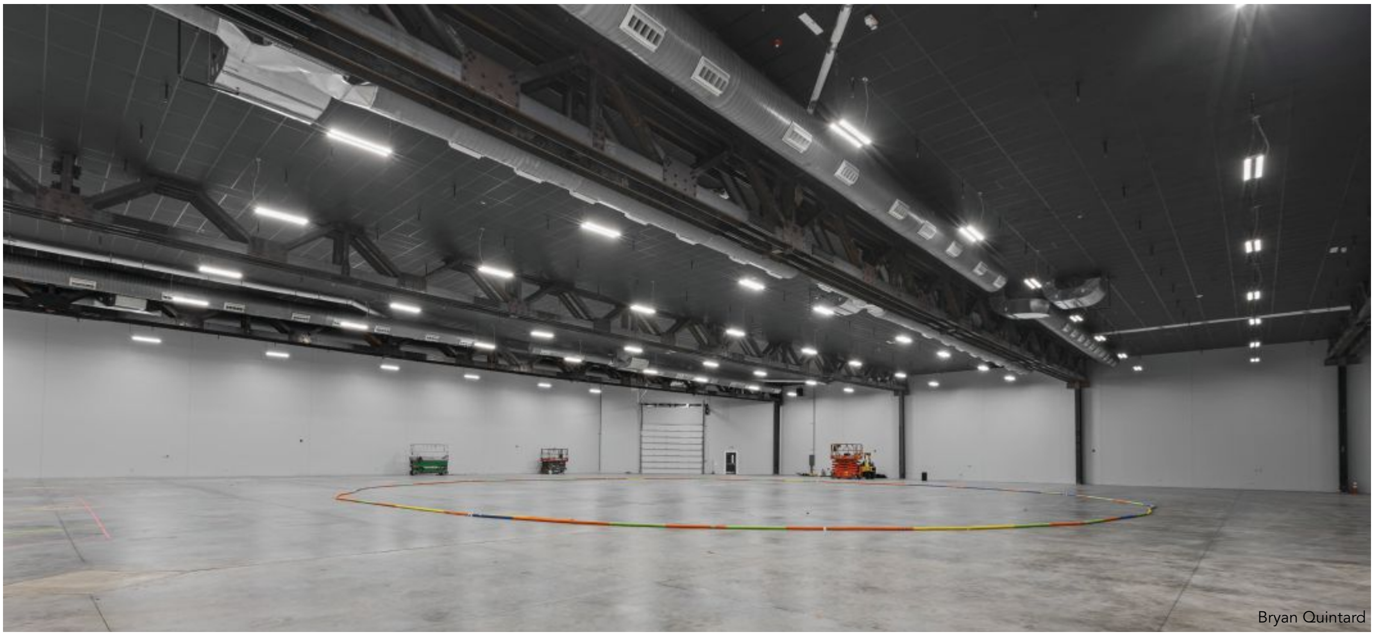


Collins Structural

A detail of the Shuriken units and slide pads.


Bryan Quintard

The trusses ranged in length from 164 ft to 206 ft and were 6.5 ft tall, making it tricky to install them in an existing building, and only one truss' worth of steel was transported to the site at a time.


Bryan Quintard

ceased further deflection, and the column began to lift slightly. This shifted the roof loads to the trusses. Angles were then welded to the existing columns based on the height of the loaded trusses, allowing them to be bolted to the side of the columns at the proper location. The lower portion of the column could then be removed without shifting or deflection of the roof structure.

Sliding Connections

The large deflections resulting from the long unsupported spans of the super-trusses also affected the end-bearing connections of the trusses. Typical welded connections would have introduced moments into the supporting perimeter columns. However, increased moments would in turn require a significant increase in the perimeter column sizes, thus reducing the open interior space. The team turned to Neoprene and CON-SLIDE bearing pads (CON-SERV) to allow for sliding action at the top of the truss and both rotation and sliding action at the bottom of the truss.

While these sliding joints require bolted connections, the proximity of the existing roof and wall to these connections did not allow for typical bolted connections in all locations, as one side of the connection was often obstructed. To resolve this issue, the design incorporated Atlas Tube's Shuriken system (which was used in other locations as well). The product, a disposable wrench that holds a nut in place, was originally created to be used inside the connection between two hollow structural sections (HSS). In this scenario, the product is tack welded to a steel plate in a four-by-four format that prevents the nuts inside the HSS from turning. This allows the bolts to be tightened only from the outside, as the interior of the HSS is completely inaccessible after the connection is made, with the wrench being left in place. This project used this concept in a slightly different way, with the wrenches being tack welded to connection plates, allowing bolted connections to be used anywhere that a connection plate using Shuriken could be slid into place.

Bryan Quintard

The building underwent a ship-in-a bottle transformation to meet the needs of its new client.

Thanks to some strategic structural surgery, the facility has been successfully modified for new use. And thanks to the paired super-truss scheme, it has emerged from its renovation stronger than ever and with plenty of uninterrupted space. ■

Owner
MrBeast

Developer/Construction Management
The Overton Group, LLC, Greenville, N.C.

General Contractor
Berry Building Group, Inc., Greenville

Architect
MHA Works, PA, Greenville

Structural Engineer
Collins Structural Consulting, PLLC, Creedmoor, N.C.

Steel Team

Fabricator
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Detailer
Cistron Technologies, Inc. (AISC Detailer), Mooresville, N.C.

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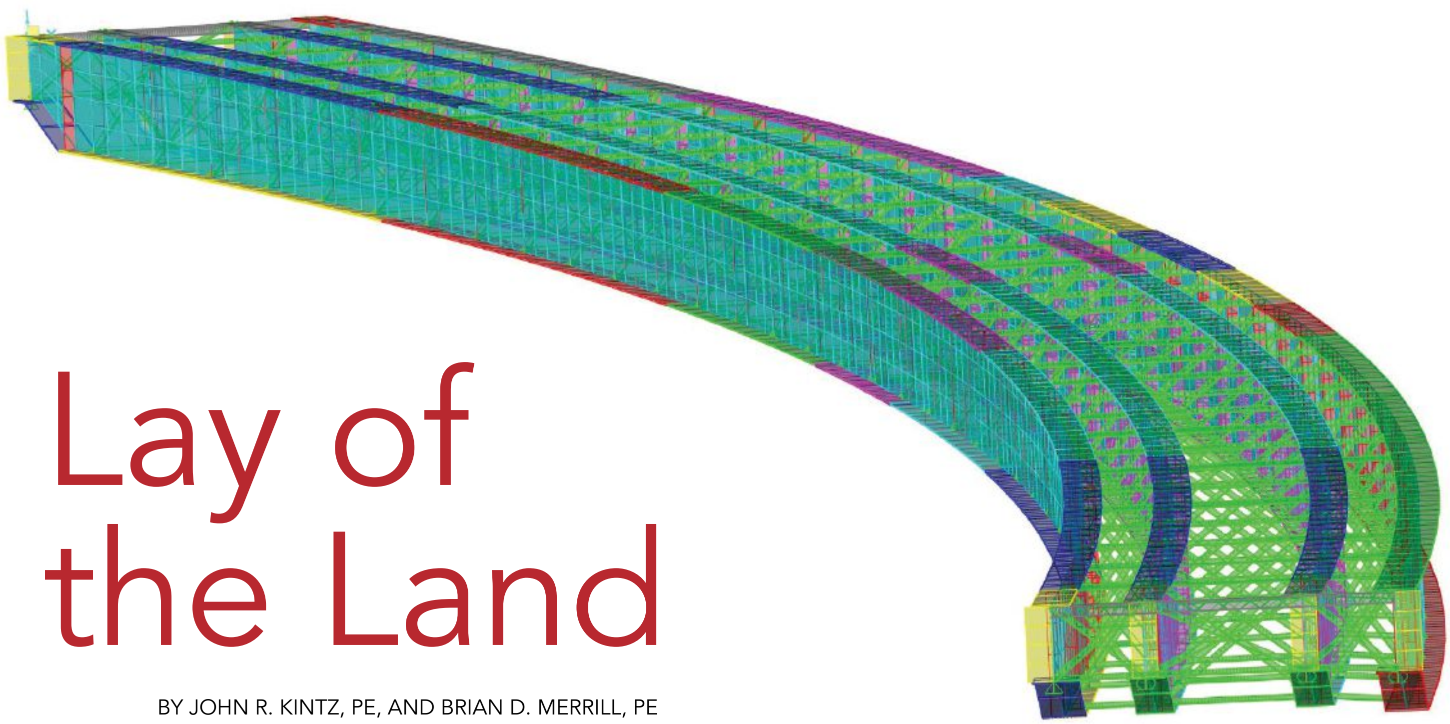
Recognizing and accommodating field constraints in bridge design.



Lay of the Land

BY JOHN R. KINTZ, PE, AND BRIAN D. MERRILL, PE

MODERN CODES and more advanced analysis tools have helped designers confidently create longer, more slender, and more complex steel bridge structures.

When developing a signature bridge or a bridge located in a high-visibility area, this often means longer spans, unique geometries, and an increased consideration of aesthetics. These bridge designs are often analyzed in the completed condition using commercial finite element software, supplementing model results with design code provisions to verify the adequacy of the structure and its components. However, understanding the proper application of these resources and anticipating the construction methods employed is a crucial part often overlooked in design.

For steel bridges, particularly plate girder bridges, the most critical structural demands encountered during the design life often occur during erection and deck placement. During this time, the girders do not act compositely with the concrete deck and, depending on construction staging, may not have all bracing installed or full girder line continuity at a given time. The AASHTO *Bridge Design Specifications* and state DOT bridge design manuals dictate that designers select girder geometries to satisfy constructability criteria and run a deck placement analysis on the completed system. Except on exceedingly complex bridges, little consideration is given to erection staging, as this is typically the responsibility of the erector and erection engineer. Regardless, adhering strictly to the design criteria may not mitigate all constructability concerns, and designers must be mindful of site constraints that may require deviation from the assumptions made in their analysis. Conversely, common situations encountered by steel erectors may require analysis methods beyond simplified models. The following case study illustrates a scenario where existing site constraints created a condition different from that assumed in the design and led to significant challenges during construction.

Project Background

The example bridge is a horizontally curved, four-plate-girder direct connector with a roughly 1,600-ft radius of curvature. The steel unit is two-span continuous over radial supports, with centerline span lengths of 312 ft (Span 3) and 294 ft (Span 4) for a total length of 606 ft. The inner three girders along the curve have a constant web depth of 9 ft, 5 in., while the exterior girder has a web depth of 10 ft. The interior bent has a post-tensioned concrete bent cap on a radial alignment that is cast integrally with the plate girders, and the column is positioned between two existing bridges carrying mainline highway traffic in each direction below. The minimum design vertical under-clearance is 16 ft, 9 in., and the mainline bridges below are skewed 67° relative to the interior bent cap.

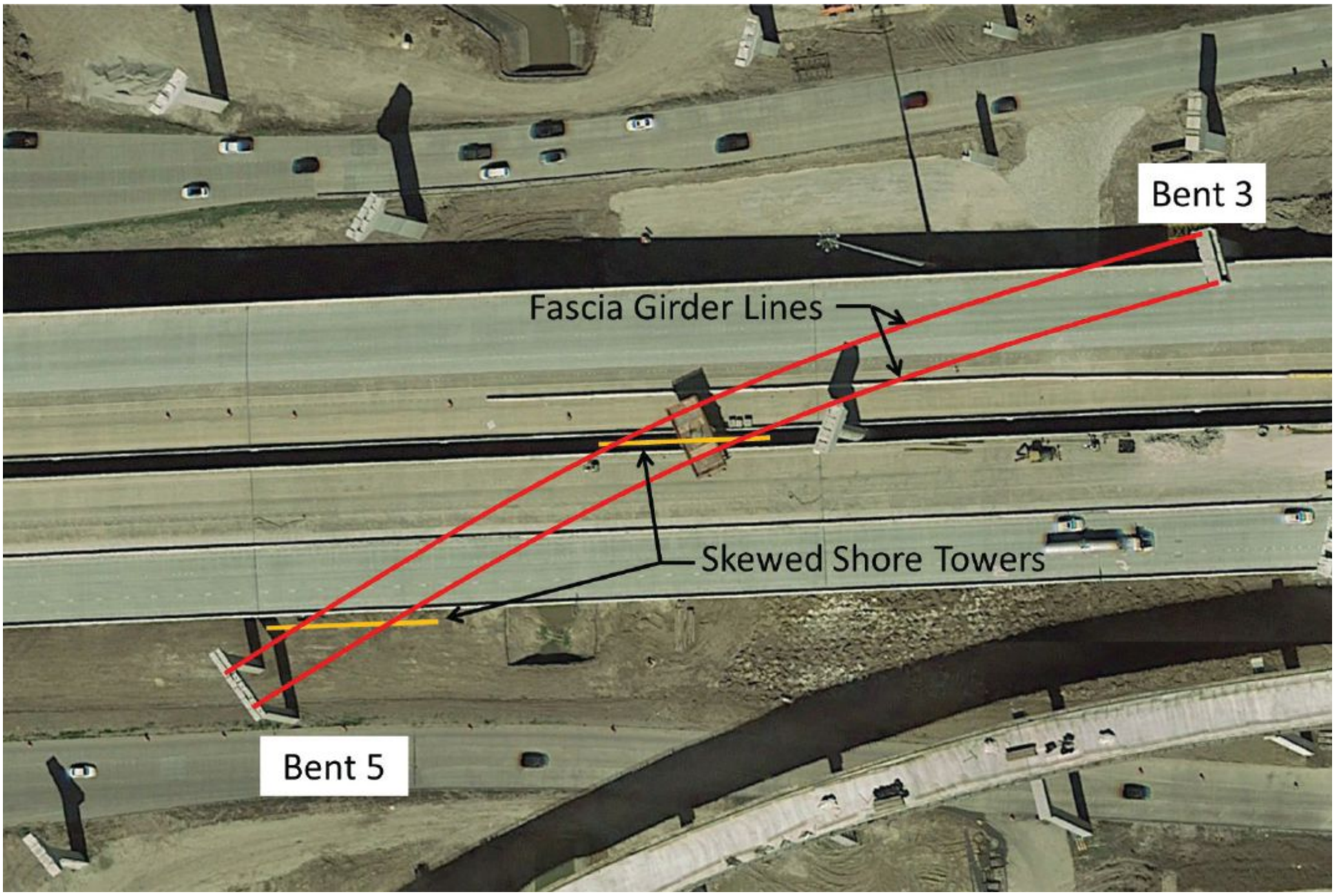
opposite page: A 3D model of the horizontally curved, four-plate-girder direct connector (with a roughly 1,600-ft radius of curvature).

below: Installing a plate girder. The inner three girders along the curve have a constant web depth of 9 ft, 5 in., while the exterior girder has a web depth of 10 ft.

Design vs. Field Conditions

Prior to construction, several key differences between the bridge configuration in the design and the temporary condition before casting the integral bent and bridge deck needed to be considered. The partially erected superstructure provided different bracing, girder line continuity, and global stability behavior than the fully erected system assumed in the design. Temporary shoring was needed for the girders at the interior bent location until the integral cap could be cast and post-tensioned. This shoring was installed at a heavy skew (67°) due to the underlying parallel highway bridges beneath either span. The temporary shoring supports also did not provide the same rotational restraint assumed from the integral bent in the design.

The differences between design and construction resulted in the construction sequence becoming the critical analysis stage for bridge behavior. Per NCHRP Report 725: *Guidelines for Analysis Methods and Construction Engineering of Curved and Skewed Steel Girder Bridges*, the bridge with the severe skew at the temporary interior support, in contrast to the assumed radial support in design, required a more advanced 3D analysis to reasonably predict behavior such as vertical displacements, cross-frame forces, flange lateral bending stresses, and girder layover at the bearings. Traditional analysis methods, such as 1D line, 2D grid, or other simplified analyses, were poor predictors of these items with greater than 30% mean error from actual behavior per the NCHRP report.



A plan schematic of the project, indicating the bridge's path as well as the skewed shoring towers.

Refining the Analysis

Structural engineer Wiss, Janney, Elstner Associates (WJE) developed a 3D finite element model using SAP2000 to analyze critical stages of the proposed construction sequence and examine the behavior of the partially and fully erected superstructure. Analyses showed that the girder deflections in the fully erected system exceeded those assumed in the design. As a result, the limited design underclearance to the highway below was a concern for the owner and engineer of record. Perhaps even more critical was that the model exhibited large vertical deflections (greater than 3 ft) and restraining forces at the end bent for the partially erected superstructure, with all four girders simply supported over the interior shore tower. In addition, cross frames and associated erection bolt connections were also overstressed in this configuration. These findings indicated a stability concern, and it was unlikely that the bridge could be erected in sequence from one end to the other.

In the end, an innovative approach was required to erect the bridge safely and keep girder deflections within acceptable tolerance while accommodating strict limits on lane closures and temporary supports. This involved the partial erection of the superstructure, constructing the integral cap before erecting the remaining girder segments.

The lesson is clear: Getting a good read on existing site conditions, even before a contractor has bid on the project, can help engineers, contractors, and owners alike construct complex bridges safely and smoothly. ■

*This article was excerpted from the 2022 NASCC: The Steel Conference session "Erection Engineering for Steel Bridges." A recording of the presentation will be posted at **aisc.org/educationarchives** in early May.*

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Solving Skew

BY MUNA MITCHELL, PE, AKSHAY PARCHURE, PE, AND KRISHNA SINGARAJU

Continuous plate steel girders address skew challenges on two new I-35 bridges over a railroad track in Laredo, Texas.

RODS Surveying, Inc.

LAREDO, TEXAS, is the busiest inland port along the U.S.-Mexico border and one of the busiest overall U.S. ports, with large trucks and other vehicular traffic straining the I-35 corridor that runs from the Mexican border north through the city.

At I-35 near Shiloh, the highway crosses underneath a Union Pacific Railroad (UPRR) bridge with substandard vertical and horizontal clearances that pose safety risks and limit expansion of the roadway. To address the situation, UPRR collaborated with the Texas Department of Transportation (TxDOT) to upgrade this section of I-35 by providing additional traffic lanes and decommissioning the existing railroad bridge, which was built in 1960. The solution involved replacing the at-grade traffic lanes with two bridges that clear the railroad right-of-way (ROW) vertically and horizontally while also widening I-35. The grading in the railroad ROW would be altered to result in the tracks being at grade instead of elevated.

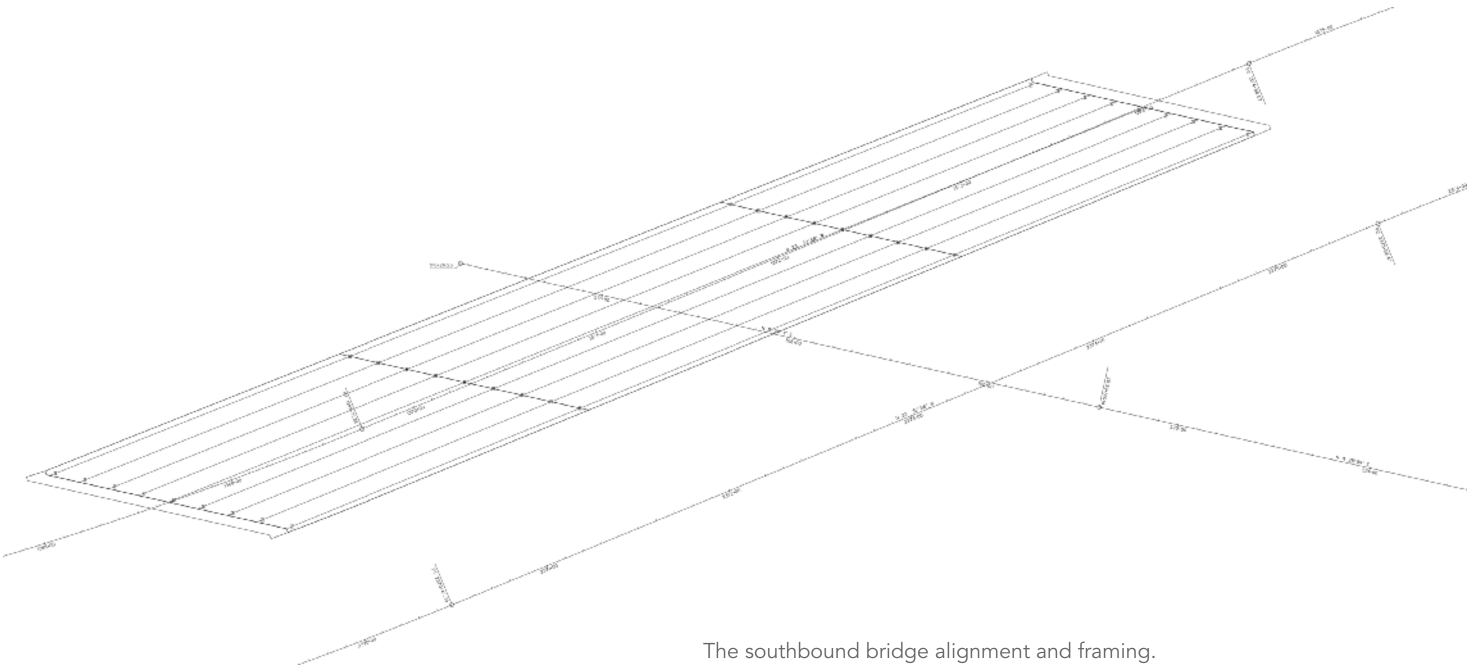
Geometric Constraints

The two new 1,700-ft-long side-by-side bridges carry four lanes of traffic in each direction, with the northbound bridge consisting of 14 spans and the southbound consisting of 15. The approach spans are concrete, and the main spans across the railroad ROW are steel. Each bridge includes a 534-ft-long three-span continuous steel plate unit to address the crossing's significant skew and dimensions, with the span lengths of each unit being 165 ft, 205 ft, and 164 ft. Steel was preferred over concrete for the long spans initially to keep the profile as shallow as possible over the railroad tracks since the vertical roadway curve was constrained by access requirements on either side of the railroad ROW.

The bent lines are oriented parallel to the railroad ROW at a skew of approximately 56° from the roadway alignment. The skews vary gradually along the approach bents by 15° or less to achieve zero skews at the abutments, and the 56° skew is maintained for all four bents in the continuous steel unit on each bridge. The steel units are designed as continuous to optimize the depth of the superstructure at the railroad ROW to meet the vertical clearance requirements while also accommodating the limits of the roadway's vertical curve.

The roadway cross section consists of four 12-ft traffic lanes in a single direction with 10-ft shoulders on both sides. The overall concrete deck is 70-ft-wide in the approach concrete units and varies up to a maximum of 74 ft, 8 in. on the steel unit. This variable width accounts for the roadway curvature while maintaining a straight steel unit to avoid using curved girders. The superstructure consists of nine plate girders with 5-ft, 6-in.-deep webs connected with cross frames at bent lines and intermediate locations along the length of each steel unit. Also, note that since the roadway curve reverses going northbound and southbound, the two parallel bridges are not completely

The existing railroad bridge across I-35 in Laredo, Texas.



The southbound bridge alignment and framing.

identical in terms of girder framing, and all subsequent discussion will focus on the southbound steel section.

Analysis and Design

The girder spacing was analyzed using an initial two-dimensional (2D) grillage analysis with MDX Software with the vertical clearance requirement setting the maximum depth of the structure. Spacing was limited to a maximum of 8 ft to avoid the need for deeper girders, and cross frames were staggered based on AASHTO LRFD and NCHRP guidelines for highly skewed steel bridges. The first and last row of cross frames were kept at a minimum distance of at least 8 ft from the skewed bent line, while the remaining cross frames were equally spaced. Due to the girder geometry, the cross-frame geometry at each location is unique, and cross frames were also provided along all four skewed bents at the bearing lines. To meet the slab overhang limits required by the AASHTO LRFD and TxDOT bridge design manuals, a unique girder spacing was provided in each bay along each bent, making the steel girders not parallel.

The initial 2D model allowed for rapid set up of the girder framing and iterations of plate sizes and girder depth; however, the final design required a more refined model. Based on NCHRP and NSBA guidelines, the cross-frame forces and dead load deflections estimated from a simple 2D grid/2D plate and eccentric beam analysis are not precise enough for a high-skew plate girder bridge. Also, a refined analysis can generate a more accurate output to calculate girder camber values for fabrication. Further, a 2D model is limited in taking the substructure stiffness into account for determining joint movements and thermal forces. As such, the team performed a three-dimensional (3D) finite element analysis (FEA) using Midas Civil software. The bents, columns, and foundations to a structural point of fixity, along with steel girder and diaphragm elements, were included in the 3D model to take substructure movements into account when determining the loading on the bearings.

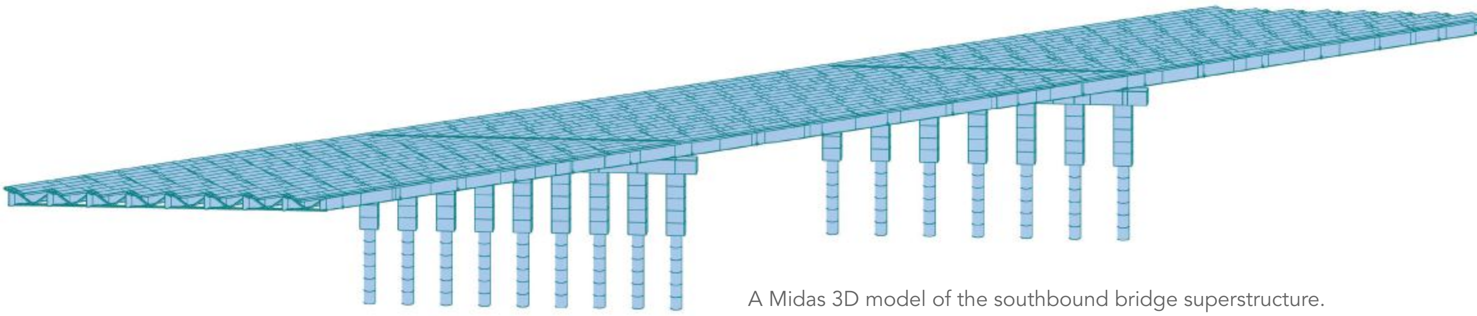
The flange plate changes and bolted splice locations were determined using the analysis results, and the Midas model was used to run multiple iterations and optimize the girder design with design limits for flange and web plates. No longitudinal stiffeners were used, and the only transverse stiffeners needed were to connect the cross-frame members. Since the steel girders were framing at an extreme skew, split pipe connecting plates were used at all bearing locations; these elements also acted as bearing stiffeners.

Initially, three rows of shear studs were proposed to provide composite action between the steel girder and the concrete deck, per the TxDOT standard. However, the number of rows was reduced to two, and shear stud spacing was subsequently adjusted to avoid conflicts around the modular joint and other reinforcing.

Superstructure-Substructure Interaction

The overall width of the bridge is 70 ft. However, due to the variations in skew, the length of the bents varies from 130 ft to 146 ft. In the preliminary design, multi-column rectangular bents were considered at all bents. Inverted T bent caps with joints on either side of the stem were later implemented at transition bents, and rectangular bent caps were used at the concrete units and for interior bents on steel units. With an inverted T bent, a joint could be used on either side of the stem, reducing the total movement in a single joint. The inverted T bent also allowed the use of a modular bridge expansion joint (MBJS) that requires the support of the stem for the joint system.

The decision to use inverted T bents evolved during the design process as the full impact of the geometry and movements were realized. The change from rectangular to inverted T bents was made late and required changes to preliminary bent designs. To avoid redesigning the steel girders, the locations of the end bents were shifted to maintain the bearing lines at the ends of the steel units. This decision prevented changes to the girder designs but caused changes to the bridge layouts because the centerlines of bents, columns, and foundations were shifted outward from the right-of-way lines, requiring coordination with other disciplines and verification of horizontal clearances from U-turn lanes on either side of the railroad ROW.



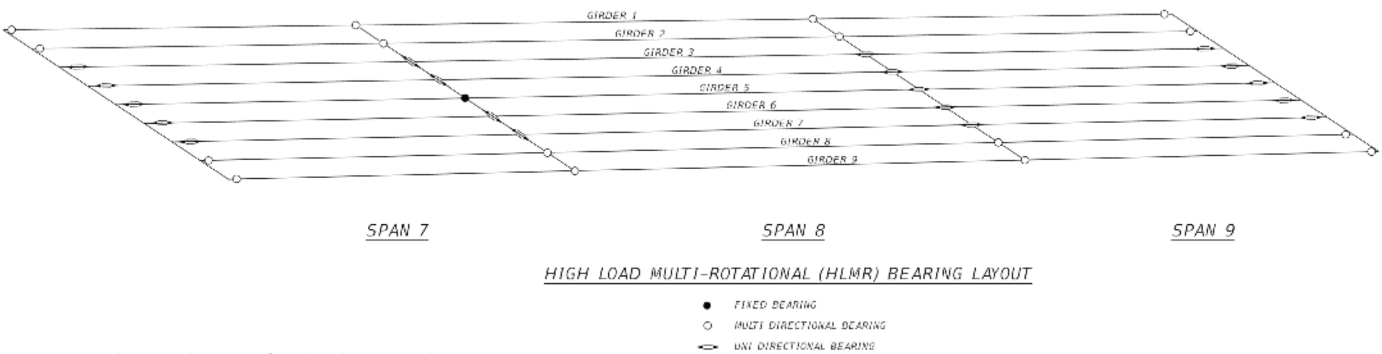
A Midas 3D model of the southbound bridge superstructure.

The designs for the substructure and bearing configuration were driven by the effects of transverse forces due to thermal loads and live loads. The preliminary FEA models did not have the substructure modeled, which resulted in improper boundary conditions and inaccurate thermal forces. To accurately capture the effect of transverse forces, it was necessary to model the substructure and assign appropriate translational and rotational properties to the bearings.

Several FEA models were developed to study the various bearing and bent configurations before determining the final configuration. In the initial study, bearings at both the interior bents were fixed against translation in all directions to limit the demand on the expansion joints. However, this approach resulted in significant forces on the bearings, so it was decided to use fixed bearings at only one interior bent. Bearings at the other interior bent are fixed in the direction transverse to the girders.

Skewed steel bridges expand and contract along the diagonal connecting the acute corners of the slab under thermal loads and not along the alignment parallel to the girders. This behavior results in twisting in the deck, so the thermal forces are not distributed equally to all the bearings. The thermal forces in the bearings increase from the center outwards, resulting in significantly high forces in the outside bearings. Instead of designing for these high forces, the team decided to use free bearings at the outside two girders on both sides of the bridge centerline, resulting in five fixed interior bearings.

The team decided on a single bent cap approach instead of separating each bent into multiple frames as the single frame would help balance the out-of-plane forces in the cap without transferring them to the substructure. Even with five fixed bearings, the transverse forces were significant on the bearings, which complicated the design of the bent cap as these elements need to



A bearing layout diagram for the three steel spans.

be designed for out-of-plane forces and torsion in addition to in-plane forces. To reduce the in-plane bending, columns were provided at each girder.

Bearing Fixity

During the letting stage, the bearing manufacturer determined that the transverse forces in the bearings were still significantly high and, as such, it would be difficult to manufacture the bearings. It was determined that instead of using bearings that resist translation in all directions, they could be fixed in only the longitudinal direction, thereby reducing the transverse forces. The orientation of the bearings also influenced the transverse forces developed in the bearings. In addition, fixing the bearings along the skew and normal to the bent instead of fixing them normal to the girders would further reduce the forces in the bearings.

To achieve constructable bearing loading, the team decided to further reduce the fully fixed bearings. Since the center bearing does not see high transverse forces, it was fully fixed in all directions, and the two bearings on either side of the center were fixed in the direction normal to the bent but free to move in the direction along the bent, with the outer two bearings on both sides free to move. This option reduced forces on the bearings significantly and was within the force range determined by the bearing manufacturer. The girders were evaluated for any changes based on the bearing design, and no changes in the girders were discovered.

There is an increasing need for complex medium- to long-span steel bridges that can address site restrictions in developed areas. One solution to addressing conditions like grade separations in congested areas is to use continuous steel girders on skewed supports. This method can allow the bridge superstructure to avoid at-grade obstructions, limits impacts to the foundation, and addresses vertical clearance constraints, as demonstrated by this project. ■

This article was excerpted from the 2022 NASCC: The Steel Conference session "Curves Ahead: Case Studies on Skewed and Curved Girder Bridge Design," which highlighted two plate girder bridge designs and was presented by Muna Mitchell of Walter P Moore and Meng Sun, SE, PE, PEng, of Parsons Corporation. A recording of the presentation will be posted at ***aisc.org/educationarchives*** *in early May.*

Owner
Texas Department of Transportation (TxDOT)

General Contractor
Webber

Structural Engineer
Walter P Moore

Steel Team

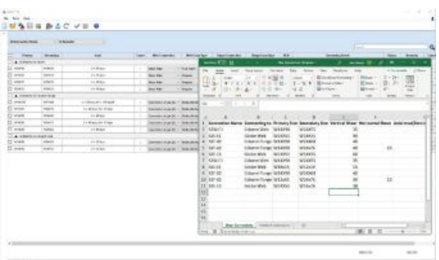
Fabricator
W&W|AFCO Steel, San Angelo, Texas (AISC Certified Fabricator)

Detailer
Precision Drafting, LLC, Bergenfield, N.J. (AISC Detailer)

Muna Mitchell is a principal and the managing director for transportation bridges and **Akshay Parchure** is a senior engineer, both with Walter P Moore. **Krishna Singaraju** is a staff structural engineer with Arcadis.

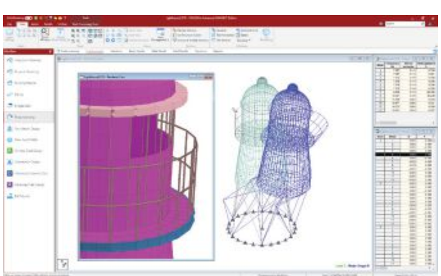
new products

This month's New Products section focuses on software packages, many of which include features that can help users achieve the goal of AISC's Need for Speed initiative: to increase the speed at which a steel project can be designed, fabricated, and erected by 50% by the end of 2025. For more on Need for Speed, see **aisc.org/needforspeed**.



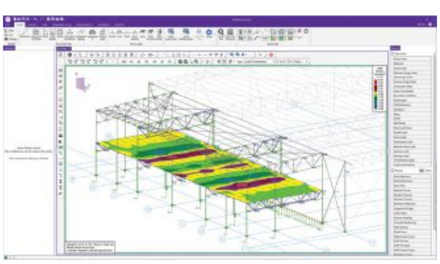
GIZA

Is faster always better? It is when you can maintain quality and accuracy! The latest release of GIZA connection design software continues to improve the speed and efficiency of the connection design process without compromising the quality and accuracy you depend on. What used to take you hours to do using other tools now takes just a few minutes with GIZA. This allows for compressed project schedules, faster collaboration, and fewer connection points during erection. With GIZA 22.0, you can import data directly from Excel spreadsheets to design connections and convert member and load information into designed connections in a matter of minutes. Even better, when using Tekla Structures in your workflow, these designed connections can be imported into your Tekla model, bringing a fabrication-ready model closer to the finish line than before. For a free trial, visit **www.gizasteel.com**.



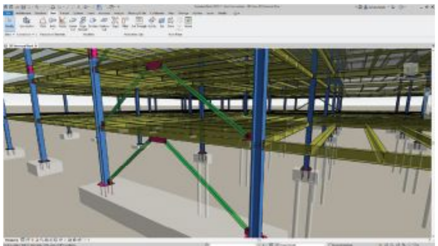
Bentley STAAD.Pro CONNECT

An important time-saver has been added to Bentley Systems' STAAD.Pro CONNECT Edition V22 Update 9. The similar concepts of load and mass as used in static and dynamic analyses often mean designers have to duplicate data to account for these related effects. That takes extra time and effort. As the static load is often defined first, the new Mass Model Generator tool enables engineers to select the appropriate loading and create a suitable reference mass case, which can then be used by a dynamic response spectrum or time history case, or even a static seismic case. To determine the dynamic response, a mass model must be defined. This may have already been defined as static loading in the vertical direction. A method to quickly create a mass model from this static data will make it possible to reach an overall solution faster, without having to manually duplicate the loads. For more information, visit **www.bentley.com**.



RISA-3D

The latest release of RISA-3D is the next step in the evolution of the completely redesigned software package. With a modern, streamlined interface that allows for customization, robust graphical modeling, result-viewing tools, expanded detailed reports, and multi-core processing. Additionally, engineers can use the complete RISA Building Suite, including RISAFloor, RISAFoundation, and RISAConnection through seamless integration between the products, allowing for efficient creation of a variety of steel buildings and structures, no matter the complexity. For more information, visit **www.risa.com**.

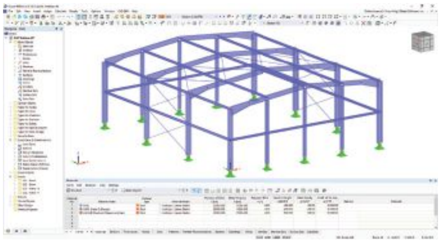


Autodesk Revit and Advance Steel

As more structural engineers use BIM to perform their coordination and documentation, there is growing demand to perform structural calculations within the same BIM environment. Autodesk has partnered with two technology partners to make that possible, enabling engineers to speed up the design of steel frames and connections. IDEA Statica steel connection design integration with Revit and Advance Steel automates the design of all connection types, both simple and complex. This removes connection design off the critical path, helping engineers speed up design model coordination, quantification, and handover. Coupled with Revit's capabilities to model steel connections, engineers can iterate on their designs more quickly. In addition, ENERCALC for Revit is a new solution for structural engineers to perform their design checks with ENERCALC's calculation libraries all within the BIM environment. This keeps their drawings completely in synch without using tedious, manual import/export or cut/paste workflows that are prone to data loss. For more information, visit **www.autodesk.com**.

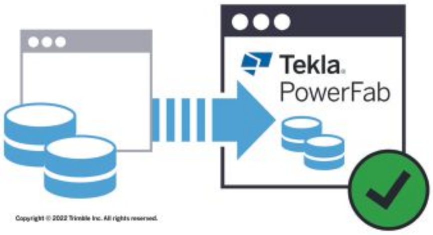
Dlubal Software RFEM 6

RFEM 6, along with the Steel Design add-on, is a powerful 3D FEA program that combines steel analysis and design into a single workflow. Design properties such as effective lengths can easily be assigned with the detection of nodes along the member length. The assigned intermediate restraints are then graphically displayed on the member for clarity, and users can take advantage of Member Representatives to quickly apply the same effective lengths conditions to multiple members at once. The RFEM steel design results include detailed output such as all factors, formulas, and references directly from the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360-16) used in the calculation. Also, seismic member design according to the AISC *Seismic Provisions for Structural Steel Buildings* (ANSC/AISC 341-16) is now available! Requirement checks include member ductility, stability bracing of beams, and slenderness ratios; design forces for the connection are also given. The detailed results provided in RFEM can be efficiently and easily followed for transparency while eliminating the guesswork for users. For more information, visit **www.dlubal.com**.



Tekla PowerFab Conversion Tool

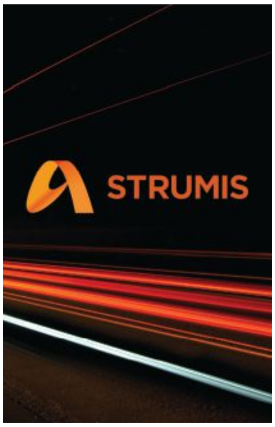
If you're interested in moving to Tekla PowerFab, Trimble's next-generation software suite for steel fabrication, you can now improve the implementation process with the PowerFab Conversion Tool. If you're concerned with preserving data from legacy fabrication software, the conversion tool will give you peace of mind by creating a human-readable backup that minimizes risk by ensuring legacy information is protected in the event of server failure or data corruption. Additionally, that information can then be used to migrate into Tekla PowerFab, accelerating the implementation process by alleviating some of the initial setup. By streamlining the onboarding process and ensuring that your historical data will be archived for future reference, the PowerFab Conversion Tool takes the stress out of changing platforms. To learn more, visit **www.choosetekla.com**.



Graitec BIM Connect

Engineers and detailers can gain speed and avoid errors by working in an ecosystem that connects, exchanges, and leverages efficient and accurate structural modeling, analysis, and detailing information from design to fabrication. With its BIM Connect technology and GTCX file format, Graitec provides a set of tools and mechanisms for fast and reliable transfer and synchronization between detailing or architectural models and the structural model (or vice versa.) For example, structural elements such as beams, columns, foundations, slabs, walls, and plates can be exported or imported to and from Graitec Advance Design, Autodesk Advance Steel, and Autodesk Revit, with associated information such as material, sections, thickness, and eccentricities. For more information, visit **www.graitec.com**.

STRUMIS



STRUMIS is proud to announce the upcoming release of STRUMIS V11, which provides increased efficiency and productivity. Enhancements include improvements to change orders/variations to contracts; new functionality to quicken the invoicing process; improved and enhanced drawing/model revision logic; the ability to automatically attach NCs and drawings when sending purchase orders; the ability to batch print drawings from almost anywhere within the package; and the ability to modify and create labor usages on the fly. The company is also releasing STRUMIS Vision, which provides time-saving and efficient browser-based access to STRUMIS! Dashboards allow users to monitor and examine business performance data at a glance from any device, including work progress, cutting plans, timesheet review, material receiving, and viewing documents and models. For more information, visit **www.strumis.com**.

BRIDGES

I-74 Bridge Over Mississippi River Now Open

After more than four years of construction, the Interstate 74 Mississippi River Bridge opened to traffic in early December, delivering four lanes in each direction and providing improved safety for all travelers. The 3,464-ft-long steel-framed bridge includes a 14-ft-wide bike and pedestrian path with a scenic overlook and connections to existing paths in Bettendorf and Moline. Indiana-based Industrial Steel Construction, Inc., an AISC certified full-member fabricator, served as the steel fabricator for the project.

The approximately $1 billion project includes twin river bridges, new interchanges, ramps, and local road reconfigurations to improve mobility and operation, delivering safer and more reliable travel for motorists, bicyclists, and pedestrians alike. The cost of the project was split between Iowa and Illinois, with the Iowa Department of Transportation serving as the lead agency during construction.

"The I-74 Mississippi River Bridge has long been a critical east-west link in the nation's transportation network," said Illinois governor J.B. Pritzker." Alongside our Iowan and federal partners, we're taking a critical piece of infrastructure that has been mainly untouched since 1960 and turning it into the centerpiece residents deserve."

"Projects like the I-74 Mississippi River Bridge are a great example of the multiplying effect federal resources can have on state and local infrastructure projects," said U.S. Senator Tammy Duckworth (D-IL). "They show the impact these federal resources can have to improve the lives of so many in our communities."

Connecting Iowa and Illinois, I-74 is an important east-west link, and the I-74 corridor serves as a primary crossing of the Mississippi River in the Quad Cities area, carrying more than 45% of total vehicular traffic across the river.

The original bridge over the river opened in 1935, with a second span finished in 1960. The bridges were made part of the I-74 corridor in the 1970s when the Iowa and Illinois departments of transportation took over co-ownership and joint maintenance. The original crossing is anticipated to be removed this year. (The I-74 Bridge is one of this year's Prize Bridge Award winners; see the related news item on the next page.)

People & Companies

Philadelphia-based structural engineering firm **Keast and Hood** has announced the transition to its third generation of ownership. At the beginning of the year, firm veterans **Denise Richards, PE**, and **John Davis, PE**, assumed full ownership of the firm, with Ms. Richards as the majority shareholder. Richards and Davis are committed to building on the legacy of quality work and client collaboration instilled in the firm by its founders. Former owners **Frederick Baumert**, **Constantine Doukakis**, and **Thomas Normile** will remain fully engaged with the firm, which was founded in 1953, to ensure a seamless transition and the transfer of institutional knowledge.

Alan Sanders, a steel industry veteran of more than three decades, has been named president of AISC member bender-roller **Max Weiss Company**. Sanders, who has served as vice president of sales and marketing since 2017, joined the company in 1989, working in numerous production roles and gaining deep hands-on experience in metal bending and fabrication processes.

Global engineering firm **Walter P Moore** opens its 23rd domestic office, in Chicago. "Our move into Chicago represents an incredible opportunity to leverage our entire platform while bringing value to our clients," said **Dilip Choudhuri**, the company's president and CEO. "Opening the office presents unique opportunities to help us maintain existing relationships and build new client connections in several of our target market sectors." **Matt Wagner** was named managing director for the firm's Diagnostics Group and will head up the new office, overseeing forensic engineering, restoration, renovation, enclosure diagnostics, and parking restoration services. Managing principal **Blair Hanuschak** serves as executive director for structures and will oversee structural engineering, façade engineering, parking services, secure design, and construction engineering.

PRIZE BRIDGE AWARDS

AISC/NSBA Names Eight Prize Bridge Award Winners

AISC and the National Steel Bridge Alliance (NSBA) recently announced the winners of the 2022 Prize Bridge Awards.

"These projects demonstrate the creativity and skill of the structural steel design and construction industry," said AISC president Charles J. Carter, SE, PE, PhD. "This is our opportunity to celebrate the achievements of these project teams."

More than 600 bridges of all sizes from all across the United States have received a Prize Bridge Award since Pittsburgh's Sixth Street Bridge won the first competition in 1928. Some of those bridges, such as the Wabash Railroad bridge in Wayne County, Mich., which won a prize in 1941 and still carries railroad traffic more than 70 years later, have outlasted the companies that built them. The winners are as follows:

Major span
- National: I-74 Mississippi River Bridge—Westbound Span (Bettendorf, Iowa/Moline, Ill.)

Medium span
- National: I-91 Interchange 29 Exit Ramp Flyover Bridge (Hartford, Conn.)
- Merit: Arlington Memorial Bridge (Washington, D.C./Arlington County, Va.)

Short span
- National: Metro-North Railroad Bridge over Atlantic Street (Stamford, Conn.)

Rehabilitation
- National: Baker's Haulover Cut Bridge Rehabilitation (Bal Harbour, Fla.)
- Merit: Hernando de Soto Bridge (Memphis, Tenn./West Memphis, Ark.)

Special purpose
- National: Green Street Pedestrian Bridge (Winston-Salem, N.C.)
- Merit: Dublin Link Pedestrian Bridge (Dublin, Ohio)

New this year is the Bridge of the Year Competition. The 2022 World Steel Bridge Symposium (WSBS) in Denver (March 23–25) will open with live presentations from the teams behind three finalists selected by our judges. Presenters will outline what makes their bridges so noteworthy, and the winner will be announced at the conference. The three finalists are:

- I-91 Interchange 29 Exit Ramp Flyover Bridge (medium span)
- Metro-North Railroad Bridge over Atlantic Street (short span)
- Green Street Pedestrian Bridge (special purpose)

For more information about the Prize Bridge Awards, please visit **aisc.org/prizebridge**. The winners will also be featured in the July 2022 issue (**www.modernsteel.com**). And to register for the 2022 NASCC: The Steel Conference and WSBS, visit **aisc.org/nascc**.

IN MEMORIAM

Deane Thomas Wallace, Former Bridge Fabrication Expert, Dies at 66

Deane Thomas Wallace, former senior vice president of bridge sales and estimating at W&W|AFCO Steel, died January 22 at the age of 66. He leaves behind a legacy of amazing steel bridges, such as the Christopher S. Bond Bridge (Kansas City, Mo.), Big Rock Interchange (Little Rock, Ark.), and the U.S. 82 Mississippi River Bridge (Greenville, Miss.).

"Our industry has truly lost one of our great champions with Deane Wallace's recent passing," said John O'Quinn, president of High Steel Structures and chair of the NSBA Market Development Committee. "His larger-than-life personality served both Deane and the industry well over the years, as you always knew where he stood on any given issue. Deane was as well-known for being a fierce competitor as he was for his firm, fair and common-sense approach as a colleague and team player. His contributions were numerous, from the Steel Centurion concept (**aisc.org/steelcenturions**) to his leadership on both the NSBA Executive Council and NSBA Market Development Committee. Deane's passion for steel bridges was impactful, helping to guide the path forward not only for the betterment of his employer, W&W|AFCO, but for our entire industry."

A graduate of the University of Dallas and a life-long resident of Little Rock, Wallace had a 40-year career with W&W|AFCO Steel. He had a passion for the Arkansas Razorbacks; duck hunting, wine, and a fine cigar; his church and devout faith; and his customers, many of whom became friends.

"Deane Wallace was a very strong advocate for the steel bridge industry throughout his career," added Grady E. Harvell, president and COO of W&W|AFCO Steel. "Deane's efforts to develop the steel bridge market with NSBA, DOT's, consulting engineers, contractors, and customers will produce benefits for bridge fabricators for years to come."

"I think one of the greatest compliments a manager can have is to be able to retire and not see a significant decline in the effectiveness of his department or the company's success when he leaves," continued Harvell. "Deane retired in 2016 after suffering a debilitating stroke but he left talented young protégés that are carrying on the traditions he put in place. Deane's philosophy was to build our bridge business around integrity and performance and count on those qualities to keep our customers coming back. It worked and it worked well. We miss his robust laugh and his leadership and friendship on a daily basis."

UNIVERSITY RELATIONS

AISC Offers more than $173,000 in Scholarships this Year

AISC is offering more than $173,000 in scholarships to juniors, seniors, and master's students studying civil/structural engineering, architecture, and related fields during the 2022-2023 academic year.

"AISC and the AISC Education Foundation are very proud of the work we do to provide scholarships to help the next generation of industry leaders reach their dreams," said Maria Mnookin, AISC's education program manager. "That remains a central tenet of our efforts to foster innovation to ensure a bright future for our industry." For the 2021–2022 academic year, AISC and its industry partners provided scholarships to 102 students at colleges and universities in the U.S., with a similar number expected in 2022–2023. The deadline to apply is May 2, 2022.

"This scholarship has helped me in many ways, particularly in the areas of academic and professional development," explained Charlie Guyer, a 2020-2021 scholarship winner at Oklahoma State University. "For the first time since coming on campus, I've been able to take a job with fewer hours so I can focus more on the higher-level classes I'm taking."

In addition to its scholarship program, AISC funds undergraduate fellowships, sponsors the Student Steel Bridge Competition, and offers an Adopt-a-School program to foster close relationships between students/faculty and nearby steel fabricators who can help by offering tours, providing practical knowledge, donating materials, and advising students on their capstone projects.

For more information on our scholarship and other educational programs, please visit **aisc.org/scholarships**.

ENGINEERING JOURNAL

Second Quarter 2022 *Engineering Journal* Now Available

The second quarter 2022 issue of AISC's *Engineering Journal* is now available. (You can access this issue as well as past issues at **aisc.org/ej**.) Below is a summary of this issue, which includes articles on buckling of angle compression members, flange buckling resistance, DuraFuse frames, and inelastic design for wind loads.

Buckling of Conventional and High-Strength Vanadium Steel Single- and Double-Angle Compression Members and Truss Subassemblies: Experimental and Computational Correlation Study

By Ahmet Citipitioglu, Mohamed M. Talaat, Ronald L. Mayes, Mark D. Webster, and Frank W. Kan

High-strength, low-alloy vanadium (HSLA-V) steel offers higher strength and toughness than conventional steel. The resulting lighter weight and more slender structural members are more susceptible to buckling in compression. This study establishes an understanding of buckling in this material and the ability to predict it analytically. A series of conventional ASTM A572 Grade 50 steel and HSLA-V (nominal Grade 80) steel angle compression members were tested at Lehigh University's Advanced Technology for Large Structural Systems (ATLSS) laboratory. A general-purpose finite element software was used in this study to simulate the buckling and post-buckling behavior of the structural members. The objective of these simulations was to establish confidence in the ability to accurately predict buckling response. The influence of the following modeling parameters on the accuracy of the compression angle member simulation results was investigated: variation in material stress-strain relationship, residual stresses, and the shape and magnitude of geometric imperfections.

Flange Local Buckling Resistance and Local-Global Buckling Interaction in Slender-Flange Welded I-Section Beams

By Wajahat Latif and Donald W. White

AISC *Specification* Chapter F characterizes the flange local buckling (FLB) strength of I-section members having a slender compression flange as the theoretical elastic plate local buckling resistance, ignoring beneficial local post-buckling strength. Previous research has shown that this results in highly conservative strength predictions for slender-flange members. Additionally, potential interaction between local and global lateral-torsional buckling modes is not considered in the AISC *Specification*. These aspects can be important in applications involving the use of slender-flange members. This paper investigates a number of potential methodologies to account for local post-buckling strength as well as local-global buckling interaction in beams having slender flanges.

Cyclic Behavior of DuraFuse Frames Moment Connections

By Paul W. Richards

Most special moment frames (SMF) rely on beam yielding to reach drifts of 0.04 rad and beyond. In contrast, DuraFuse Frames (DFF) incorporate a fuse plate that acts as the yielding element. Nine full-scale DFF specimens were tested using AISC 341, *Seismic Provisions for Structural Buildings*, Chapter K, to prequalify the DFF connection for use in SMF and inclusion in AISC 358, *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications*. Eight specimens were tested with the standard protocol and exceeded the qualification criteria. The other specimen completed a custom protocol representing three maximum credible earthquakes (MCE) in sequence. The experiments demonstrated that the stiffness of the DFF connection is sufficient to classify the connection as fully restrained.

Steel Structures Research Update: Inelastic Design Method for Steel Buildings Subjected to Wind Loads

By Judy Liu

Ongoing research on an inelastic wind design method for steel buildings is highlighted. This study is underway at Brigham Young University, led by Dr. Johnn Judd, Assistant Professor in the Department of Civil and Construction Engineering. Dr. Judd's research interests include seismic performance of steel moment frame buildings, field evaluation and structural health monitoring of steel bridges, and wind performance assessment of buildings. The research team is in the third year of the four-year study. Selected results from the study are highlighted along with a preview of future work.

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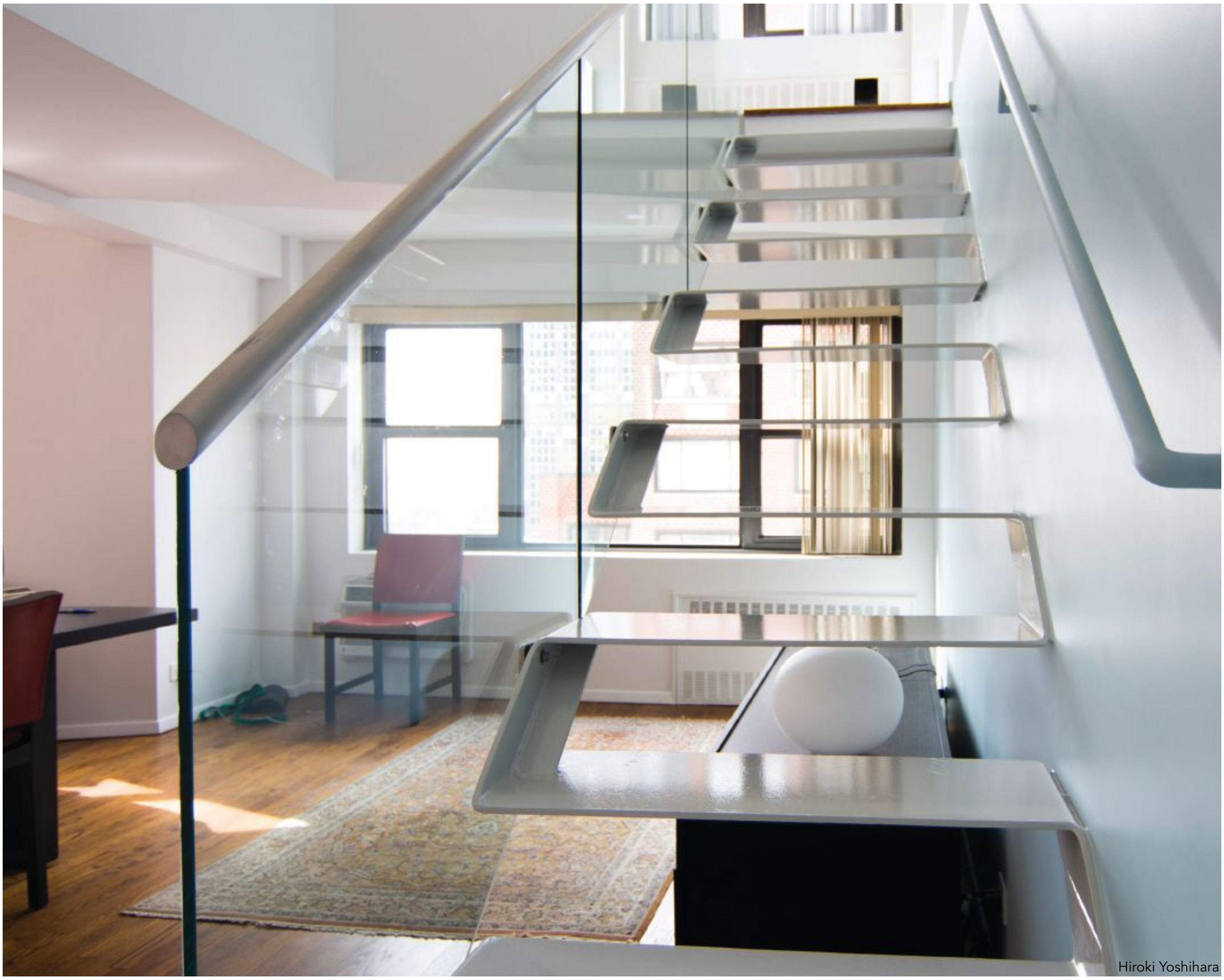

Hiroki Yoshihara

Celestial Staircase

KNOCKING DOWN A WALL to combine two apartments is fairly common.

Combining two apartments that are aligned vertically? Less so.

But this was the scenario in a 1960s-built Manhattan apartment building where two units, one top of the other, were joined by opening the floor in the top unit and inserting a new staircase. The new two-story-high volume and the staircase were designed to become the focal point of the enlarged apartment while capitalizing on the spectacular views of the East River and the nearby United Nations Building.

The risers are fashioned from a single serpentine steel element, folded into S-curves, that climbs from the bottom to the top floor. The continuous strand of steel is much more delicate than a typical cantilevered staircase and evokes a ribbon floating in the air, while the transparent design facilitates an open aesthetic.

To create the form, a large sheet of ⅜-in.-thick steel was folded just four times and, after folding, was sliced "diagonally" into six identical modules before being stacked. This procedure resulted in precisely identical modules that would have been much more difficult to achieve by bending the strips one by one. This accuracy was crucial to accommodating the glass handrail, which required precise alignment.

The project, called Ascension of the Celestial Maiden, was designed by Yoshihara McKee Architects and Yoshinori Nito Engineering and Design, PC, and is one of this year's AISC IDEAS² Award winners. To read more about this project and the rest of this year's winners, see next month's (May) issue at **www.modernsteel.com**.

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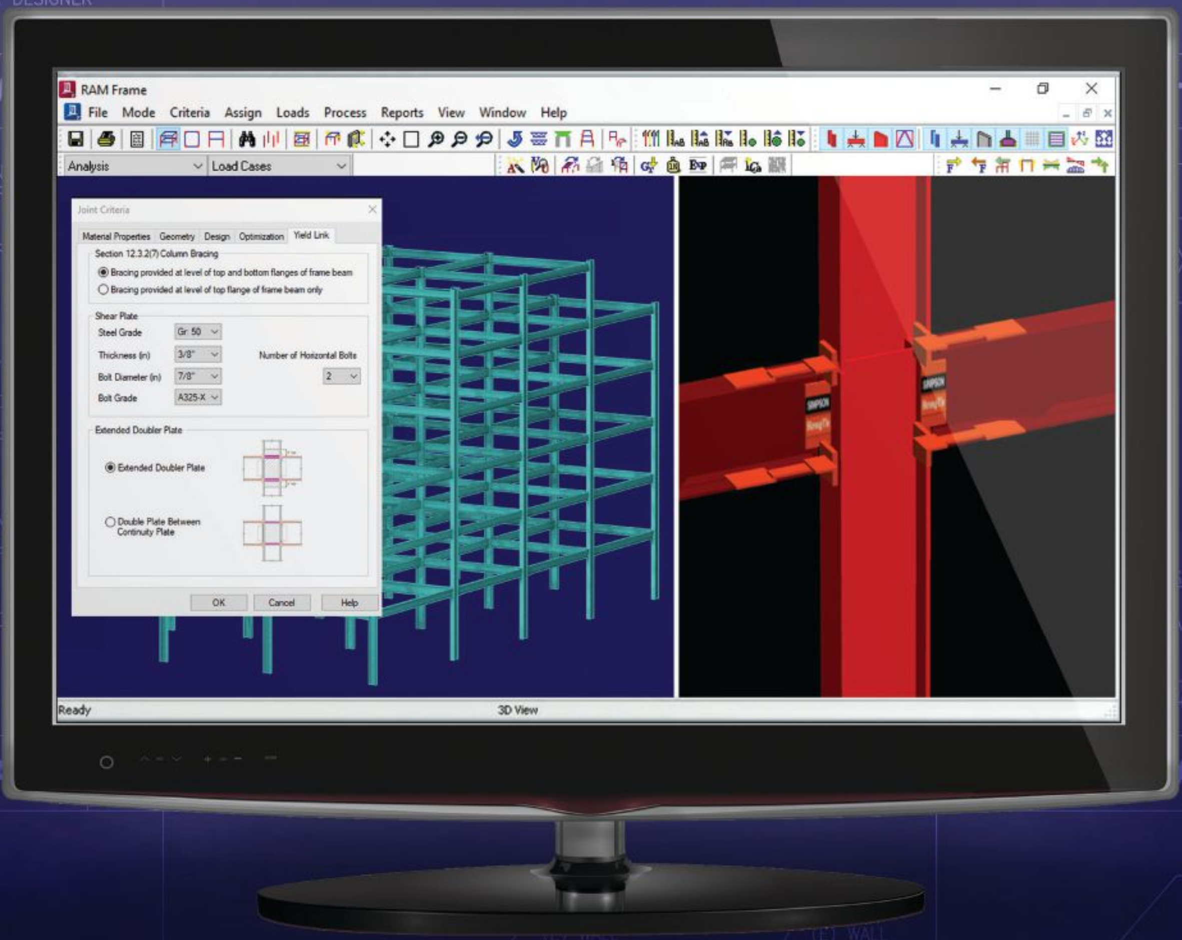

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