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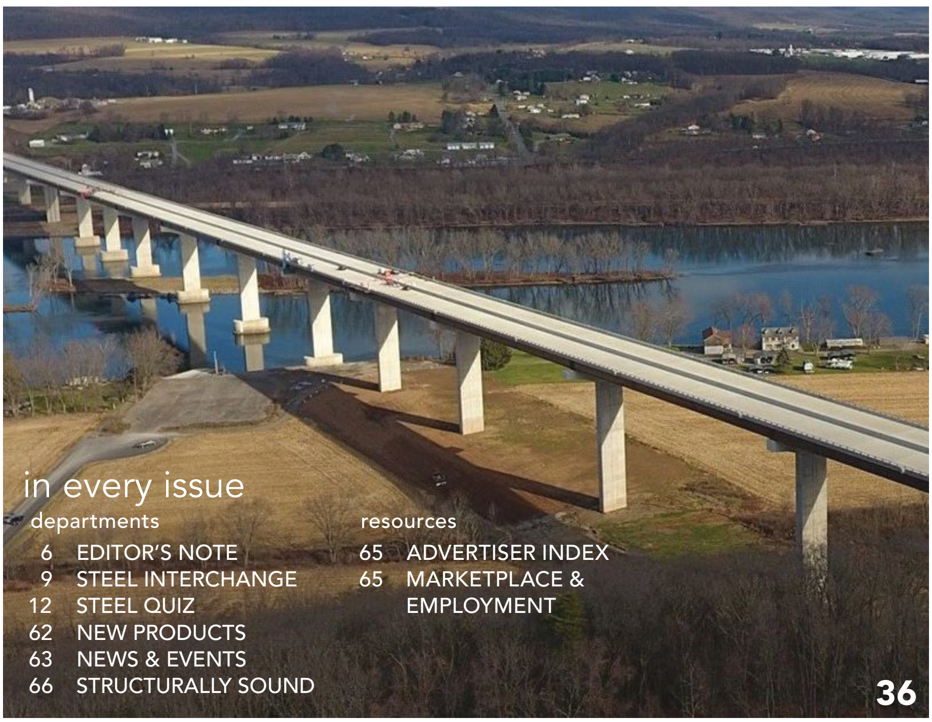

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ON THE COVER: Hanging out at Nashville International Airport, p. 30. (Photo: Courtesy Hensel Phelps/Matt Good – www.mattshootsforgood.com)

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Has anyone (everyone?) told you how fun ziplining is?

Well, they're right. It's really fun. If you haven't done it and you have the means and wherewithal to give it a go, I highly recommend it.

I'd tried it a couple of times in the past here in the Midwest, but I didn't *really* try it until we were in Costa Rica. (Kind of like mountain biking in Chicago versus mountain biking in the Rocky Mountains; you're technically on a bike in both places, but…)

The ziplines themselves (made of steel cables!) were long (one of them was over a kilometer), the rainforest setting was spectacular, the weather was perfect, and the guides were fantastic. We even heard howler monkeys. The only bummer was that we didn't see any sloths (but I'm sure they saw us).

As fun and exhilarating as the experience was, it was also safe. Like, *really* safe.

Basically, you were tethered to an immovable object at all times. There were two cords with carabiners attached to your harness, and when you got to the first launch platform, a guide attached the first carabiner to a line that was attached to a tree, then they attached you to the actual zipline with the second carabiner, and *then* they attached your first carabiner to the zipline. The process was performed in reverse at the landing platform, and the whole thing was repeated for each zipline. There were seven lines in all, as well as three belaying spots, where you could pretend you were Spider-Man (I certainly did). The concept was similar to that of an airlock. Close one door before opening the other so no one gets sucked out into the cold vacuum of space.

Were there opportunities to hurt yourself? Well of *course* there were, but you had to make a real effort to do so and, thankfully, no one in our group was up for that.

You know where else a lot of attention is paid to safety? The American ironworking industry. Don't get me wrong, ziplining and ironworking can both take place at great heights, and the potential for disaster is definitely there. But it's *because* both are so dangerous that they're so safe—i.e., given their inherent nature, both industries have developed stringent safety requirements over time and work to enforce them.

The Ironworker Management Progressive Action Cooperative Trust (aka IMPACT) knows ironworking safety better than anyone, and they're happy to demonstrate it at one of their many training facilities across the country. In fact, 11 IMPACT facilities will be hosting SteelDay events involving presentations, tours, and demonstrations of steel erection practices like welding, bolting, and navigating through a structure. And the number one thing they emphasize for all of these activities? Safety.

And IMPACT is just one of this year's SteelDay hosts. Taking place Friday, October 21 (with events leading up to it all week), and sponsored by AISC, SteelDay offers events throughout the country for AEC professionals, faculty and students, and the public to see firsthand how the U.S. structural steel industry works to build our country's buildings and bridges.

You can read a brief SteelDay preview on page 60. You can also learn more about SteelDay and sign up to attend an event or webinar at **aisc.org/steelday**. We'll see you at one of them—and in the meantime, stay safe!

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Web Sidesway Buckling

Can you please clarify the axis to be used for M_u (LRFD) or M_a (ASD) in order to select C_r for equations J10-6 and J10-7 (Web Sidesway Buckling Check) in the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360)? Does the *Specification* intend that these values be for the major, X-X axis? That is, M_{u_xx} (LRFD) or M_{a_xx} (ASD) should be used, correct?

The short answer is: Yes. The required flexural strength (M_u *or* M_a) is based on the X-X axis.

It might be helpful to consider the physical behavior that the sidesway web buckling provisions in AISC *Specification* Section J10.4 intend to check. Deriving equations in the *Specification* can also help one understand what is being done. I will attempt to derive Equation J10-7 as an example. Note that I have not taken the further step of validating the accuracy or suitability of this equation in the *Specification*, as this has likely been done by members of the AISC Committee on Specifications before being incorporated. But even this first pass at a derivation (shown below) should still provide one with a better understanding of this equation.

When a concentrated compressive load is applied to a beam, it causes bending in the beam. The top flange is subjected to compression, and the bottom flange is subjected to tension. Based on the type of loading (tension or compression), many engineers may feel that any instability that exists, exists only relative to the top compression flange, because elements in tension do not suffer from instabilities. However, tests indicated that some beams fail, as shown in Figure 1.

It may appear that the tension flange has pulled the web sideways but in fact, the web has buckled, pushing the bottom flange sideways. The web is, in effect, a column and can therefore buckle (see Figure 2).

This behavior can be modeled as shown in Figure 3, if the web is pinned (laterally restrained but flexurally free) at the top flange, which is the assumption made in Equation J10-7.

Another possible assumption is that the web is fixed at the top flange, which is the assumption made in *Specification* Equation J10-6. We will only examine the case where the top flange is pinned (Equation J10-7).

The model adopted by Yura (see Figure 4) determines the stiffness of the bottom flange to resist buckling using a simple beam model.

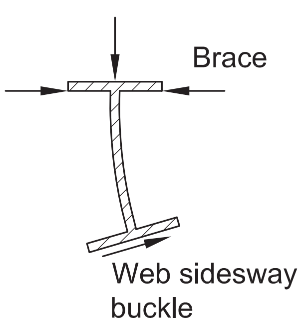


Fig. 1. Web sidesway bucking.

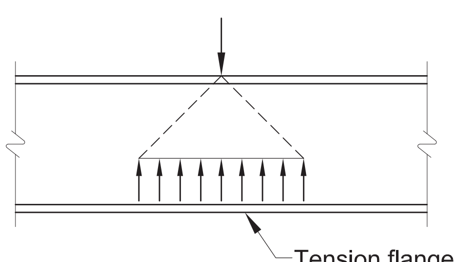


Fig. 2.
Web sidesway buckling

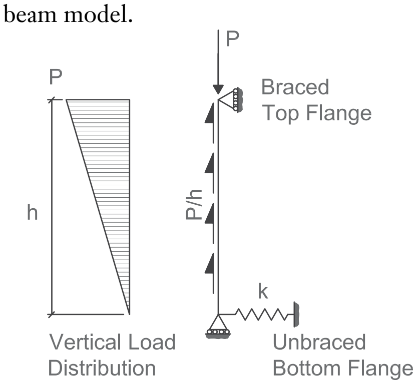


Fig. 3. Column model.

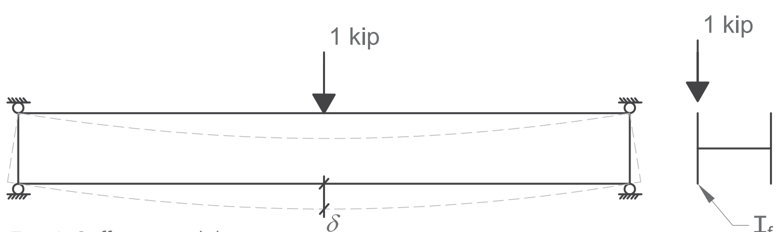


Fig. 4. Stiffness model.

continued >>

The stiffness of the tension flange is:

$$k_f = \frac{1}{\delta} = \frac{48EI_f}{L^3}$$

The moment of inertia of the flange is:

$$I_f = \frac{t_f b_f^3}{12}$$

This yields:

$$k_f = \frac{4Et_f b_f^3}{L^3}$$

This stiffness acts essentially like a point brace relative to stabilizing the web. Section 6.2.2 of the AISC *Specification* addresses point bracing requirements, and the stiffness requirement in this section, *Specification* Equation A-6-4a, can be rewritten as:

$$P_r = \frac{k_f h}{8} = \frac{\frac{4Et_f b_f^3}{L^3} h}{8} = \frac{Et_f b_f^3 h}{2L^3}$$

There are two problems with this approach. First, *Specification* Appendix 6 assumes the worst case. As stated in the Commentary for Appendix 6 Section 6.2: "For one intermediate brace, $\beta_i = 2P_r/L_{br}$, and for many braces, $\beta_i = 4P_r/L_{br}$… The most severe case (many braces) is adopted for the brace stiffness requirement in Equation A-6-4…" Second, Appendix 6 doubles the demand. It will be assumed that neither assumption needs to be applied to this problem. This results in:

$$P_r = \frac{2Et_f b_f^3 h}{L^3}$$

Now let's turn to *Specification* Equation J10-7. This equation assumes a pinned support at the top flange, as evidenced by the statement, "If the compression flange is not restrained against rotation." Equation J10-7 can be rewritten as:

$$R_n = \frac{C_r t_w^3 t_f}{h^2} 0.4\left(\frac{h^3 b_f^3}{t_w^3 L_b^3}\right) = 0.4C_r t_f b_f^3 \left(\frac{h}{L_b^3}\right)$$

If the tension flange remains unyielded, then C_r = 960,000 ksi, and Equation J10-7 can be rewritten as:

$$R_n = (384{,}000 \text{ ksi})\, t_f b_f^3 \left(\frac{h}{L_b^3}\right) = 13.2\left(\frac{Et_f b_f^3 h}{L_b^3}\right)$$

We can now compare the result from the Appendix 6 buckling model to Equation J10-7:

$$P_r = 2\left(\frac{Et_f b_f^3 h}{L^3}\right)$$

$$R_n = 13.2\left(\frac{Et_f b_f^3 h}{L_b^3}\right)$$

Equation J10-7 produces a strength that is 6.6 times larger than the strength predicted by the Appendix 6 model. Grondin and Cheng (1999) propose two assumptions:

1. "It is also assumed that the vertical load on the web is linearly distributed… Replacing this triangular load distribution by a constant load of 50% of the maximum load…" This, in effect, doubles the load that can be carried. (This essentially assumes half the load at half the height and presumably assumes that the other half of the load is carried in a manner that does not lead to instability.)
2. "For simple lateral supports, *C* takes a value of 48, and for fixed lateral supports, the value of *C* is 192. Assuming an intermediate value of 80…"

These two modifications result in:

$$P_r = (4)\left(\frac{80}{48}\right)2\left(\frac{Et_f b_f^3 h}{L^3}\right) = 13.3\left(\frac{Et_f b_f^3 h}{L^3}\right)$$

At this point, I will mention that I have some doubts regarding the assumptions made by Grondin and Cheng. There would be no reason to believe that the tension flange is restrained at its ends somewhere between pinned and fixed. The assumption that results in the fourfold increase seems arbitrary. However, there are credible sources of additional strength that are not accounted for in the simple model. For example, the tension in the bottom flange will tend to stiffen the flange, and the bottom flange is not the only source of restraint. It is not necessary to accurately assign all effects to specific behaviors if it can be shown that the equation produces useable results.

Figures in this discussion are taken from the Commentary sections of the following publications:

- Summers, P. A., and Yura, J. A. (1982), *The Behavior of Beams Subjected to Concentrated Loads*, Phil M. Ferguson Structural Engineering Laboratory Report No. 82-5, University of Texas, Austin, Texas, August. (**http://fsel.engr.utexas.edu/pdfs/82-51.pdf**)
- Grondin, G.Y.; Cheng, J.J.R. (1999), "Sidesway Web Buckling of Steel Beams," *Engineering Journal*, American Institute of Steel Construction, Vol. 36, pp. 169–180. (**aisc.org/sidesway-web-buckling-of-steel-beams**)

Larry Muir, PE

Larry Muir is a consultant to AISC.

steel quiz

When has a client ever said, "We really wish you would take longer to fabricate our steel bridge"?

This month's Steel Quiz will help you learn how to increase the speed of steel fabrication by optimizing the activities that take place on and support the shop floor. You can find hints in the newly published National Steel Bridge Alliance (NSBA) guide *Accelerated Steel: Achieving Speed in Steel Bridge Fabrication* (available for free at **aisc.org/nsba**). And to learn about AISC's Need for Speed initiative, visit **aisc.org/needforspeed**.

1 The actual processing of material into bridge parts can only begin once the following are in place:
a. Approved shop drawings
b. Procuring the required materials
c. Approved welding procedures
d. All of the above

2 To keep material shipping cost- and time-effective, designers should size webs and flanges so they are readily cut from commonly available slab lengths, not to exceed:
a. 75 ft **c.** 90 ft
b. 83 ft **d.** 96 ft

3 **True or False:** The most customary practice in steel bridge fabrication is to require unit assembly.

4 **True or False:** Quality is achieved by correctly performing work on the shop floor and not by "inspecting in" quality.

5 Which of the following is/are common dimensional errors associated with camber issues that a bridge design engineer should avoid:
a. Showing a distorted girder in the output
b. Providing an incorrect vertical curve
c. Not showing proper dead load deflections
d. a and b
e. a, b, and c

6 **True or False:** Generally speaking, if a stiffener is mislocated by a minor amount (perhaps, say, an inch), the best course of action should be to cut it out, repair the base metal, and install a new stiffener.

7 Using uncoated weathering steel is the fastest and most cost-effective durability solution for steel bridges. While superstructures built of weathering steel can be processed with no cleaning or coating, which of the following surface preparation standards is generally recommended for all surfaces?
a. SSPC-SP1 **c.** SSPC-SP5
b. SSPC-SP3 **d.** SSPC-SP6

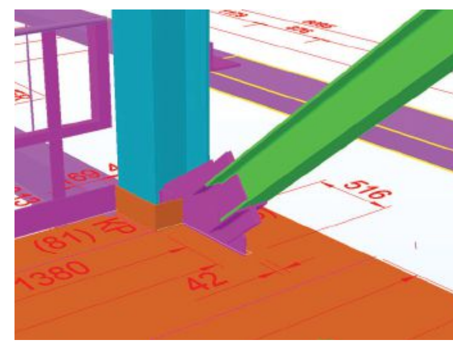
8 **True or False:** The general contractor should discuss the erection scheme with the fabricator before developing shop drawings.

9 In a design-build steel bridge project, before a fabricator provides feedback, a good guideline to optimize the substructure for a long, multi-span bridge is to start with a maximum I-girder depth of __________?
a. 6 ft **c.** 10 ft
b. 8 ft **d.** 12 ft

TURN TO PAGE 14 FOR ANSWERS

NEED FOR SPEED

AISC's Need for Speed initiative recognizes technologies and practices that make steel projects come together faster. Check out **aisc.org/needforspeed** for more.



Vulcraft's online design tools and 3D modeling software helps maximize efficiencies in the detailing process.

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**.

1 **d.** All of the above. The actual processing of material into bridge parts can only begin once the following are in place: approved shop drawings, having the required material, and approved welding procedures. These are done in association with other fabrication operations like estimating, bidding and contracting, scheduling, and planning. That's why when it comes to accelerating bridge fabrication, teamwork between the fabricator, owner, engineer, and contractor is essential to make sure no one is holding up a specific aspect of the fabrication process. Learn more about the fabrication process and how you can optimize it for your next steel bridge project in Section 2.10 of the *Accelerated Steel* guide.

2 **b.** 83 ft. Material lead time is a crucial schedule driver on a steel bridge project. Material is generally delivered to fabricators by rail car, and plates must fit on one rail car to keep material shipping cost and time effective. Rail cars are 85 ft long, and the usable shipping length of the cars is 83 ft. Fabricators use shop splices to help fit ordered plates to lengths that will fit on one rail car. For more information on optimizing material procurement for faster steel bridge fabrication, see Section 2.7 of the NSBA guide.

3 **False.** The most customary practice in steel bridge fabrication is to require line girder assembly and not unit assembly. Line assembly (also known as "lay down" and "progressive assembly") is the assembly of girders, end-to-end, for either (1) making the connections and thereby also checking the connections or (2) putting girders together to check the connections, having drilled the holes full-size independently. Unit assembly (also known as "full show assembly" or "complete shop assembly") is an assembly that includes both girders and cross-frames—i.e., the entire unit. Unit assembly is not very common and, for most bridges, is not necessary. If unit assembly is specified, recognize that this will likely add time and cost to the project. Learn more about the shop assembly of steel bridge fabrication and how to optimize it in Section 2.11 of the NSBA guide.

4 **True.** Quality cannot be inspected into a project. Workers achieve quality in the shop and not by inspection after fabrication. The owner's inspector cannot control the shop workers and must not direct or otherwise interfere with their work. From the owner's standpoint, the best means of providing quality is ensuring that the fabricator has quality control practices in place and that the fabricator is following them. The best first step to doing this is to require that the fabricator is certified for bridge fabrication by AISC. Additionally, an owner should expect inspectors to be objective and cooperative, including respecting the fabricator's schedule, communicating with the appropriate fabricator representatives, and establishing an escalation practice to resolve disputes. Learn more about best practices on behalf of the owner for accelerating steel bridge fabrication in Chapter 3 of the NSBA guide.

5 **e.** a, b, and c. Dimensional errors are a common source of lack of correctness in design, and they should be avoided whenever possible. They can hold up a project for weeks or even months if the resolution process is not clear and efficient. Common dimensional errors associated with camber issues include showing a distorted girder output indicating a camber error, providing an incorrect vertical curve, and not showing proper dead load deflections required to calculate steel fit conditions. Learn more about best practices for bridge designers to accelerate steel bridge fabrication in Chapter 4 of the NSBA guide.

6 **False.** Fabricators strive to avoid rework, but repairs are occasionally needed and are normal in bridge fabrication. Some repairs have design implications, while others do not. For example, if a stiffener is mislocated by a minor amount, the best course of action may be to leave the stiffener where it is rather than cutting it out, repairing the base metal, and installing a new stiffener. Generally, the design is not sensitive to such minor errors in the fabrication process. When called upon to review and approve repairs, strive for the "leave as-is" condition, when possible, to avoid unnecessary project delays. See Section 2.10 of the NSBA guide for more information on best practices regarding repairs during the fabrication of steel bridges. And be sure to use repair practices that align with AASHTO/NSBA *Guidelines for Resolution of Steel Bridge Fabrication Errors* (G2.2-2016), available at **aisc.org/nsba**.

7 **a.** SSPC-SP1. Superstructures built of weathering steel can be processed without cleaning or coating. However, specifying SSPC-SP1 cleaning is advisable so that the steel looks clean and free of cutting and drilling fluid. See Section 2.12 of the NSBA guide for more information regarding cleaning and coating best practices to achieve faster steel bridge fabrication.

8 **True.** The general contractor (GC) should discuss the erection scheme as early as possible with the fabricator, particularly the sequence of erection before shop drawings are developed, in case this will affect the overall approach to fabrication. For example, if the GC intends to use erection braces or lifting devices that are temporarily bolted to the steel, the connections must be shown on the shop drawings. Learn more about best practices on behalf of the GC to improve the speed of steel bridge fabrication in Chapter 5 of the NSBA guide.

9 **c.** 10 ft. Using the best design practices has a significant impact on the project speed of a design-build project. It is best to get fabricator input as early as possible, but before a fabricator can provide direct feedback, you must start somewhere. For long, multi-span bridges where the desire is to optimize the substructure, start with 10-ft-deep I-girders as a reasonable maximum depth. Larger girders are more challenging to fabricate, but up to about 10 ft deep, fabrication remains reasonable and straightforward. Find more design guidelines for achieving constructability in the early stages of a design-build project in Section 6.5 of the NSBA guide.

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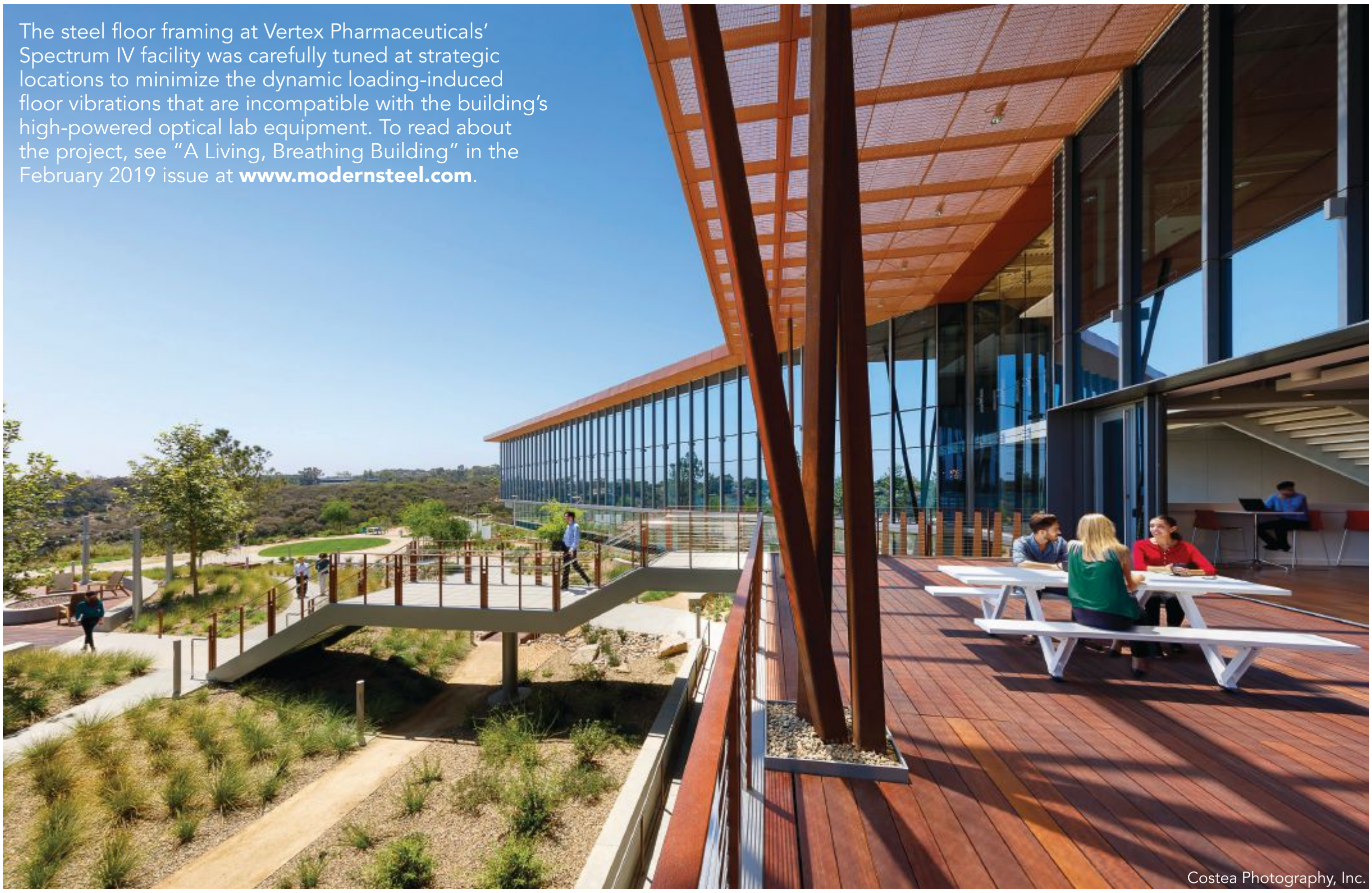
Sound Advice

BY FRANKLIN D. LANCASTER, PE, RA

Designing for sound and vibration in steel facilities is easy when you use the right tools.



The steel floor framing at Vertex Pharmaceuticals' Spectrum IV facility was carefully tuned at strategic locations to minimize the dynamic loading-induced floor vibrations that are incompatible with the building's high-powered optical lab equipment. To read about the project, see "A Living, Breathing Building" in the February 2019 issue at **www.modernsteel.com**.

Costea Photography, Inc.

SPEAKING FROM personal experience, I can say you're never more aware of the critical nature of sound and vibration control than when you're designing a secure space where sensitive information can be viewed and discussed to prevent outside surveillance or spying.

Steel framing is ideal for such facilities, as well as others where sound isolation and structural vibration issues are critical to achieving performance objectives. Vibrations caused by mechanical equipment, people walking on a structured floor, or airborne noise can disrupt occupants in any type of building.

For instance, laboratory building vibrations can interfere with sensitive equipment, derail experiments, and affect the behavior of laboratory animals. Uncontrolled sounds in recording and television studios and concert venues can ruin productions. Hospital vibrations and noise can impede surgical procedures and interfere with patient recovery.

Design considerations to mitigate vibration and noise problems apply to all types of building construction, including wood, concrete, masonry, and steel. However, the most robust design tools that allow architects and structural engineers to optimize buildings for specific vibration design parameters are specifically geared toward steel-framed structures. And engaging them sooner rather than later in a project can help you eliminate sound- and vibration-related surprises before they even have an opportunity to emerge.

Sound Isolation and Noise Control

Published in 2015, AISC Design Guide 30: *Sound Isolation and Noise Control in Steel Buildings* is an authoritative reference for mitigating noise problems. There are three common measurements further explained in the publication:

- Sound transmission class (STC)
- Impact insulation class (IIC)
- Noise reduction coefficient (NRC)

Each measurement addresses a different concept, and each concept involves various adjustments to construction assemblies.

STC. STC is a laboratory measure of how much airborne sound a structure blocks. Simply put, the higher the number, the less sound can pass through a given structure. Typical wall assemblies are commonly associated with certain STC values. For example, a typical 4-in. metal stud wall with a layer of ⅝-in. gypsum board on each side offers an STC of 38. Adding fiberglass batt insulation to the wall increases the STC to 43, and increasing the mass by adding a second layer of drywall to both sides increases the STC to 45. STC values higher than 60 can be reached by using a double-stud wall with an air gap separation or introducing resilient elements to the design. (See Tables 8-1 and 8-2 in Design Guide 30 for a summary of wall assemblies and their STC values.)

To be effective, partitions meant to block sound from traveling to an adjacent space must maintain a complete seal against all edges. If not properly sealed, flanking noise can occur from one space to another. A one-inch square hole through a wall can ruin the STC rating of a rigorously designed assembly. When sealing the top of non-load bearing partitions, install materials that allow the floor system to deflect without loading the walls. Preformed materials for just this purpose are available to match the profile of the metal deck (see Figure 1).

IIC. STC values also apply to floor-ceiling assemblies, as does another noise measurement, IIC, which is a laboratory measure of how much impact a structure blocks. Taken together, STC and IIC values can measure the efficacy of a floor-ceiling assembly for resisting both airborne noise and noise from impacts such as dropped objects or footfalls transmitting from an upper to lower space.

For steel buildings, standard floor-ceiling assemblies contain an interstitial void that acts as a sound barrier between adjacent stories, similar to a double-stud wall. Such assemblies have natural advantages over flat slab construction without suspended ceilings. For example, the common construction assembly illustrated in Figure 2 incorporates a resilient floor underlayment and ceiling suspended with wire hangers, providing a floor-ceiling

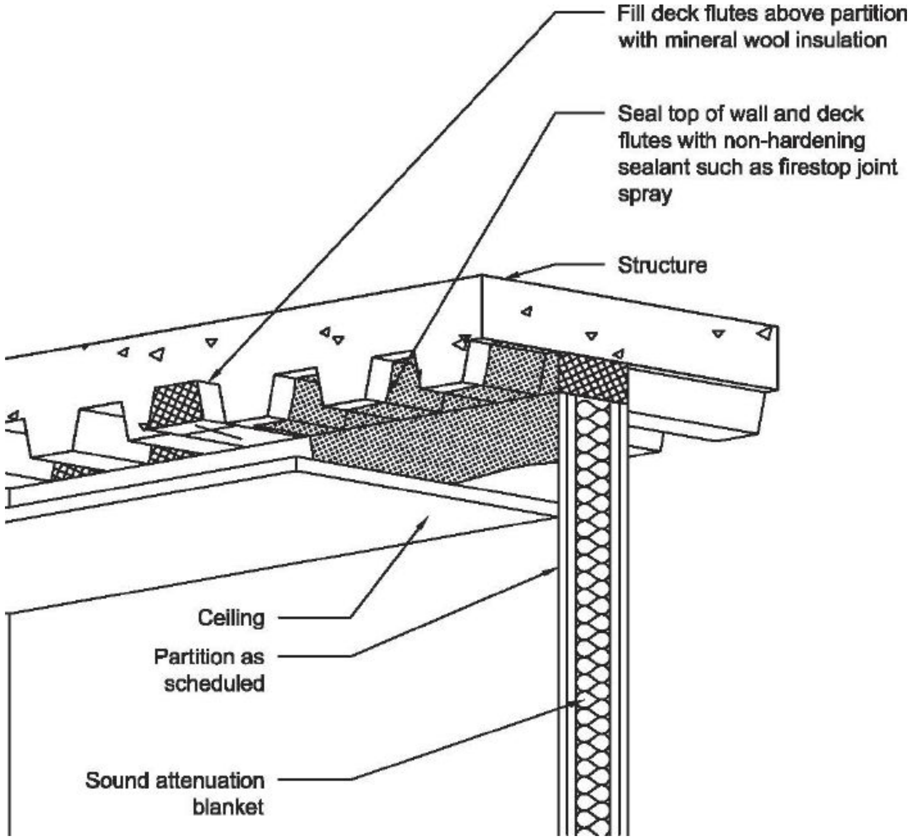


Fig. 1.

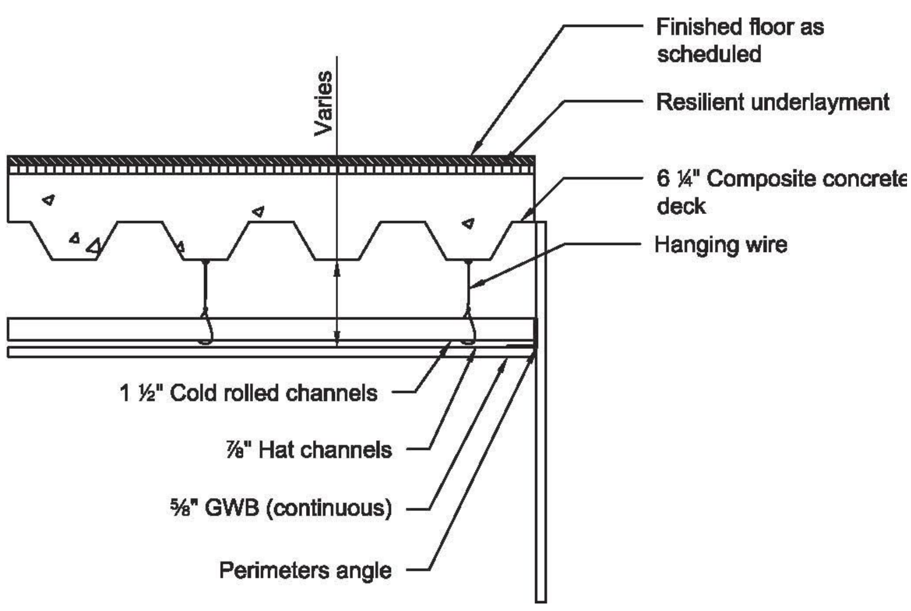
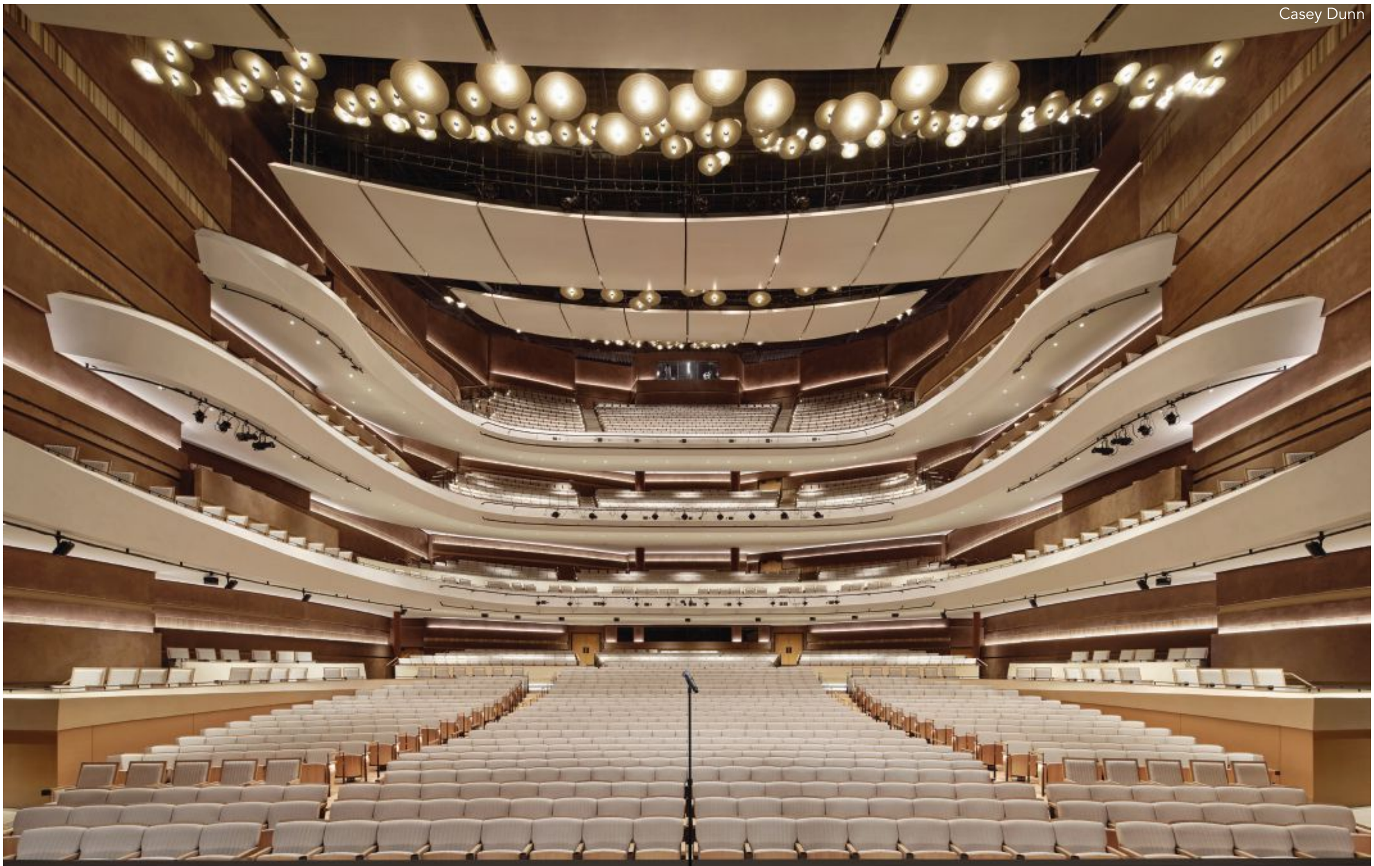


Fig. 2.



Vibration from rhythmic activities on the balconies of the Buddy Holly Hall of Performing Arts and Sciences in Lubbock, Texas, was a major consideration given the large cantilever length of the rakers. To read about the project, see the IDEAS[2] Awards coverage in the May 2022 issue.

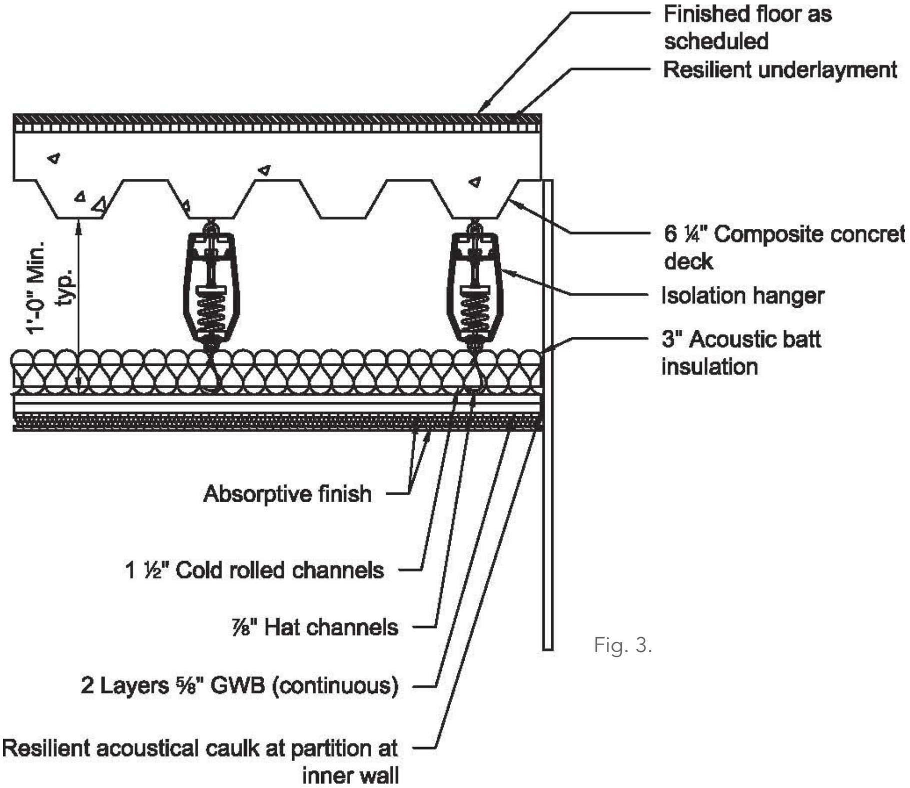


Fig. 3.

assembly STC of 60 and IIC of 50, which is suitable for multi-family residential buildings as well as many commercial and healthcare facilities.

By contrast, Figure 3 details what can be achieved by incorporating more robust measures such as spring isolation hangers, acoustic batt insulation, and additional ceiling mass with an absorptive finish. This floor-ceiling assembly achieves an STC of 70 and IIC of 65, providing effective isolation between residential spaces above retail or restaurant spaces or sound isolation for trial jury suites. (See Tables 8-6 through 8-8 in Design Guide 30 for STC and IIC ratings of floor-ceiling and roof-ceiling assemblies.)

In terms of sound control, the foregoing discussion makes clear that the key is in the details. However, a simpler way to look at it is this: How much mass and separation can be provided between spaces? As an example, my firm recently leveraged this understanding in the design of an instructional space at a military air training facility.

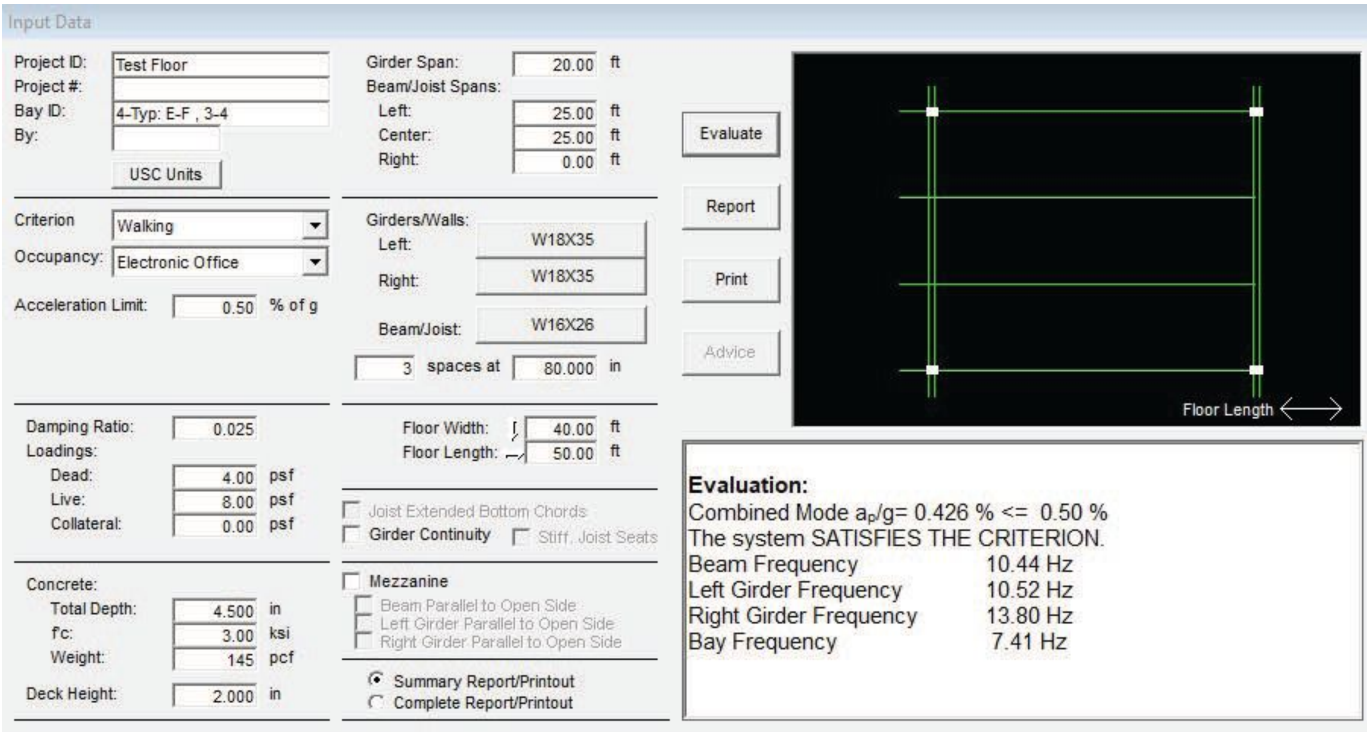


Fig. 4.

Although roof deck would have been structurally adequate, we used a concrete slab on metal deck for the roof to prevent the noise created by jets and propeller aircraft at a busy air base from interfering with the quiet conditions needed for classroom training inside the building.

NRC. This parameter refers to the sound absorption qualities within a space. Noise, defined as unwanted sound, can be controlled within a room through various methods, such as carpeting the floor, installing acoustical ceiling tiles, or mounting fabric panels on the walls. These materials absorb some frequencies and reduce reverberation.

Note that modifications to room elements to improve the NRC are made to benefit the occupants of the room and have little effect on the transmission of sound from one space to another. For example, adding an acoustical ceiling in a mechanical room does not effectively shield the occupant on the floor above from noise.

Floor Vibration

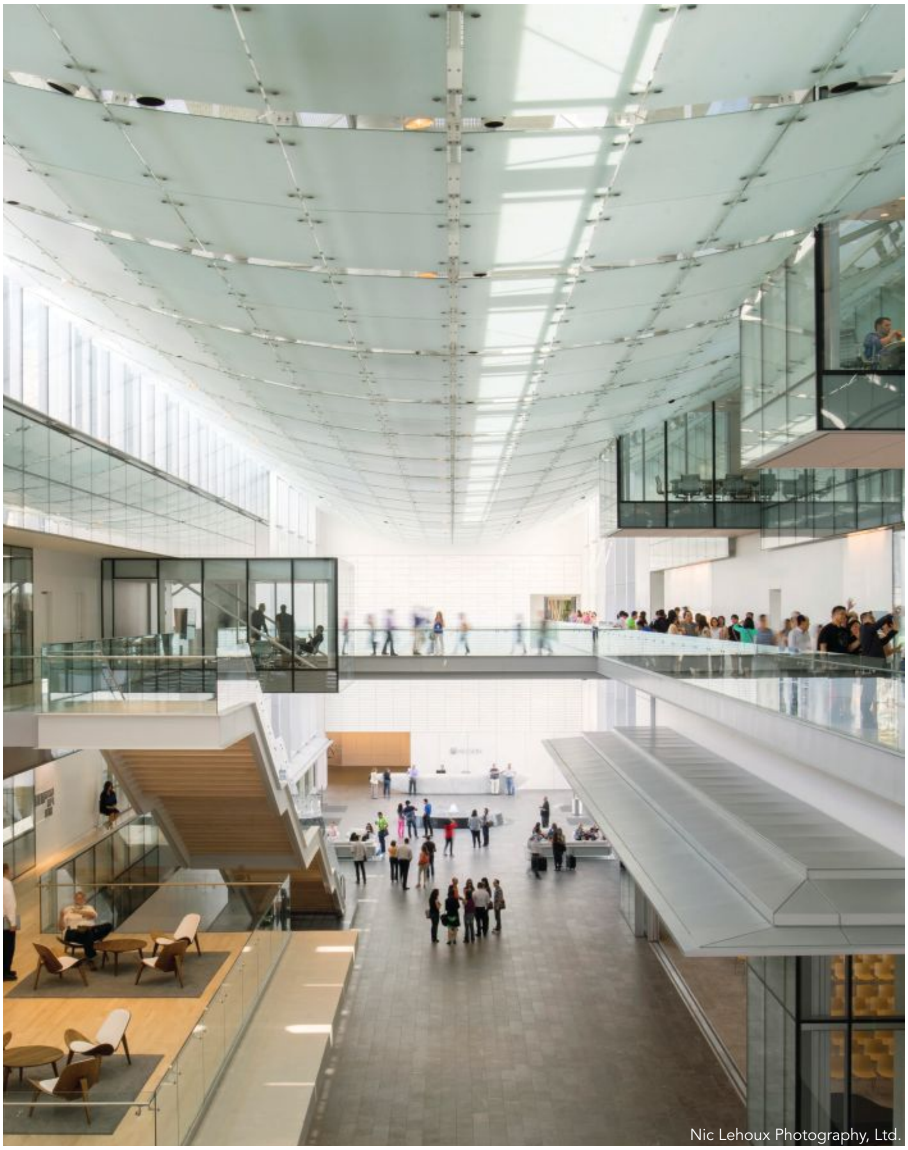
In addition to controlling noise transmission between adjacent spaces, floor vibration and the prevention of structure-borne noise from multiple sources must also be addressed and represent more significant challenges for the design team. Many buildings that we design consist of steel frame construction with floors of steel beams acting compositely with concrete slabs on metal deck. Floor beams in such an assembly vibrate at a natural frequency when an impact force is applied. This frequency depends upon the beam span, spacing between beams, and beam depth—properties that affect the stiffness of the framing system.

Methods to calculate the frequency of floor framing systems are included in publications such AISC Design Guide 11: *Vibrations of Steel-Framed Structural Systems Due to Human Activity*. In addition, FloorVibe is an analysis program (developed by renowned vibration expert Tom Murray, professor emeritus at Virginia Tech and co-author of Design Guide 11) that uses procedures in Design Guide 11 and is available as a stand-alone program (via **www.floorvibe.com**) or as a feature within Bentley's RAM Structural System.

Vibration perceived by building occupants is mitigated by damping and effective mass of the framing system, which acts to reduce peak acceleration in a vibrating system. Damping arises from the attachment of nonstructural elements, such as ceilings, mechanical equipment, partitions, and furnishings, to a floor system. The self-weight of a system significantly contributes to the effective mass.

Therefore, the components most under the control of the design engineer are the stiffness of the framing system and the mass of the floor slab. FloorVibe offers the designer the ability to adjust these parameters to perform a "what if" analysis, leading to an optimized design (Figure 4 illustrates FloorVibe user interface and input variables).

Vibration comes from various sources, including vehicular traffic on adjacent roads, airplanes, footfall traffic on supported floors, and mechanical equipment. Although all vibration sources must be considered, the most significant causes stem from foot traffic and mechanical equipment. Evaluation of design options, damping, source vibrations, and functions sensitive to vibration disturbance leads to basic layout and planning principles particularly applicable to steel buildings.



Nic Lehoux Photography, Ltd.

The Nu Skin Innovation Center in Provo, Utah, houses multiple space types, including research laboratories and a data center, that are sensitive to vibrations. To read about it, see "Extreme Makeover" in the February 2016 issue.

Corridors. The simple act of walking can produce troublesome vibrations within a bay of floor framing. In a typical building with a central corridor and rooms on both sides, it's structurally efficient to place columns along only one side of the corridor. This results in a long span from the corridor line of columns to the farthest exterior wall. The long span supports both the rooms and the corridor, and vibrations caused by footfall traffic in the corridor are directly transmitted into the rooms sharing the corridor support beams.

To mitigate this problem, place columns along both sides of the corridor. Although this requires additional columns and foundations, isolating corridor traffic with separate framing prevents vibrations from propagating into adjacent spaces. Furthermore, the shallower members that frame the short corridor span provide extra depth for utilities that compete for limited space above corridor ceilings.

Another corridor design consideration is the speed at which people walk. A fast-walking person generates vibration velocities 15 times greater than that of a person walking slowly. Therefore, corridor design should encourage slower-paced walking, such as designing with turns that break up the monotony of a longer, uninterrupted pathway. If this isn't feasible, incorporate visual breaks in floor patterns and lighting that emphasize elements transverse to the length of the corridor. Providing visual variety calms traffic, and people tend not to rush through pleasant spaces as fast as unpleasant ones.

Span. Bay size plays a critical factor in the vibration characteristics of a floor system. Since the stiffness of a beam varies with the cube of its length, shortening the span is an effective way to adjust its flexibility.

Note that not all spans in a building must be short. Designating sensitive equipment zones can provide vibration-safe areas and maintain a certain amount of flexibility for moving equipment within the zones but not penalize the entire structure with closer column spacing everywhere. Similarly, not all floor framing systems must satisfy the most stringent equipment requirements. Criteria are available that categorize sensitivity to vibration based upon equipment (such as magnification power of microscopes) or by use (such as micro-surgery) and can help the structural engineer fine-tune spaces for known uses.

Mass. The mass of floor slabs affects the vibration characteristics of the space. Office building floors often consist of 3¼ in. of lightweight concrete over the metal deck top flutes, yielding a two-hour fire rating. By comparison, 4½ in. of normal-weight concrete is required over the top flutes of the deck to achieve the same fire rating. Using lightweight concrete allows the use of lighter beams and can reduce footing sizes. However, vibration-sensitive spaces benefit from the greater effective mass provided by normal-weight concrete, and the special placement and finishing demands of lightweight concrete are eliminated. Even if the building code requires less stringent fire separation and a thinner slab would suffice, constructing a heavier slab improves the performance of the floor system from a vibration perspective.

Layout. A footfall impact at the midspan of a beam produces greater vibration than the same impact near a column. Furthermore, vibrations dissipate as they cross column lines, walls, and framing. Consequently, sensitive equipment placed close to columns and far away from corridors will perform better than equipment placed near bay centers and close to sources of excitation.

From an overall planning perspective, it's important to hold early discussions to identify critical equipment or functions and decide their appropriate locations within the building. For example, particularly sensitive equipment may want to occupy isolated slab-on-ground space rather than an elevated slab level.

A research facility we recently designed included an electron microscope with a particularly high sensitivity to environmental vibrations. This single piece of equipment needed a 3-ft-thick slab foundation isolated from the adjacent slab-on-ground with full-depth joints filled with a compressible material. Upper steel-framed floors were designed for a generic vibration criteria velocity tolerance limit of 2,000 micro-in. per second, suitable for bench microscopes up to 400 times magnification. (See AISC Design Guide 11 Table 6-2.)

Special Considerations

Of course, there are plenty of specific scenarios that require their own design considerations.

Floor isolation. One method of isolating an entire floor is constructing a room within a room. A secondary slab floating above the base structural slab on neoprene pads provides effective isolation of discrete areas. Combined with high-STC walls and an independent ceiling structure, this type of construction creates a well-protected shell. However, support of the base structural slab must still meet basic deflection limits, and the frequencies of the intended isolation must be determined. This type of construction typically involves an acoustical consultant.

Mechanical equipment isolation. Modern installations of mechanical equipment include vibration isolators, flexible couplings, and resilient hangers designed to prevent the transmission of equipment vibration into the structure. These are typically designed by the equipment manufacturer and not the project engineer. However, there is a useful concept to know about equipment isolators: Neoprene pads effectively prevent the transmission of high-frequency vibrations, such as those produced by a running motor. However, they are ineffective at preventing the transmission of low-frequency vibrations, such as jolts created when a motor starts and stops. Springs are needed to handle that type of action. For this reason, the best isolators for motors are comprised of both spring and neoprene materials.

Sensitive equipment isolation. Some specialized equipment comes standard with its own isolation system designed to prevent transmission of structure-borne vibrations into the equipment. Many of these systems include some type of inertia damper, and the structure must be designed for the additional weight.

Commissioning. More and more building owners are realizing the many benefits of commissioning, particularly with the demand for achieving LEED (Leadership in Energy and Environmental Design; see **www.usgbc.org**) certification. The intent of commissioning is to verify and make sure that fundamental building elements and systems are designed, installed, and calibrated to operate as intended. Discovering improperly installed or short-circuited isolation devices during the commissioning process can avoid complaints from users and potential equipment damage.

SCIF design and HEMP protection. As we design secure facilities for U.S. Government and private clients, we are often called upon to incorporate spaces protected from outside interference. A sensitive compartmented information facility (SCIF) is not only soundproof but also provides protection from radio frequency (RF) interference and other types of espionage. For critical electronic systems that must be in perpetual operation, high-altitude electromagnetic pulse (HEMP) protection is also required. HEMP is a near-instantaneous electromagnetic energy field produced in the atmosphere by the power and radiation of a nuclear explosion that damages electronic equipment over a wide area. Usually steel-framed, these facilities are highly specialized and complex and provide protection well beyond structure-born or airborne vibrations. A HEMP-protected space may be completely lined with steel plates with fully welded seams on all six sides.

High Performance

Steel-framed structures perform well when it comes to vibration and sound transmission parameters—especially when these parameters are addressed up front and using the proper tools. With AISC's related Design Guides, as well as analysis programs like FloorVibe, structural engineers and architects are armed with all the tools they need to accurately design steel floor systems to meet specific vibration-related performance criteria. With full control of adjusting the damping ratio, bay span, beam depth, beam spacing, walking criteria, and slab mass, the design engineer can optimize a steel-framed floor system, confident of meeting serviceability expectations. ■

You can find Design Guides 11 and 30, as well as the rest of AISC's library of Design Guides, at ***aisc.org/dg****. If you're looking for more information on these topics, AISC's "Facts for Steel Buildings" series (****aisc.org/publications/facts-for-steel-buildings****) is written in an FAQ-type format, addressing hundreds of practical questions that arise on projects every day. Volume 4 of the series covers sound isolation and noise control, and Volume 5 covers vibrations. You can also check out Benjamin Markham's engaging webinar, Sound Isolation and Noise Control, at* ***learning.aisc.org/catalog/?category=Demand****.*

Franklin D. Lancaster (**frank.lancaster@jacobs.com**) is the Global Federal Structural Practice Director and Southeast Operations Director for Jacobs.

Off to Work, We Go!

BY JOE DARDIS

The most recent domestic jobs report brings good news for the construction industry—and hopes that it will continue.

Fig. 1.
Total U.S. Non-Farm Employment (Seasonally Adjusted)

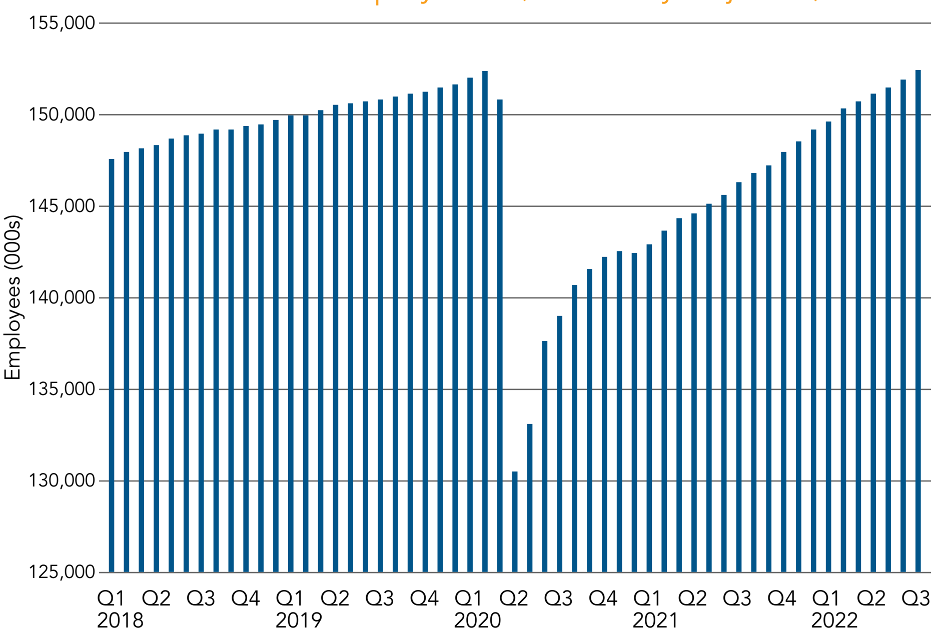
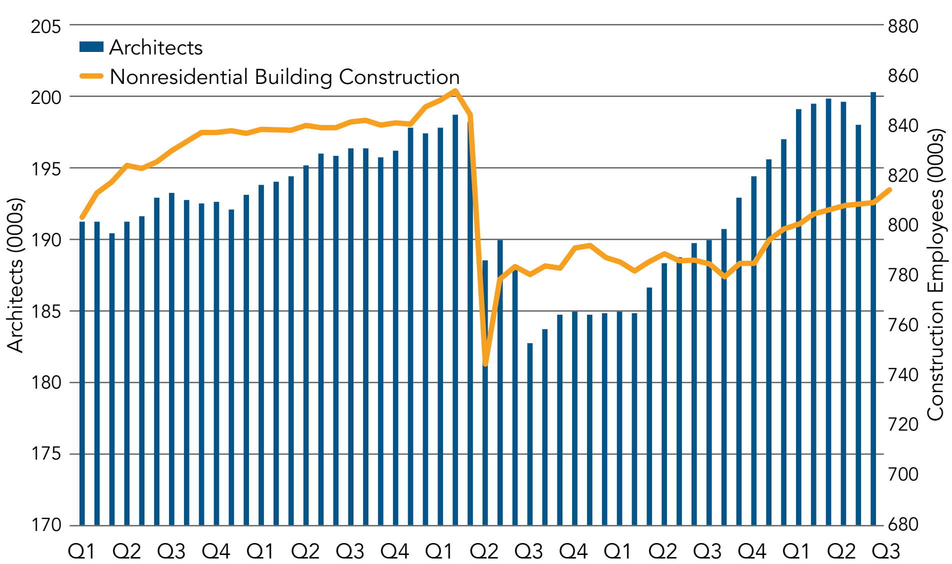


Fig. 2.
U.S. Architectural and Nonresidential Building Construction Employment (Seasonally Adjusted)



THE RELEASE of the July U.S. jobs report indicates that the economy has crossed a major milestone: U.S. employment levels have finally surpassed what they were pre-pandemic, totaling 152.5 million jobs, roughly 30,000 above the February 2020 employment level (Figure 1). Not only is this positive for the U.S. economy at large, but it's also great news for the building construction market.

Simply put, higher employment typically fuels nonresidential construction activity, driving demand for more office space, whether in traditional downtown cores or elsewhere–even in the form of residential add-ons to be used as home offices. Additionally, having more jobs implies that more individuals will be traveling, which is a catalyst for the retail and hospitality markets. And it drives demand for manufacturing space, as there are more workers on the floor. Ultimately, having more jobs equates to more money changing hands, more people occupying different spaces, more tax revenue collected, and subsequently more buildings.

Higher employment is also welcome news on the design side. Architectural employment (Figure 2), which dropped from 199,000 in February 2020 to roughly 184,000 in August 2020, surpassed 200,000 in June 2022. The increase in architecture employment indicates that firms are busier designing buildings, which bodes well for future building starts, particularly in architecturally heavy sectors like schools and hospitals.

Despite all the positive news, there is still "work" to be done. Figure 2 also shows nonresidential building construction employment, which is still lagging significantly from pre-recession levels. With overall and architectural employment on the upswing, it's a bit surprising to see nonresidential building construction employment lagging behind. The first reason for this is the mix of the current building market. Warehouses currently make up nearly half of commercial construction starts in terms of square footage, and these are simpler structures that require fewer trades onsite. The second reason is there aren't enough individuals to fill the open positions. There is, however, some recent positive momentum in the labor market. The number of general construction job openings has decreased by around 25% since April 2022, which also coincides with recent gains in employment levels for nonresidential construction.

Overall, there is reason to feel good about the construction market with the latest jobs report. Looking at the big picture, higher employment points to a higher level of building activity. The greater number of architects working also points to more building activity, although more in the institutional realm rather than distribution and warehousing. While this is all great news for the construction industry at large, including the steel design and fabrication community, it's only one jobs report. Time will tell how what the next report will bring, but in the meantime, this is welcome news, especially in the wake of a long string of not-so-good news over the past couple of years. ■

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

Half a Century in Steel

INTERVIEW BY GEOFF WEISENBERGER

Grady Harvell has been a driving force in Arkansas' steel industry, as well as in bringing a structural research lab to the state's flagship university.

Karen E. Segrave

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**.

GRADY HARVELL has not only been in the steel industry for a half-century, but he's also been with the same company the entire time.

And he's risen to the top, now serving as its president.

He was also one of this year's AISC Lifetime Achievement Awards in recognition of his drive to fund research to make steel bridges more economical, his commitment to steel bridge education and research, and his contributions to the National Steel Bridge Alliance (NSBA).

I had the chance to chat with Grady at the 2022 NASCC: The Steel Conference in Denver, where he was recognized, along with the rest of this year's AISC award winners. We talked about how he got into the steel business, his favorite bridges, his successful initiative to build a structural research laboratory at his alma mater (the University of Arkansas in Fayetteville), and his advice to students considering a career in the steel industry.

As the winner of an AISC Lifetime Achievement Award, I'd like to hear about your life in the steel industry. How did you get into the steel business in the first place?

I had a structures professor who introduced me to Harold Engstrom, who was involved with students at the University of Arkansas during my senior year, and Mr. Engstrom, then the vice president of engineering with AFCO Steel, asked if I'd be interested in interviewing with the company in Little Rock when I graduated from college (W&W Steel purchased AFCO Steel in 2002 and combined the companies into W&W|AFCO Steel). And I did. I accepted the job and I've been there for 50 years.

That is definitely a lifetime in the industry! So you started off with building projects at AFCO?

Yes, I started with building structures. I was hired as a design engineer. I have a bachelor of science degree in civil engineering with a specialty in structures, and my first two years there were spent doing nothing but design work on steel buildings.

How did you move into bridges?

Mr. Engstrom asked me to start helping our bridge team and in 1976, asked me to become part of the sales team. So I started with that group and got involved in the sales and estimating of the bridges, as well as the fabrication, and I've been there ever since.

Speaking of bridges, do you have a favorite steel bridge?

Obviously, it would be the "Stan Span"—the Stan Musial Veterans Memorial Bridge—over the Mississippi River in St. Louis, a cable-stayed bridge that we did back around 2010 or 2011. And then there's also the Christopher S. Bond Bridge, also known as the New Paseo Bridge, over the Missouri River in Kansas City. So we have bridges on both sides of the state of Missouri that we fabricated—iconic and very pretty structures. (The Stan Musial Veterans Memorial Bridge was a Merit winner in the 2016 Prize Bridge Awards competition; see the June 2016 issue at **www.modernsteel.com**.)

"After you do a design, you need to really look at things from a broader point of view and try to make sure that everything you're designing is rational."

Excellent! Let's talk about your interest in students and your drive to further education. If you're talking to a college student who's thinking about a career in steel bridge design or fabrication, are there certain things they should keep in mind?

Number one, I'd say don't lose sight of standing back and looking at your work. After you do the design, you should also do an overview of it. Engineers can get so lost in the details and the minutiae that we sometimes forget to sit back and look at a design to see if it makes sense. You need to really look at things from a broader point of view and try to make sure that everything you're designing is rational. I think that's the best advice I can give.

Can you talk about some of your work with NSBA?

Well, I was on an NSBA committee for several years, involved in promoting weathering steel. We were also looking at shear studs on steel bridges and have been very instrumental in working with my alma mater, the University of Arkansas, doing stud research to try to reduce the number of steel studs that are required in composite action. So far, I think we've been successful in accomplishing that and getting it into the AASHTO LRFD *Bridge Design Specifications*. That makes steel bridges more economical for everyone.

Speaking of steel bridge research, I understand you now have a lab named after yourself at the University of Arkansas, the Grady E. Harvell Civil Engineering Research and Education Center. Can you talk a little bit about your involvement in getting that project off the ground?

We set a goal in 1999 to build a structures lab for the University of Arkansas' Civil Engineering Department because they needed it. The students were able to learn the technical aspects of design, but that didn't always give them a feel for the structure. A lab gives you the opportunity to actually see and feel and watch structures as they fail and how they react when they're put under stress and loads. And I think that's a very important part of a student's education and engineering degree—to physically work in the lab and see the structures as they interact with the forces that are applied to them.

I love the university, and my thought was that if they wanted to stay competitive, it was worth pursuing a lab. And with the help of a lot of people, we were able to get it accomplished, and it opened in July of 2021. In fact, one of the first research projects Gary Prinz, a professor in the Civil Engineering Department, has been working on is a project for AISC involving reduced beam sections.

That's what we like to hear! Speaking of AISC, since we're here at NASCC, I'm just curious, how many Steel Conferences have you been to?

I lose track of those. I don't go to all of them, but I'll go to one every few years, depending on how busy I am at the time. But I always insist that our engineering and operations departments send people to attend so we can keep up with the technology and the research and innovations in the steel industry—especially equipment. Equipment changes constantly, and you have to stay up to speed with what's going on since it's such a competitive industry. ■

This column was excerpted from my conversation with Grady. To hear more from him, check out the October Field Notes podcast at ***modernsteel.com/podcasts****. Grady was one of several award winners that I interviewed at this year's Steel Conference in Denver, and we'll post videos of all the interviews later this year on AISC's YouTube channel at* ***youtube.com/AISCSteelTV****. And you can also read interviews with a couple of other winners: Gian Rassati in the June issue and Allen Adams in the September issue, both available in the Archives section at* ***www.modernsteel.com****.*

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

The Value of Reverence

BY DAN COUGHLIN

Mutual respect can elevate just about any relationship at work, at home, or anywhere else.

REVERENCE IS A DIGNIFIED WORD. Since I'm a self-professed non-fancy-word kind of guy, I had to look it up. It sounded so, well, fancy to me. This time, I like the Merriam-Webster definition better than anything I could have come up with. The definition of reverence is "respect felt or shown."

I love that. It's so simple. Success in relationships comes down to respect that goes both ways. The respect that you feel coming from the other person and the respect you show the other person. The enormous value of reverence is true in marriages, friendships, families, communities, and work relationships. Rather than trying to break respect down into seven easy-to-remember steps, I'm just going to share with you one remarkable example of reverence in my life.

It's about my friend Jeff Hutchison. I met "Hutch" in 1978 when we were 15-year-old sophomores in Mr. Calacci's World Cultures class. We sat right next to each other. We hit it off from day one. He's been my best buddy for 43 years.

In high school, Hutch was already a salesman extraordinaire. He went on to have a fabulous career in sales, first as a rep and then as an executive. He's worked for Proctor and Gamble, Brach's Candy, Boston Scientific, Medtronic, Motus GI, and a few other great companies. He's lived in Texas, Minneapolis, Chicago, and Nashville.

I was an aspiring teacher when we met. In the summers, I worked at camps for grade school kids and then went on to be a high school math teacher, a soccer coach, and eventually an executive coach and seminar leader. I lived in Indiana, Chicago, and St. Louis.

Since 1981, Hutch and I have gone to different colleges, lived in different cities, and worked in different industries. Hutch has three children and I have two, and they are all in their twenties. Our personal and professional lives never overlapped, except for three weeks in 1989 when we lived together in Chicago, as he was moving to the Windy City and I was leaving.

And yet somehow, we've managed to talk at least once every other week for 43 years.

Hutch has been married to Jean for 32 years, and I've been married to Barb for 25 years.

Last weekend, for the first time ever, the four of us spent a weekend together in Nashville without anyone else. And we had a blast for three days. It was as if we were together all the time.

What's the secret? How in the world have Hutch and I been able to maintain such a high-quality friendship over the past five decades? It all comes down to that fancy word: reverence. But *how* has it worked?

- We've consistently shown each other respect and felt respect from each other
- We know every dream the other person has aspired after, and we've respectfully cheered each other on
- We know each other's successes and failures
- We have respectfully given each other mountains of advice, and we have each received the advice in a respectful way

- We have respectfully been supportive of the other person's children and their efforts
- We listen respectfully to each other and apologize when we make a mistake
- We still occasionally hand write respectful letters of encouragement to each other
- We look forward to our next respectful conversation

Imagine if every relationship in our lives was filled with reverence. What would our work lives be like? What would our families, our communities, our politics, and our world be like if we could all value reverence as a top priority?

In 1993, a slim book called *Reverence for Life*, was published, and a second edition came out in 2016. It's a collection of statements from Albert Schweitzer, the famous jungle doctor, that were culled from more than 50 years of his writings. *Reverence for Life* was the core philosophy of Schweitzer, who lived from 1875 to 1965. This little book is filled with powerful statements about the importance of reverence in relationships.

Here is a quote from page 9, which Schweitzer first said in an interview in 1959:

"When we are truly filled with the idea of reverence for life, all our attitudes, thinking, and actions change. We must go deep into ourselves to find inspiration. If we turn within, pondering our duty in this world in silence, and act to move toward this goal, a change will come about. There are many opportunities to prove that we live in the spirit of the philosophy of reverence for life."

I think it's a great mindset, and I think if you take it seriously, you'll see improvements in your relationships at home, at the workplace, and everywhere else. You won't always agree with everyone in all of those environments, but your relationships with them will almost certainly become more positive. ■

Since 1998, **Dan Coughlin** has worked with business leaders to consistently deliver excellence, providing coaching and seminars to executives and groups, as well as guiding strategic decision-making meetings. And now he is also focused on helping people on their inner journey to excellence. Visit his free *Business Performance Idea Center* at **www.thecoughlincompany.com**. Dan has also given several presentations in recent years at NASCC: The Steel Conference. To hear recordings of them, visit **aisc.org/education-archives** and search for "Coughlin."

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Trimble.

Nashville's upgraded airport will soon greet passengers with a signature steel "airwave" roof and accompanying pedestrian bridge.

Riding the Wave

BY KEVIN A. KUNTZ, SE, AND TERRY PALMER, PE

Courtesy Fentress Architects

LAST YEAR, NASHVILLE made headlines when it topped the list of American cities experiencing the most economic growth.

For proof, one simply needs to walk the city's downtown streets and observe the cranes crowding the skyline and construction sites transforming city blocks. This regional growth also has spurred Nashville International Airport (BNA) to pursue its "BNA Vision." This bold, forward-looking expansion plan creates a world-class facility serving the city's booming population and the airport's record-breaking passenger volumes.

BNA Vision includes multiple elements—Concourse D, the Central Utility Plant, a three-phased Terminal Parking Complex, an on-site Hilton hotel, a future Transit Connector, and the Terminal Lobby and International Arrivals Facility (IAF) expansion. When completed in 2023, a pedestrian bridge will connect the Terminal Parking Complex to the Terminal Lobby and IAF, which offer two dozen passenger-screening lanes, six state-of-the-art gates for international travel, and a new marketplace food court with clear airfield views and a stage for live music.

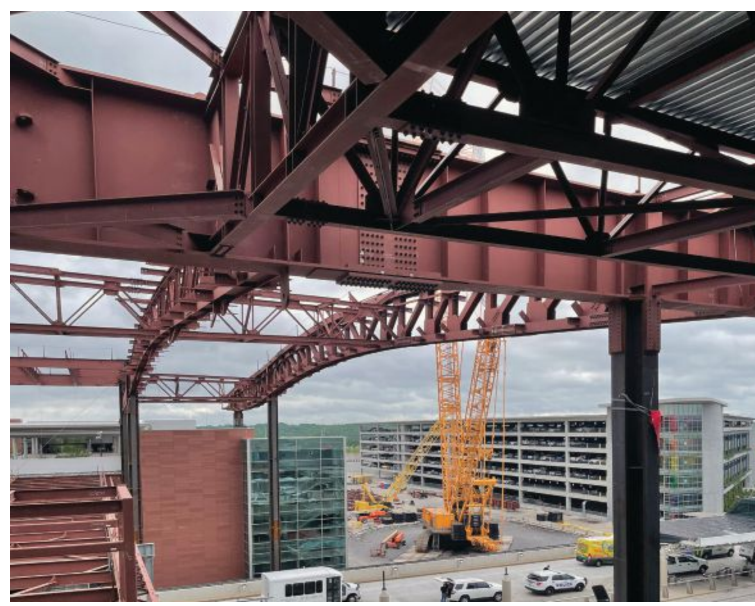
The signature feature of the Terminal Lobby and IAF project is a sleek, iconic "airwave" roof canopy. This 150,000-sq.-ft, curvilinear structure completely reshapes the terminal's form and volume, creating a singular architectural mantra from the passenger drop-off at the roadway to the airfield beyond.

To ensure a uniform campus design, the Metropolitan Nashville Airport Authority selected Corgan as the "master architect" tasked with guiding the airport architecture, creating cohesive concepts for each project, and phasing the construction to keep the airport fully operational around the clock. In addition, a opposite: Nashville International Airport's (BNA's) iconic "airwave" roof.

Images this page courtesy MKA

above and below: Long-span spine trusses support the airwave roof.

left: Large cruciform columns were designed to support the gravity and lateral loads against the wind during the roof's erection and upon the structure's completion.



progressive design-build method for each project provided quick and efficient delivery.

The new Terminal Lobby and IAF expansion generated much construction-industry interest and fierce competition. As a result, the design-build team—Hensel Phelps (HP), Fentress Architects, and Magnusson Klemencic Associates (MKA)—searched for opportunities during the request for proposals (RFP) stage to enhance the design concept, reduce cost, and minimize risks that might interfere with airport operations.

Long-Span Spine

HP's team proposed a key structural design enhancement: raising the proposed airwave roof up a few feet to allow it to span the roadway and existing terminal. By doing so, the existing interior columns above the departures level floor could be removed to achieve extraordinary openness, enhanced views, and ideal daylighting within. In addition, leaving the existing roof in place provided two ancillary functions: weather protection until the new roof was built and a work platform to install some of the new ductwork, lights, and sprinkler pipes. Moreover, the existing columns and footings did not require retrofitting, saving over $5 million.

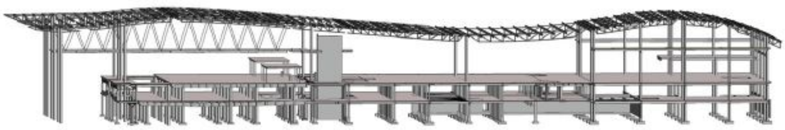
The proposed long-span roof was created by inserting two longitudinal "spine" trusses that traversed the 660-ft-long airwave from the garage to the airfield. This solution minimized the number of curved trusses, eased fabrication costs, and enhanced the roof's stability during erection.

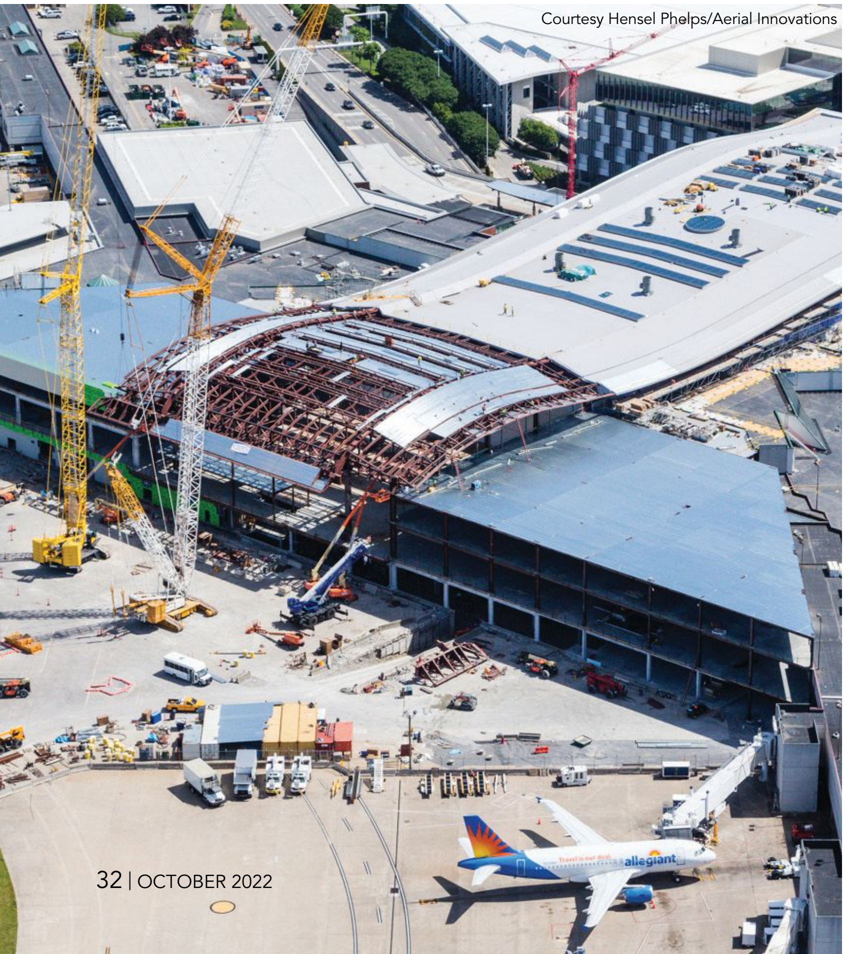
With the roof concept finalized, the next crucial step was to identify locations to surgically place columns without impacting

The airwave roof spanning the existing terminal and roadway.

Courtesy MKA

The original RFP concepts (above) compared to MKA's design (below). The latter reduced the number of columns by 68% and eliminated the braced frames.





Courtesy Hensel Phelps/Aerial Innovations

Courtesy Hensel Phelps/Matt Good (www.mattshootsforgood.com)

above: A roof spine truss being erected.

left: The airwave roof's third section being erected.

below: Cantilevered trusses taper down to a knife-edge resembling the shape of aircraft wings.

Courtesy Hensel Phelps/Matt Good (www.mattshootsforgood.com) airport operations whatsoever—a challenge, to be sure, given that they needed to be placed within the adjoining garage egress core, through the existing roadway, inside the terminal's glass façade, and outside the existing terminal on the current airfield.

The desire to minimize the number of columns also resulted in the innovative use of two W36s welded together to create large cruciform columns to support the gravity load and lateral loads against the wind during the roof's erection and upon the structure's completion. This clever solution proved invaluable during a 90-mile-per-hour windstorm that occurred when the roof was 50% erected! In addition, cruciform columns eliminated the need for temporary roof shoring and minimized temporary braces during steel erection. The final steel portion was located directly adjacent to the airfield. Since this area consists of all new construction, more moment frame elements were installed to provide the final lateral stability for the entire new terminal.

Overall, the final structural design reduced the number of columns supporting the airwave roof from 88 in the RFP concept to 28 in the final structural design—an impressive 68% reduction in columns. This resulted in open spaces that yield incredible views, ample natural light, and a resilient design that readily accommodates future floor plan changes without having columns or braces in the way.

Supporting the Airwave

Early in the design, MKA worked closely with HP, fabricator Banker Steel, and steel erector Derr and Isbell to vet fabrication, connection, and erection issues. In addition, the team studied geometric clarity for the radial arcs and tangents of the desired roof form to determine the most cost-effective way to bend and connect the roof members.

Ten-ft-deep Pratt trusses with W36 chords oriented in their weak axis comprised the 660-ft-long spine trusses, thus providing a naturally stable truss readily pre-assembled in the shop and transported via truck to the site with minimal field splices. Secondary transverse trusses fill in the rest of the airwave roof between and outside the spine trusses. Early on, MKA proposed using straight secondary transverse trusses spanning 130 ft to frame into the curved spine trusses. This framing layout resulted in the minimum number of curved members, thus saving considerable fabrication cost and, most importantly, creating an elegant roof form that delicately curves to create the true roof structural shape. Workers positioned 50-ft-long wing trusses outboard of each transverse truss. These cantilevered trusses contain W10 chords and double-angle webs configured in a modified Warren truss profile and taper down to a knife-edge resembling the shape of aircraft wings.

As mentioned, column locations had to be coordinated closely with the existing terminal. The spine trusses did not land directly on a column in some areas, so support at these offset locations was provided with tapered plate girders 10 ft deep and spanning the cruciform columns, thus creating a colossal moment frame. The robust plate girders were fabricated from grade 65 (ASTM A913) plates with 1-in.-thick webs and flanges measuring 20 in. wide and 2.5 in. thick.

A Grand Entry

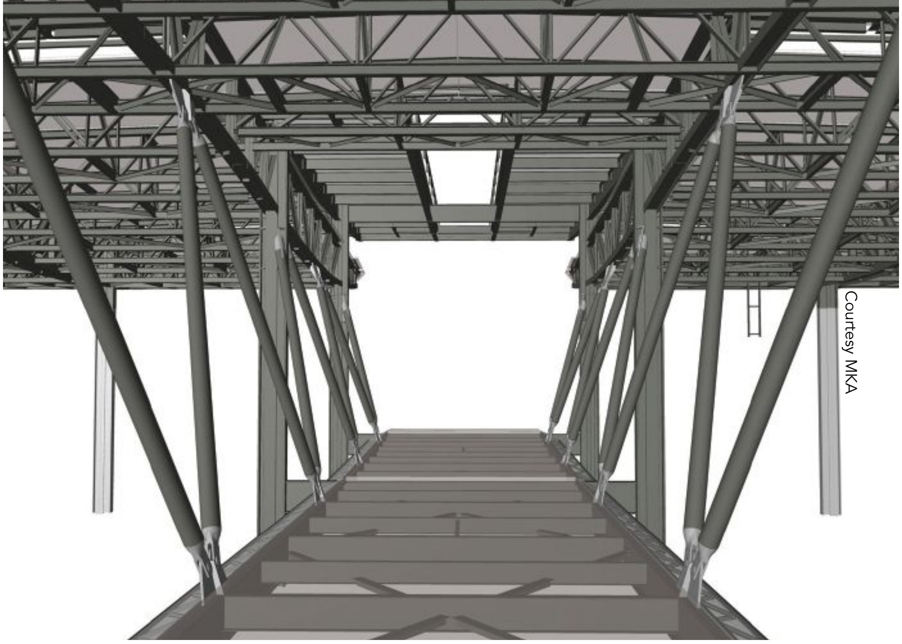
Another design opportunity for the team involved connecting the Terminal Parking Complex to the Terminal Lobby and IAF using a steel pedestrian bridge spanning the roadway that creates a dramatic first impression for passengers and gives them tremendous views as they enter the terminal.

Initially, the concept design envisioned a pedestrian bridge hung from the roof via cables. However, after studying several design options, MKA opted to move the bridge's support columns to avoid penetrating or reinforcing the existing roadway below. In addition, to alleviate bridge vibration issues and deflections, as well as reduce steel tonnage, MKA determined that 14-in.-diameter round hollow structural sections (HSS) could replace the cables and create full-height trusses.

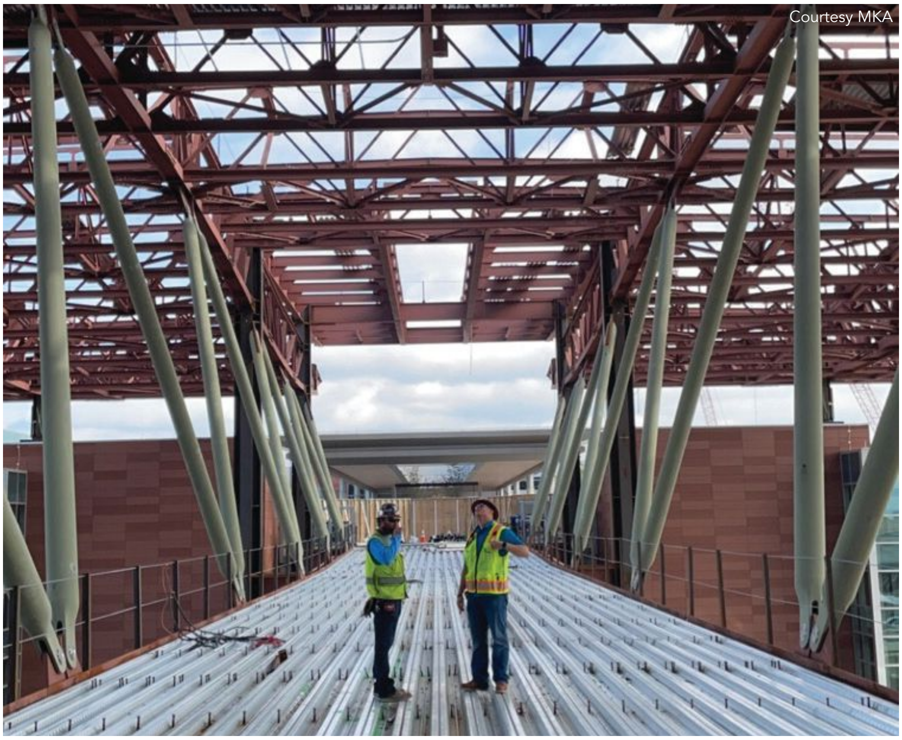
The resulting bridge structure, which is 48 ft deep, is efficient, meets AISC Design Guide 11: *Vibrations of Steel-Framed Structural Systems Due to Human Activity* criteria (**aisc.org/dg**), and easily spans 170 ft with no perceivable vibration or deflection. In addition, stainless steel castings provided by Cast Connex provide an elegantly exposed diagonal connection to the top and bottom chords.

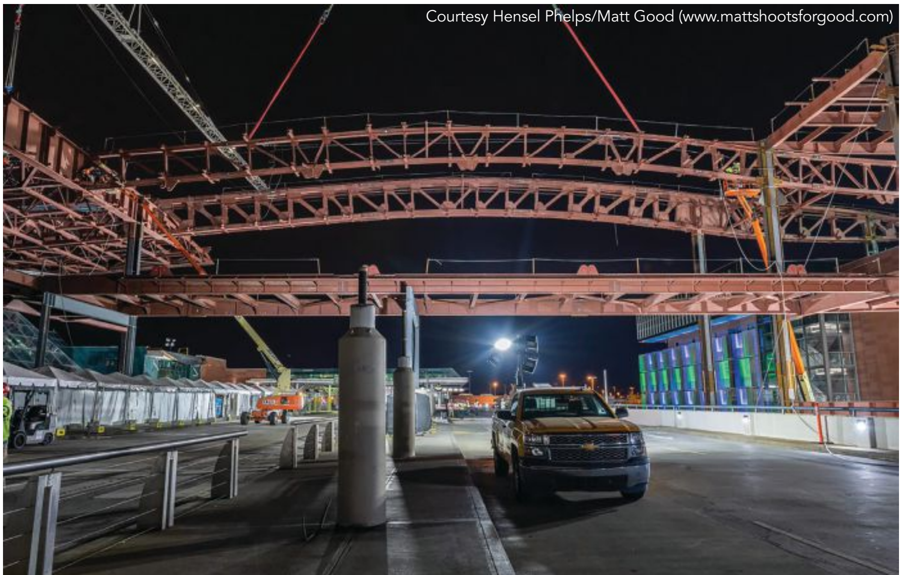
Airport officials made it clear the roadway could never shut down, and traffic restrictions to install temporary shores were prohibited. Therefore, MKA worked closely with HP and Derr and Isbell to develop a phased structural analysis of the pedestrian bridge. This analysis considered the top two trusses supporting the roof above the bridge as independent members that initially support some roof loads. These trusses connected to the floor girders via diagonal web members to create a deep truss, and Derr and Isbell elected to field-measure the diagonals and "cut to fit" to achieve the precision needed for the pin connection installation.

The project contains 6,255 tons of steel, with 4,418 tons erected in 2021 alone. Placing that much steel is challenging, especially when erecting steel over an operational airport terminal, requiring precision planning and microphasing. Site constraints further complicated construction and required more than half of the roof steel to be staged across the airport roadway and erected from a Demag CC 8800 crane. This mammoth crawler crane, with a lifting capacity of 3,200 tons and a main boom reaching 384 ft, allowed for the precise installation of major


Courtesy MKA

above and below: A pedestrian bridge spans the roadway and connects the terminal parking complex to the terminal lobby and IAF.


Courtesy MKA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Trusses erected at night over the roadway.

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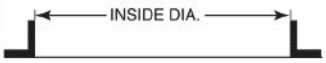
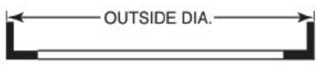


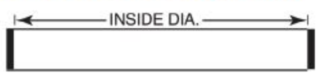
10" x 10" x 1" Angle

2 **Angle Leg In**


10" x 10" x 1" Angle

3 **Flat Bar The Hard Way**


24" x 12" Flat

4 **Flat Bar The Easy Way**


36" x 12" Flat

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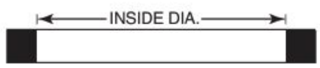
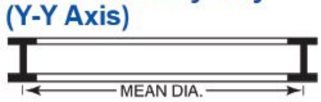
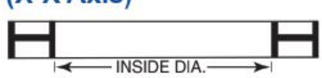


18" Square

6 **Beam The Easy Way (Y-Y Axis)**


44" x 335#, 36" x 925#

7 **Beam The Hard Way (X-X Axis)**


44" x 285#

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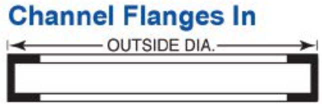
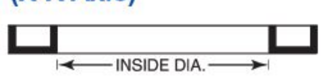


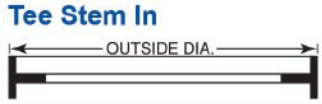
All Sizes

9 **Channel Flanges Out**


All Sizes

10 **Channel The Hard Way (X-X Axis)**


All Sizes

11 **Tee Stem In**


22" x 142 1/2# Tee

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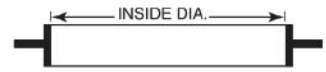
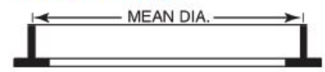
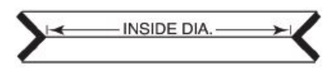
12 **Tee Stem Out**


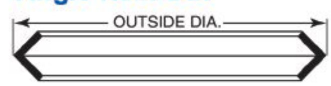
22" x 142 1/2# Tee

13 **Tee Stem Up**


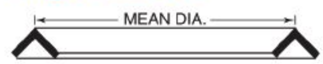
22" x 142 1/2# Tee

14 **Angle Heel In**


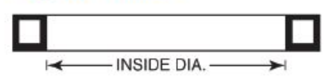
8" x 8" x 1" Angle

15 **Angle Heel Out**


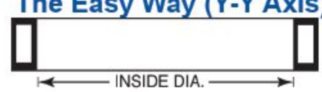
8" x 8" x 1" Angle

16 **Angle Heel Up**


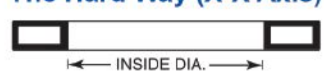
8" x 8"x1" Angle

17 **Square Tube**


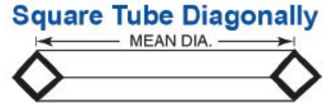
24" x 1/2" Tube

18 **Rectangular Tube The Easy Way (Y-Y Axis)**


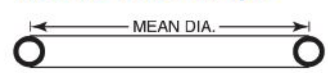
20" x 12" x 5/8" Tube

19 **Rectangular Tube The Hard Way (X-X Axis)**


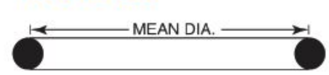
20" x 12" x 5/8" Tube

20 **Square Tube Diagonally**


12" x 5/8" Square Tube

21 **Round Tube & Pipe**


24" Sched. 80 Pipe

22 **Round Bar**


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steel elements over the operating terminal and roadway below.

The steel structure for the Terminal Lobby and IAF Expansion was topped out in May 2022, and the new terminal will open in phases starting in January 2023 and fully open by the end of 2023. This new world-class facility will be the major gateway to Nashville and the region, one that proudly defines and represents Music City. ■

Owners
Nashville International Airport
Metropolitan Nashville Airport Authority

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Architect
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Associate Architect
TM Partners

Master Architect – BNA Vision
Corgan

Lead Structural Design
Magnusson Klemencic Associates

Substructure Design
Logan Patri Engineering

Steel Team

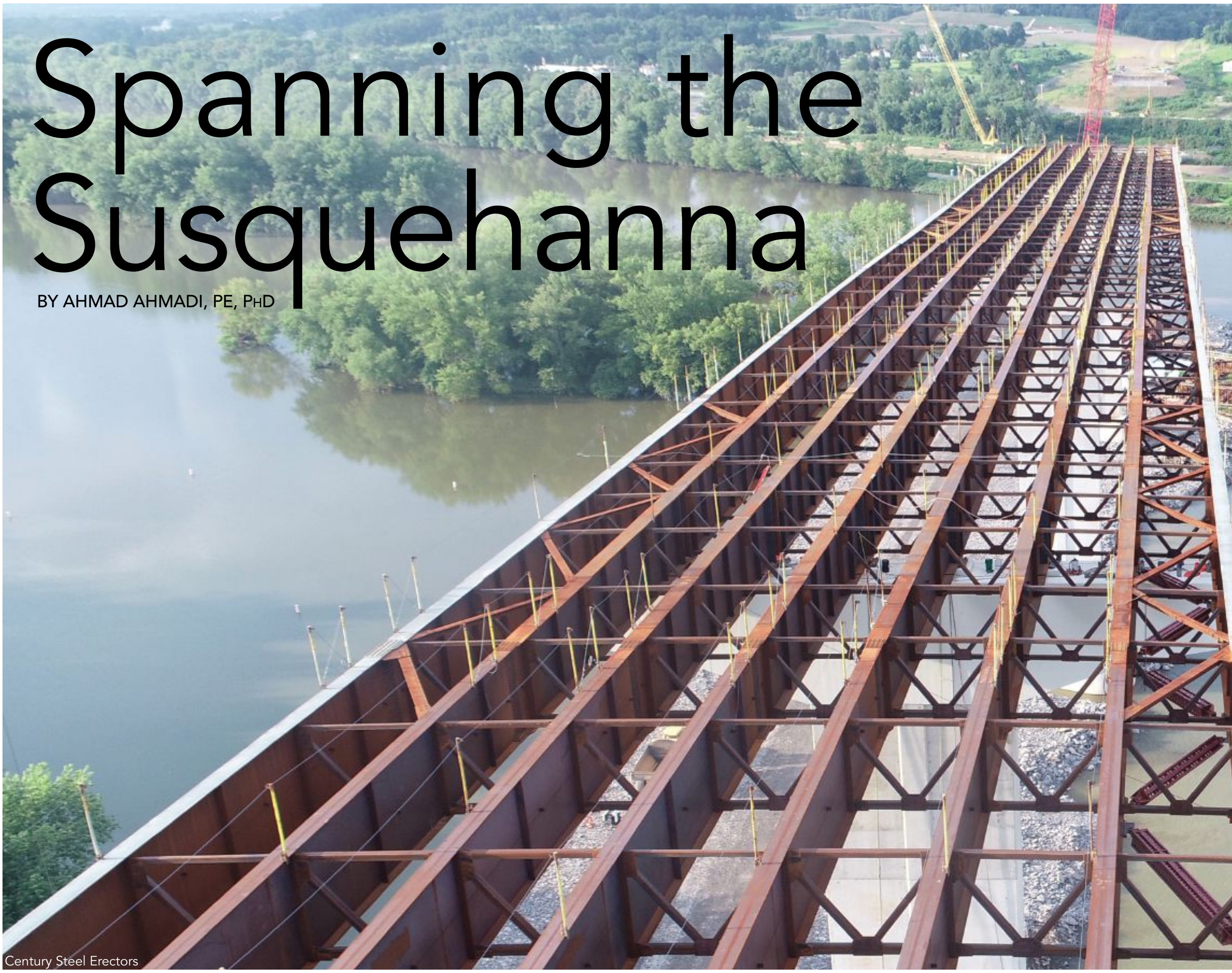
Fabricator
Banker Steel Company
Lynchburg, Va.

Erector
Derr and Isbell (now a subsidiary of Schuff Steel)

Kevin A. Kuntz (kkuntz@mka.com) is a senior design engineer at Magnusson Klemencic Associates, and **Terry Palmer** (tpalmer@mka.com) is a senior principal who leads the firm's Aviation Market Sector.

Spanning the Susquehanna

BY AHMAD AHMADI, PE, PhD



Century Steel Erectors

THE SUSQUEHANNA RIVER, the longest river on the East Coast, bisects Pennsylvania from top to bottom.

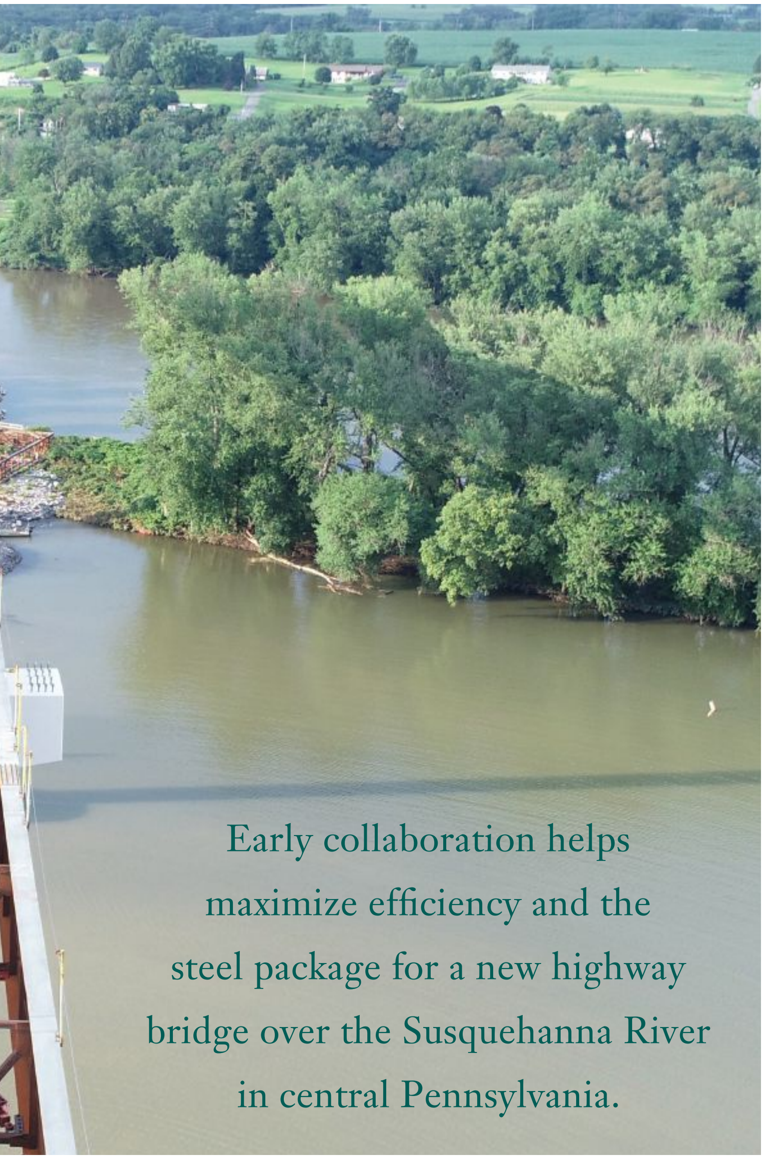
And bisecting this massive waterway in central Pennsylvania is the new Central Susquehanna Valley Transportation (CSVT) River Bridge, the eighth-longest crossing in the Pennsylvania Department of Transportation (PennDOT) catalog.

The 4,545-ft, six-lane bridge over the Susquehanna's west branch is part of a new 13-mile-long limited-access highway connecting PA 147 in Northumberland County to US 11/15 in Snyder County in central Pennsylvania. Built to provide a convenient new crossing over the river, improve safety, reduce congestion, and accommodate growth, the bridge is framed with 11,750 tons of structural steel.

The bridge consists of three five-span units, each 1,515 ft long, with spans ranging from 238 ft to 350 ft, and the superstructure comprises eight weathering steel plate girders. The out-to-out width is nearly 90 ft, and the bridge was designed to be widened during future re-decking to nearly 96 ft. The 14 piers vary in height from 75 ft to 180 ft and are supported by spread footings on rock or caissons with pile caps and stub abutments supported on steel piles.

The bid package for this project provided plans for the "as-designed" steel bridge and permitted companies to submit an alternate steel or concrete bridge design with their bid. At Trumbull's (the general contractor) request, SAI Consulting Engineers developed an alternate steel bridge design, including preliminary drawings and quantities, in less than three months. After reviewing SAI's alternate steel bridge design and the as-designed bridge, the contractor decided to bid SAI's alternate steel design. During the final design of the superstructure and substructures, constant communication between SAI and Trumbull helped reduce the steel package by more than 2,500 tons of structural steel and 4,000 tons of steel reinforcement from the original as-designed plans.

Overall constructability of the bridge, including girder erection, was completed without any major issues. Connections were drilled with computer numerically controlled (CNC) equipment, and shop assembly was performed by one girder line check assembly only (no cross frames or lateral braces included). Girders were designed with lateral bracing for wind in the three to four diaphragm spaces from both sides of the piers with the assumption that additional lateral bracing will be provided (if needed) during the girder erections. Based on the girder erection analysis, additional lateral bracing was later added. To improve the overall construction schedule, the team acquired steel and started steel fabrication as early as possible, which



Early collaboration helps maximize efficiency and the steel package for a new highway bridge over the Susquehanna River in central Pennsylvania.

was made possible because the superstructure was designed and submitted for review and approval while the substructure was under design. In addition, the design simplified steel procurement by using standard details that could be easily detailed and fabricated, and SAI consulted with fabricator High Steel Structures during the design phase to develop the most cost-effective details.

3D Analysis and Modeling

SAI analyzed all construction stages, including steel erection (performed by AISC certified erector Century Steel Erectors), deck placement sequence, wind loads, as-built condition, staged re-decking, and future widened conditions with its in-house, PennDOT-approved Load3D program. The program creates an influence surface for each structural member and then loads the surface to maximize the force effects due to AASHTO/PennDOT vehicular loads. Since the model is 3D, the actual girder depth, flange sizes, diaphragm sizes, and all other structural elements are included.

While Load3D was used for all vertical load cases, STAAD-Pro was used for all lateral load cases, including wind load and overhang bracket loading. Loads used for designing the diaphragms and lateral bracing and girder cambers were obtained from a 3D model of the structure.

The 4,545-ft, six-lane bridge over the Susquehanna's west branch is part of a new 13-mile-long limited-access highway connecting PA 147 in Northumberland County to US 11/15 in Snyder County in central Pennsylvania.

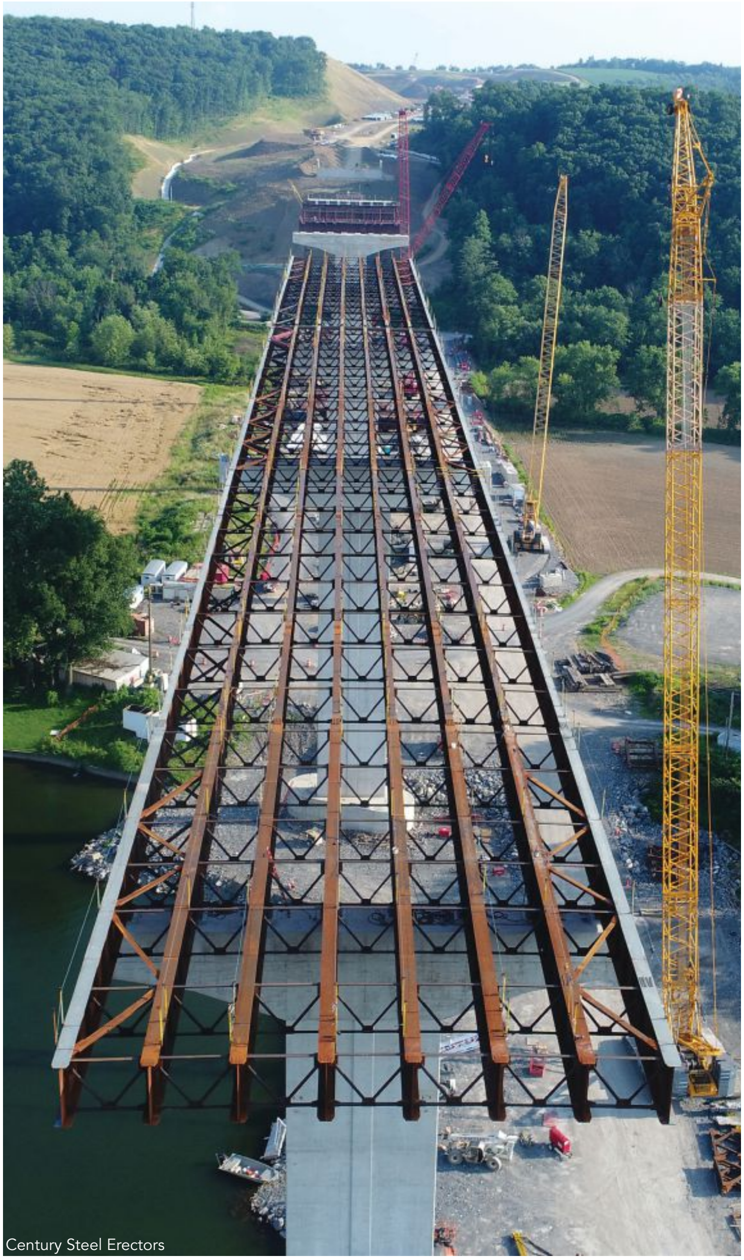
McTish, Kunkel & Associates

Girder Design

All bottom flange and some top flange plate steel is ASTM A709 Grade HPS 70W, and web plate steel, all 9.5 ft deep, is ASTM A709 Grade 50W. In addition to the ongoing collaboration between engineer and contractor, employing Grade 70 steel, 3D modeling for wind analysis during construction, and 3D modeling for detailed analysis of the diaphragms for the final superstructure cross sections and the future phased re-decking contributed to the significant weight savings.

Grouping structural elements for design and "simplifying" details allowed for significant repetitive detailing in the structure, which increased the competitiveness of the steel multi-girder alternative. Considering the length of the structure, every small flange change resulted in tens of thousands of pounds of steel. In addition, the economy of scale was magnified due to the replication of two of the three units. During conceptual design, various girder configurations were considered, and SAI and Trumbull eventually settled on the most efficient number of (eight) and spacing between (12 ft, 3 in.) girders, resulting in an optimal girder, deck, stay-in-place (SIP), and overhang design.


Century Steel Erectors


Century Steel Erectors

The bridge consists of three five-span units, each 1,515 ft long, with spans ranging from 238 ft to 350 ft, and the superstructure comprises eight weathering steel plate girders. In all, the bridge uses 11,750 tons of structural steel.

Using 3D modeling for lateral stresses due to wind was also crucial to designing an efficient girder. The most common types of failure from this load case are top flange lateral torsional buckling failure or top flange local buckling, which can occur due to large lateral stresses from wind combined with compression in the top flange due to self-weight. From experience, it was anticipated that scenario could govern the design, so it was investigated during conceptual design, resulting in the top flange being changed to Grade 70 from Grade 50 in some cases to alleviate over-stressing the flanges. All flange width changes were made at the field splices in order to reduce costly shop splice width transitions. Flange thickness changes were made wherever possible so that around a minimum of a half-ton of steel savings were achieved to justify the labor of introducing the shop (welded) splice.

Girder field sections were limited to 120 ft for shipping purposes, resulting in a total of 384 field splices. To simplify fabrication and construction, all 384 splices were divided into 12 different groups, which were used throughout the job for all girders. The effort involved in compiling the loading data for all 384 splices was extensive, and grouping the splices based on loading and flange geometry was equally challenging. However, the simplicity of only having 12 splice types throughout the job reduced potential construction and fabrication issues, and saving time in this area helped free up time for field crews to align and tighten nearly 100,000 bolts.

The future widened overhang governed girder design. As a result, the exterior girders carried a significantly higher live load compared to the interior girders. In addition, the exterior girders carried more wind load, especially at mid-span. A separate design was performed for the interior and exterior girders to increase savings. With the exterior girders being stronger, the AASHTO requirement that the exterior girder shall not have less resistance than the interior was satisfied.

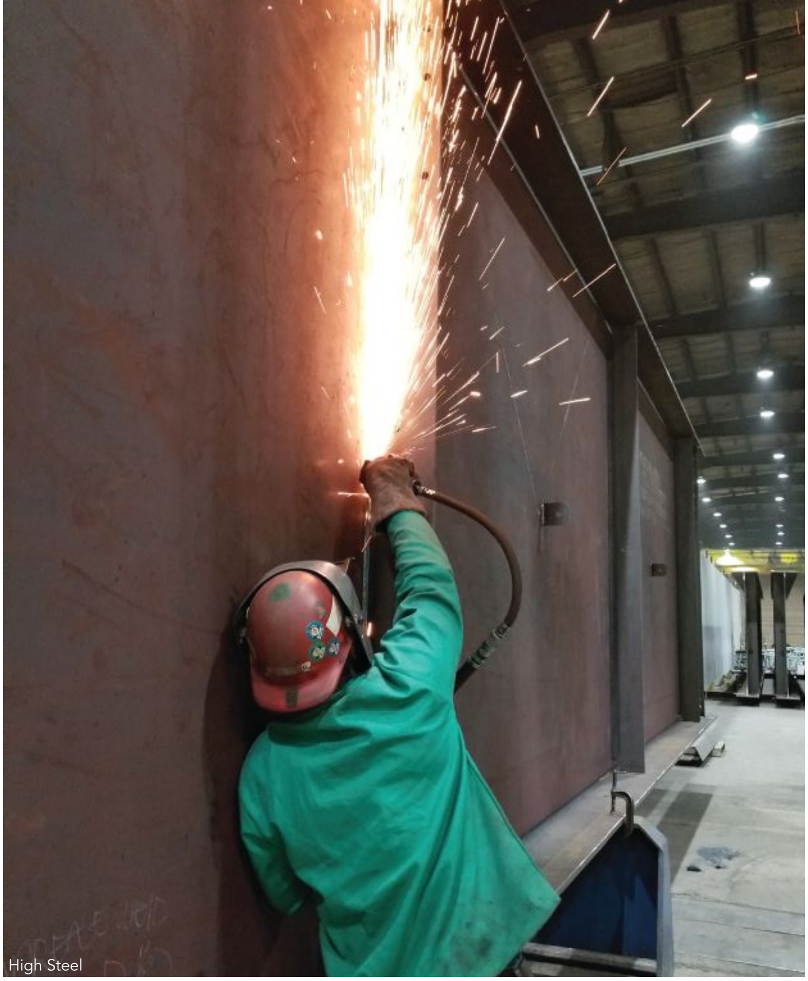
To simplify the design of the unique interior and exterior girders, all shop and field girder splices were made at the same longitudinal distance along the girders. Attempts were made to keep the stiffness of the girders similar so that they remain compatible for deflection purposes. Camber levels for all girders were similar such that they were combined into one camber table for all eight girders. These simplifications made using unique interior girders and exterior girders beneficial for all parties as the only changes were limited to the flange sizes and grade of steel.

Diaphragm Design

Diaphragms were evaluated as primary members, and each unit has approximately 476 diaphragms. Since the diaphragms will stay connected during the future partial-width re-decking, they will carry a significant load when concrete on half of the deck is removed and the other half carries traffic. The diaphragms were checked for wind loads in accordance with the AASHTO *Guide Specifications for Wind Loads on Bridges During Construction* and PennDOT BD-620M; the wind pressure was selected based on a construction duration of six weeks to a year. Diaphragm members, gusset plates, and connections were investigated for strength, service,

Century Steel Erectors

The out-to-out width is nearly 90 ft, and the bridge was designed to be widened during future re-decking to nearly 96 ft.


High Steel

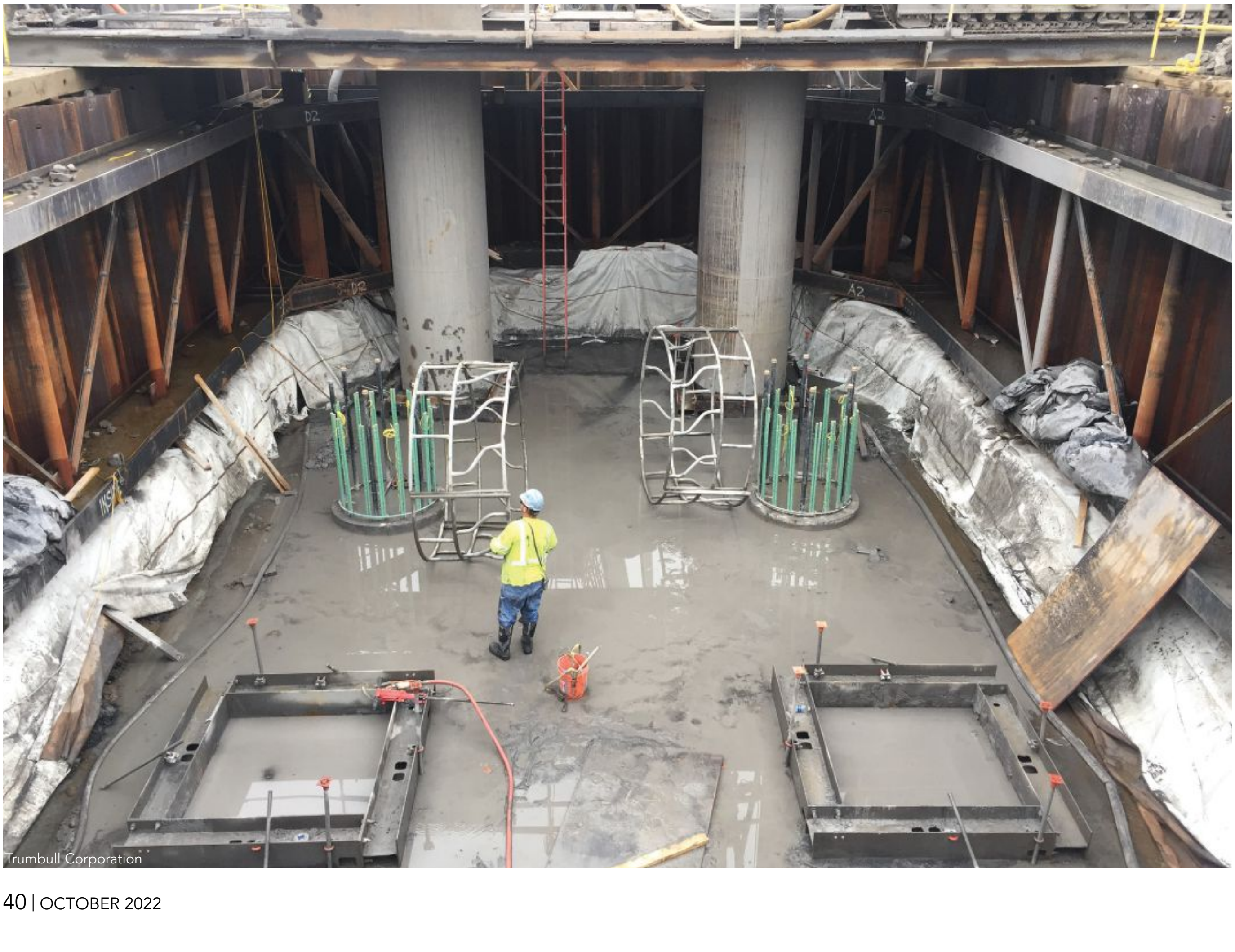
and fatigue load combinations where appropriate. Typical K-frame configurations were used for the diaphragms, which were all made from steel angle shapes. Approximately 62,000 ft of steel angles were used for the diaphragms. Overall, nine different diaphragm configurations were used, implementing five different angle sizes in the three superstructure units. Each of the nine diaphragm types has unique member sizes, weld lengths, and bolt configurations, resulting in simple yet efficient diaphragm designs.

Substructure

Due to the topology of the valley, the substructure units vary substantially in height along the length of the bridge. The abutments are placed on considerable amounts of fill (approximately 110 ft at the near side of the bridge) to minimize bridge length. The piers near the ends of the bridge are located where the bedrock is close enough for spread footings, resulting in approximately 75-ft-tall piers. Near the middle of the bridge, the distance to bedrock increased significantly, and drilled caissons were required with pile caps. These piers range from 120 ft to 180 ft tall.

left: Shop fabrication of a plate girder.

below: The 14 piers vary from 75 ft to 180 ft and are supported by spread footing on rock or caissons with pile caps.


Trumbull Corporation

To avoid the superstructure skew, the pile caps of all the river piers have a plinth structure aligned with the river flow, which is ultimately skewed to the pier stems and the superstructure. The plinth structure provided increased stiffness while also reducing hydraulic impacts.

The bridge substructure consists of tall, slender hammerhead piers on either spread footings or drilled caisson foundations, with significantly varying stiffness and consecutively fixed bearings. To optimize the design and capture realistic behavior, system substructure interaction was modeled using second-order analyses with nonlinear material properties. This approach resulted in a more accurate design and significant steel reinforcement savings. Strut-and-tie analyses were performed on certain substructure elements based on their size. For the computation of seismic forces on the bearings and substructures, seismic analysis (Zone 1) was performed using the computer program SEISAB in lieu of the percentage of the girder reactions as presented in AASHTO. This analysis helped to optimize anchor bolt designs and reduce seismic forces transferred to the substructures.

The bridge opened to traffic in July 2022 at a cost of $164,000,000. Though a structure of this size will never be simple, collaborative efforts made during design can help simplify construction and fabrication through constant communication, as well as reduce overall steel tonnage. And these collaborative efforts will result in better "collaboration" between two counties on either side of the Susquehanna Valley. ■

Owner
PennDOT District 3-0

General Contractor
Trumbull Corporation

Structural Engineer
SAI Consulting Engineers, Inc.

Steel Fabricator and Detailer
High Steel Structures, LLC (AISC Certified Fabricator)
Lancaster, Pa.

Ahmad Ahmadi (aahmadi@saiengr.com) is vice president/structure manager with SAI Consulting Engineers, Inc.

Choose Your Own (Steel) Adventure

BY BOB ANDERSON, SE, PE, DREW MILLER, PE, AND RUSSEL DINGMAN

Courtesy of AECOM

Courtesy of THEA

The Selmon West Extension provides a new choice for drivers.

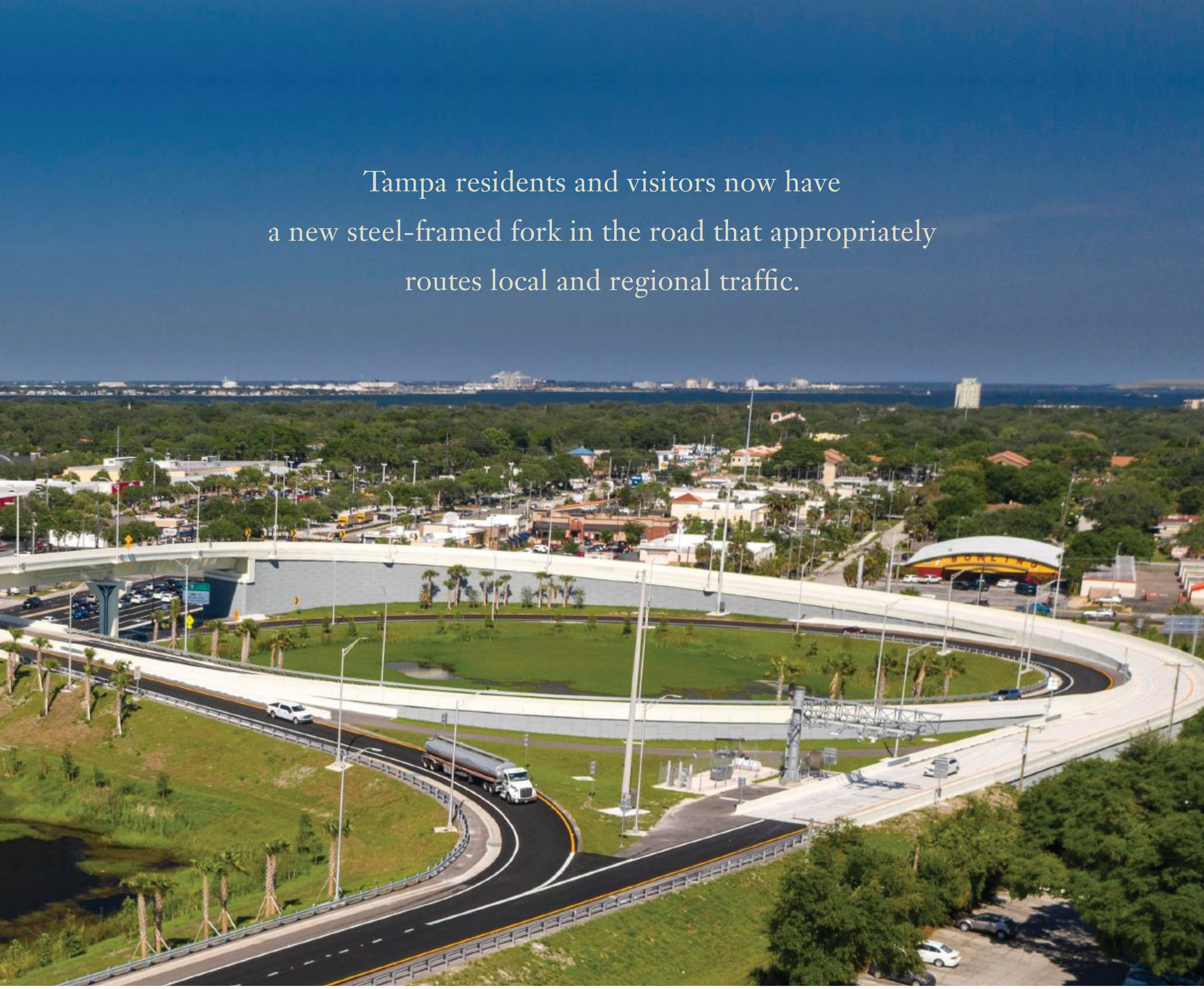
"HOW DO WE BUILD a bifurcated variable-width bridge over railroad tracks while maintaining traffic, mitigating disruption to neighborhood businesses and residents, and keeping a consistent, clean, and aesthetic theme?"

This was the rather cumbersome question presented by Kiewit/AECOM, the design-build team for the $235 million Selmon West Extension in Tampa, Fla., when discussing the technical proposal for the project.

But the answer was simple: Use primed and painted weathering steel tub girders.

This bifurcated variable-width steel tub girder bridge is an important part of the overall Tampa Hillsborough Expressway Authority (THEA) project. The new roadway offers a choice for local residents and regional travelers to use Gandy Boulevard for local destinations or the 1.6-mile Selmon West Extension for a direct connection to the Lee Roy Selmon Expressway, Dale Mabry Highway, or the Gandy Bridge to St. Petersburg.

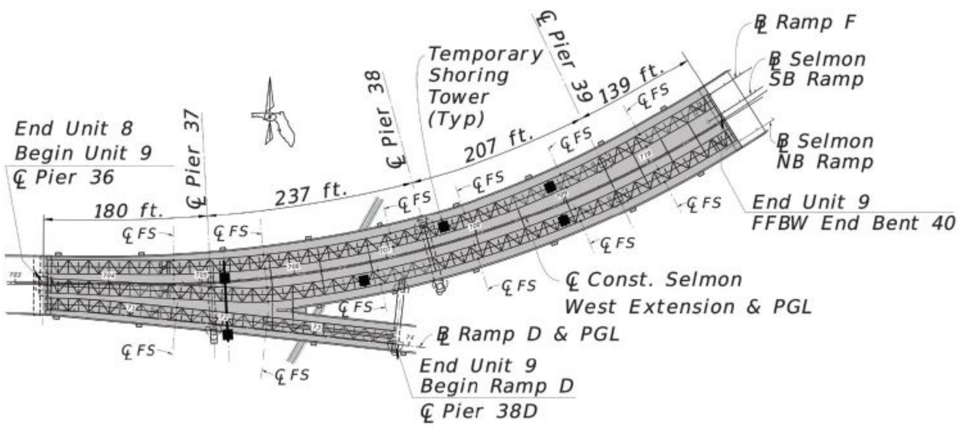
Tampa residents and visitors now have a new steel-framed fork in the road that appropriately routes local and regional traffic.



The project consists of three main components: 1) an eight-unit concrete segmental viaduct, 2) the East Interchange, consisting of five ramps, including a new five-span concrete I-beam bridge and nine mechanically stabilized earth (MSE) walls, and 3) a four-span steel box girder flyover and five-span ramp structure, the topic of this article. In its entirety, the elevated viaduct allows travel at highway speeds along a vital hurricane evacuation route while avoiding the routinely congested Gandy Boulevard and its multiple signalized intersections. Using the viaduct, a routine trip time through the corridor can be reduced from 20 minutes to only two minutes. In a nutshell, it separates commuter traffic from local traffic, providing safer and smarter regional connectivity while alleviating traffic congestion and creating greater capacity and access for neighborhood businesses and residents.

above: The new bifurcated variable-width steel tub girder bridge is an important part of the overall Tampa Hillsborough Expressway Authority (THEA).

below: A plan view of Unit 9.



High Score

The Kiewit/AECOM team was tasked to provide a "best value" solution to THEA with scoring criteria that included design, construction, maintenance of traffic, schedule, and price. Developing, designing, and constructing a solution using steel tub girders proved to be the winning strategy. As part of the technical proposal, the team submitted an alternate technical concept (ATC) that requested to use steel tub girders for Unit 9 and Ramp D, which cross the CFX rail corridor. In addition, the ATC requested using a single-cell box girder at Ramp D. The ATC was accepted by THEA and the Florida Department of Transportation (FDOT), provided that the design met redundancy and loading criteria. Note that Gandy Boulevard (US92) is an FDOT-maintained State Highway. Because the tub girders go over this route, FDOT's involvement was to ensure traveler safety on the roadway beneath and to confirm compliance with FDOT standards, as this elevated roadway will ultimately be maintained by FDOT.

In the final design, Unit 9 is a 763-ft-long structure with spans of 180 ft, 237 ft, 207 ft, and 139 ft. At Pier 36, the transition pier between the adjacent viaduct structure, three tub girders are initially used for two spans, and the three girders diverge in the second span. The southernmost tub girder (Girder 3) splits from the two other girders, which curve to the north, and initiates the Ramp D structure. This extension of Girder 3, which ends with a modular expansion joint at Pier 38D, was called the "thumb." Unit 9 crosses over the westbound lanes of Gandy Boulevard and the CSX rail corridor with the help of post-tensioned straddle bents at Piers 38 and 39 and a set of single-column supports at Pier 39, and the twin-girder portion structure terminates at End Bent 40.

Ramp D continues with a single girder from the expansion joint at Pier 39D to the end bridge at End Bent 5, and the 786-ft-long, five-span structure comprises three 150-ft spans followed by 175-ft and 161-ft spans. For Span 1 of Unit 9, the girder spacing varies from 18 ft to 30 ft at Bay 1 and 20 ft to 26 ft at Bay 2. At Unit 9, Span 2, the spacing of Girders 1 and 2 at Bay 1 transitions from 30 ft to 36 ft. For the remaining spans of Unit 9, the spacing of Girders 1 and 2 is gradually increased from 36 ft to 43 ft. Tub Girders 1 and 2 of Unit 9 are 15 ft wide between centerlines of top flanges. For Ramp D, a single box with 13 ft, 4-in. separating the top flanges supports a 29-ft, 8-in.-wide deck. All tub girders are 8 ft deep with a transition to a 6.5-ft deep section at Pier 36.

A web slope of 3:1 was used for all the tub girders. This is a flatter angle than the typical 4:1 and allowed for substantial material savings for the girder bottom flanges because they were not as wide and closer bracing points of the webs made them stiffer.

The team used LARSA 4D to model Unit 9 and Ramp D individually, creating a comprehensive model that included all girder, diaphragm, cross-frame, bracing, and stiffening elements. Along with staged construction, including the deck pouring sequence, all load cases were considered in a single model. The deflection information for each web was transmitted to Tensor, the steel detailer, who developed cutting diagrams based on a no-load fit basis.

Redundancy and Loading Criteria

In response to the submitted ATC, THEA/FDOT laid out numerous conditions for approval, including the specifying of redundancy and loading criteria. During construction and prior to opening to traffic, a redundancy factor equal to 1.0 was employed for all components. For the permanent structure after opening to traffic, redundancy factors in accordance with the ATC and FDOT's *Structural Design Guidelines* were used, as summarized in Table 1.

To verify serviceability in the event of bottom flange fracture, Ramp D was analyzed and designed for an extreme event assuming a loss of moment capacity at any one cross section in the positive moment regions. The loading included HL-93 live load within the limits of the striped lanes and was based on the following load combination:

Extreme Event III: 1.05 (DC + DW) + 1.15 (LL + IM)

The following factors were also applied to this extreme event:

- Resistance factor = 1.0
- Redundancy factor for superstructure components = 1.0
- Multiple presence factor =1.0

Further, this requirement was in addition to the fracture-critical member requirements of the FDOT *Guidelines*.

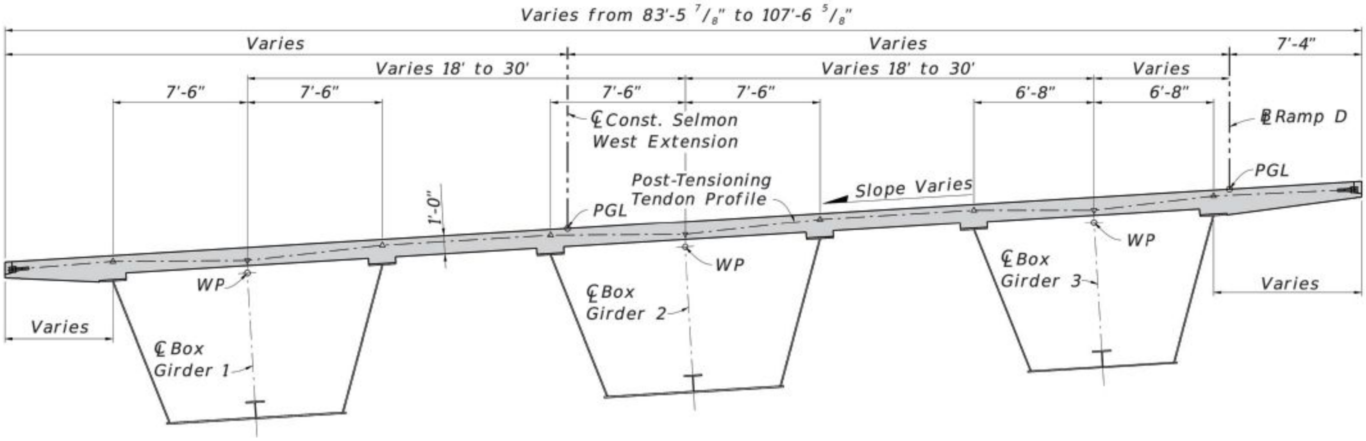
To meet the redundancy criteria for the end spans of Ramp D, a pair of bolted W12×136 sections were used for the bottom flange longitudinal stiffeners. These elements were bolted to the bottom flange to provide capacity to the section in the event of a bottom flange fracture. For the two-girder system at Spans 2L to Span 4 of Unit 9, full-depth external diaphragms are used at the piers and the quarter points of the spans. Per the project criteria, this allowed the use of a 1.0 redundancy factor for these spans and resulted in an overall savings of steel weight.

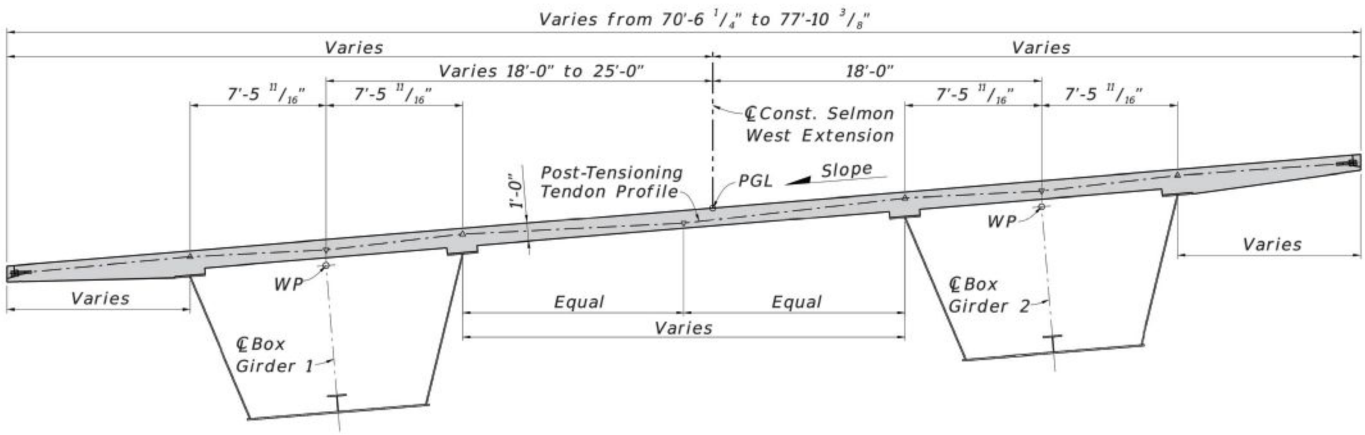
To accommodate deck spans of up to 28 ft and deck cantilevers of up to 10 ft, the deck was transversely post-tensioned with four 0.6-in. strand tendons at variable spacing along the length of the bridge, and flat duct was used to attain maximum eccentricity. The deck thickness for the cantilevers is 10.5 in. at the tips, 17 in. at the root of the cantilever, and 12 in. between girders. The interaction between the post-tensioned deck and the girder system was analyzed with finite element analysis (FEA) models, using Midas Civil, to determine the

Table 1. Redundancy Factors for Superstructure Components

<table>
<tr><th colspan="5">Redundancy Factors for Steel Girder Bridges</th></tr>
<tr><th>Location</th><th>Span ID</th><th>Number of Girders in Cross Section</th><th>Without Exterior Diaphragms</th><th>With Exterior Diaphragms</th></tr>
<tr><td>Ramp D</td><td>1 to 5</td><td>1</td><td>Not less than 1.2*</td><td>—</td></tr>
<tr><td rowspan="3">Unit 9</td><td>36</td><td>3</td><td>1.05</td><td>—</td></tr>
<tr><td>37R (Thumb)</td><td>1</td><td>Not less than 1.2*</td><td>—</td></tr>
<tr><td>37L to 39</td><td>2</td><td>—</td><td>1.00</td></tr>
</table>

*Per the Alternate Technical Concept (ATC) submitted by Kiewit/AECOM and accepted by THEA/FDOT.





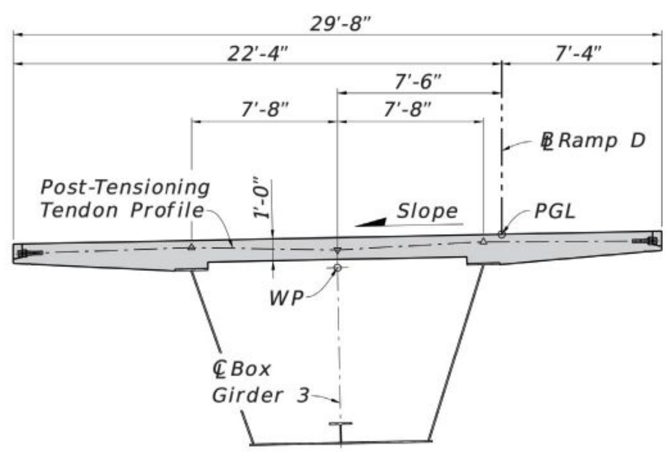
post-tensioning forces shared by each element. Shear studs were given some flexibility, based on published data, to account for minute slippage of the concrete-steel shear interface.

Construction

The steel tub girders and external diaphragms were delivered to the construction site from Tampa Steel Erecting Company's fabrication facility using US 41 and the existing Selmon Expressway. The girders and diaphragms were hauled during daylight hours and staged on the Selmon Expressway near the job site until the nighttime erection window. The longest field section delivered to the site was 140.5 ft and weighed 88.5 tons, and the heaviest section delivered and erected was 117 tons. The total steel tonnage was 1,597 tons and 572 tons for Unit 9 and Ramp D, respectively.

Each evening during the nighttime erection window, all affected lanes of Gandy Boulevard were temporarily closed, counterweights were assembled on the erection cranes, and each field section that had been staged on the Selmon Expressway during the day was trucked to the location where it would be erected. At the completion of each erection shift, prior to opening Gandy Boulevard to traffic for the day, the crane counterweights had to be offloaded so that all cranes could be staged off Gandy Boulevard until the next shift.

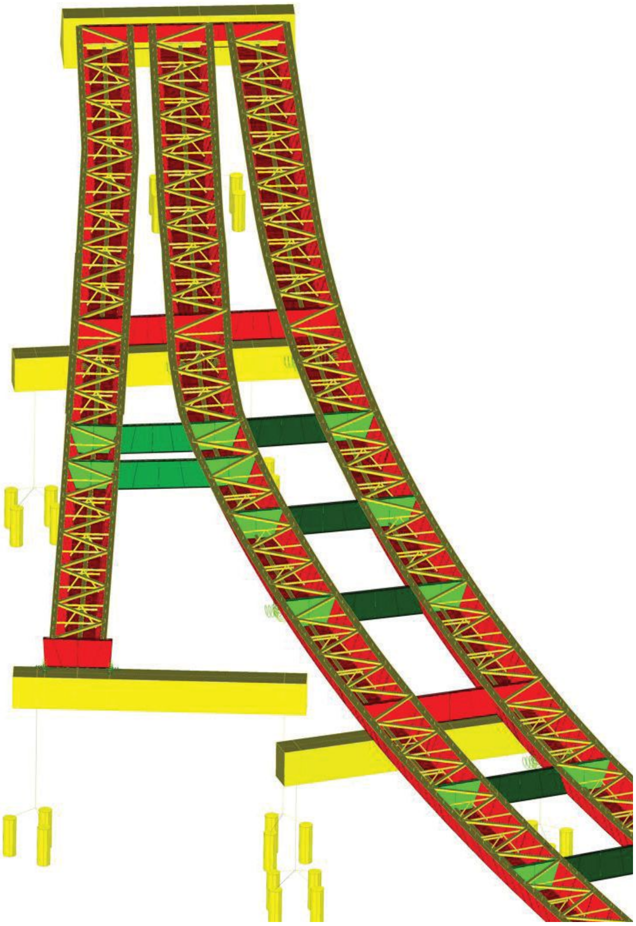
In all, five different cranes were used during various stages of erection depending on piece size, weight, and reach required, with capacities varying from 230 tons to 700 tons. All cranes operated from a stationary position when picking and placing field sections, and typical picks involved two cranes per field section, with two field sections being maneuvered concurrently by a total of four cranes to splice the field sections without the use of temporary

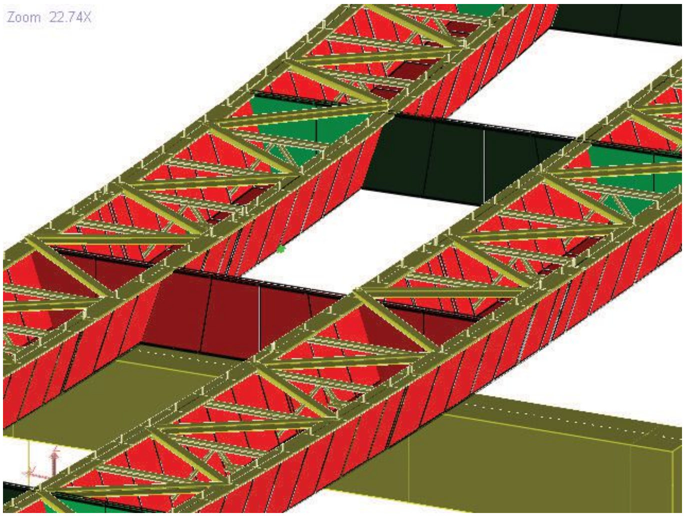


Top to bottom: Typical sections at Span 1 of Unit 9, typical sections at Spans 3 and 4 of Unit 9, and a typical section at Ramp D.

towers (air splicing). With the exception of two locations, girder field sections were air spliced.

In addition to traffic restrictions on Gandy Boulevard, erection also had to be coordinated with CSX Transportation, whose tracks run under Span 37 of the Unit 9 superstructure. Each night that girders were erected or superstructure assembly took place in the vicinity of the railroad tracks, a trained CSX flagger had to be employed to control train traffic and coordinate between the railroad and erection team. The major challenge of working near the railroad tracks was erecting the Span 37 girders, where several





A LARSA Model for Unit 9 (global view at left and close-up view at right).

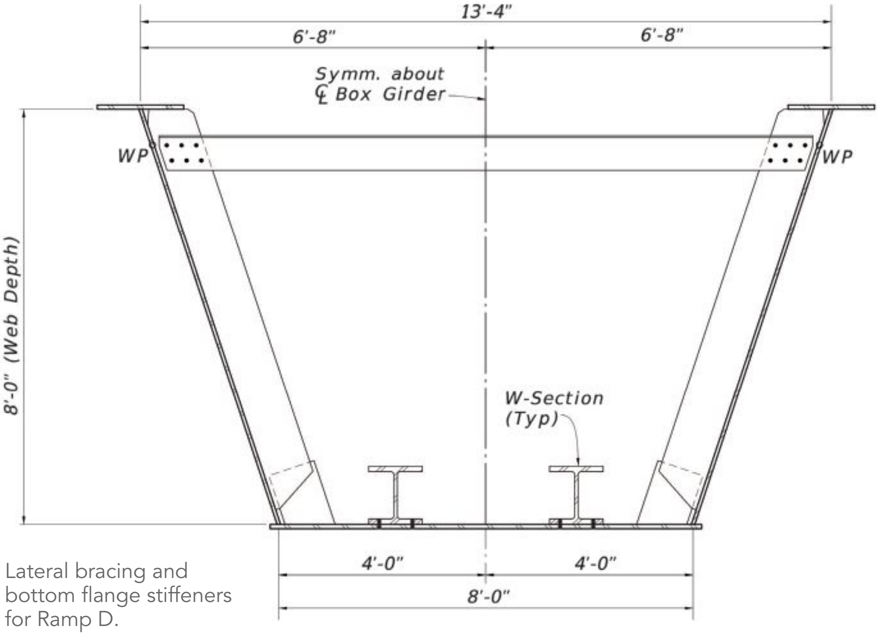
field sections had to be parked over the tracks. This activity had to be coordinated closely with the railroad and, at times, the girder erection had to be put on hold until a scheduled train had passed through the construction site.

To allow for girder erection tolerance at the permanent disk bearings (provided by RJ Watson, Inc.), the 1.5-in. bearing anchor rods were placed in 4-in. preformed holes that were grouted after the girders were all set in place. In addition, the connection between the bearing sole plate and the girder's bottom flange was modified during fabrication to utilize oversized holes.

To limit the stay-in-place metal deck form depth to 3 in. and avoid conflict with tub girder top lateral bracing, continuous temporary supports were used at the center of all SIP forms. Timber forms supported on structural steel double channels hung from the top flanges were used to support the deck placements between tub girders. Once the deck was cured and post-tensioned, the temporary supports inside the tub girders were removed.

To complete the deck in the timeliest manner, the team had to overcome challenges due to 1) the time limit between placing post-tensioning strand in ducts and completion of stressing and grouting dictated by the FDOT specifications, 2) minimum curing times for bridge decks, and 3) the necessity of isolating newly placed or cured deck sections from the post-tensioning effects of mature, nearby spans or sections. Adding to the time constraints for post-tensioning and deck curing was the required coordination with CSX during concreting operations near the railroad tracks to ensure trains did not pass under the span where concrete was being placed.

The deck for Unit 9 was cast in 11 sections, generally alternating over positive and negative moment regions, and none of the 11 total sections were cast concurrently. The deck for Ramp D was cast in nine sections, with several sections cast concurrently. For both Unit 9 and Ramp D, the boundaries of the deck placement sections were chosen to optimize the stresses experienced by the structural steel during casting as well as to limit stresses in young, previously placed concrete sections.

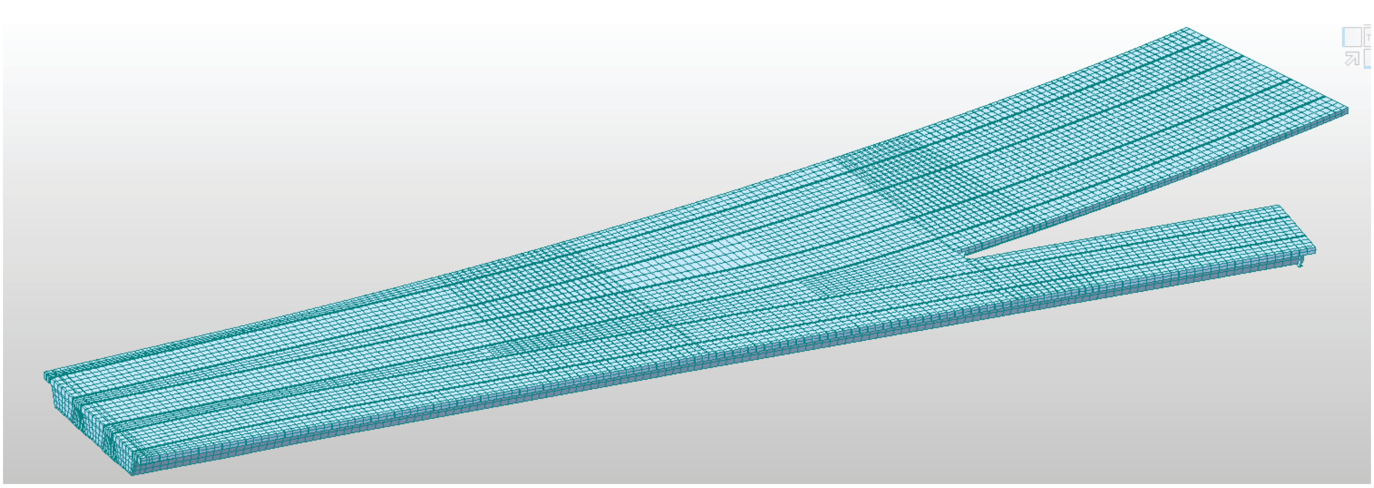


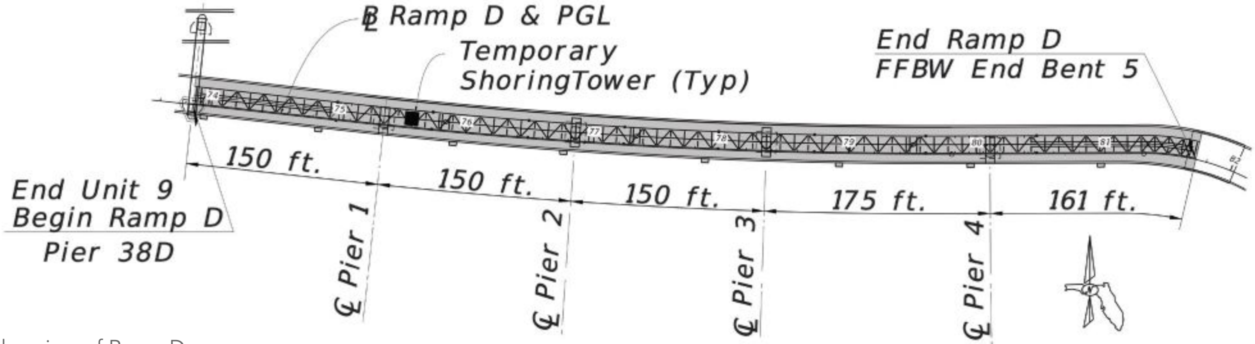
Lateral bracing and bottom flange stiffeners for Ramp D.

Courtesy of Kiewit

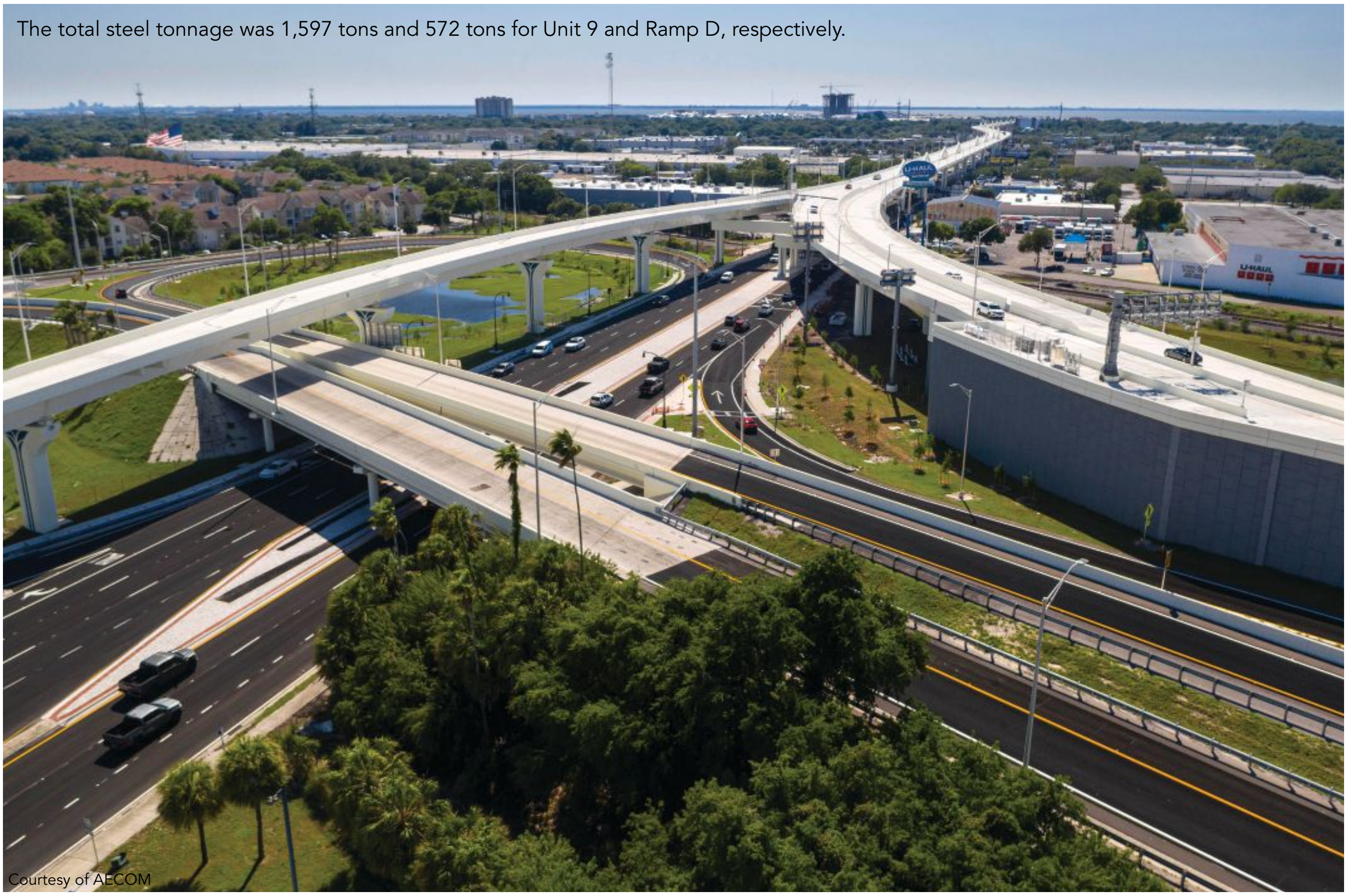
left: Erecting Span 1 of Unit 9 over the CSX rail corridor.

below: An FEA model of the bridge deck.





A plan view of Ramp D.



The total steel tonnage was 1,597 tons and 572 tons for Unit 9 and Ramp D, respectively.

Courtesy of AECOM

The design plans required 72 hours between successive deck pours within a continuous unit, and FDOT specifications required a minimum of seven days of curing or 75% design strength for form removal. The deck was also required to be transversely post-tensioned prior to form removal. Further, FDOT specifications required stressing and grouting of post-tensioning to occur within 14 calendar days of placement of post-tensioning strands within the ducts. This time limitation, considered in conjunction with the time required between deck placement and stressing of post-tensioning tendons, meant that the permanent strands could not be placed in the ducts at the time of concrete placement. Because of this limitation, the transverse post-tensioned deck anchor detail was modified from the design plans to allow the anchors to be installed after the deck portion to be stressed had reached the required conditions for stressing, just prior to stressing the tendons. This allowed temporary strands to be placed in the ducts prior to concrete placement to help maintain the duct shape and geometry. When it was time to stress a deck section, the temporary strands were removed, and new strands were pushed through the empty ducts.

The design dictated that no spans were to be stressed prior to both adjacent spans being completed and curing for a minimum of seven days. Based on the design deck placement sequence, this limitation would have required that a full continuous unit, either Unit 9 or Ramp D, be completed prior to any deck tendons being stressed. However, some relief was offered during construction that allowed more mature deck sections to be stressed over limited lengths as long as the prestressing force would not impart compressive stresses to younger adjacent sections, assuming a 45° spread of the compressive force from the post-tensioning.

Once the decks of both Unit 9 and Ramp D were fully prestressed, the forms between box girders and overhang forms could be removed and a barrier could be placed. Modular expansion joints were placed at the ends of each unit, followed by deck grinding and grooving of the integral concrete wearing surface that included ½ in. of sacrificial thickness. The box girders and exterior diaphragms were then painted to match the connecting segmental viaduct, completing the construction of these distinctive steel tub girder bridge units and providing a much-needed split between local and regional traffic. ■

Owner
Tampa Hillsborough Expressway Authority (THEA), Tampa

General Contractor
Kiewit Infrastructure South Co., Tampa

Structural Engineer
AECOM, Tampa

Erection Engineering
Atlas Engineering Group, Stuart, Fla.

Steel Team

Fabricator
Tampa Steel Erecting Co., Tampa

Detailer
Tensor Engineering, Indian Harbour Beach, Fla.

Bob Anderson is the engineer of record and **Drew Miller** is an engineer, both with AECOM, and **Russel Dingman** is a project sponsor with Kiewit.

Complementary Design

The aesthetics of the steel spans for Unit 9 and Ramp D were intended to be complementary to the rest of the project. The piers use the "estuary" concept, employing organic rounded corners and a motif created with form liners that conceptually represent a river delta or canopy of trees. This aesthetic concept was overwhelmingly chosen by the public in an online vote sponsored by THEA, and this contemporary form was flexible enough to be implemented for all the piers of Unit 9 and Ramp D.

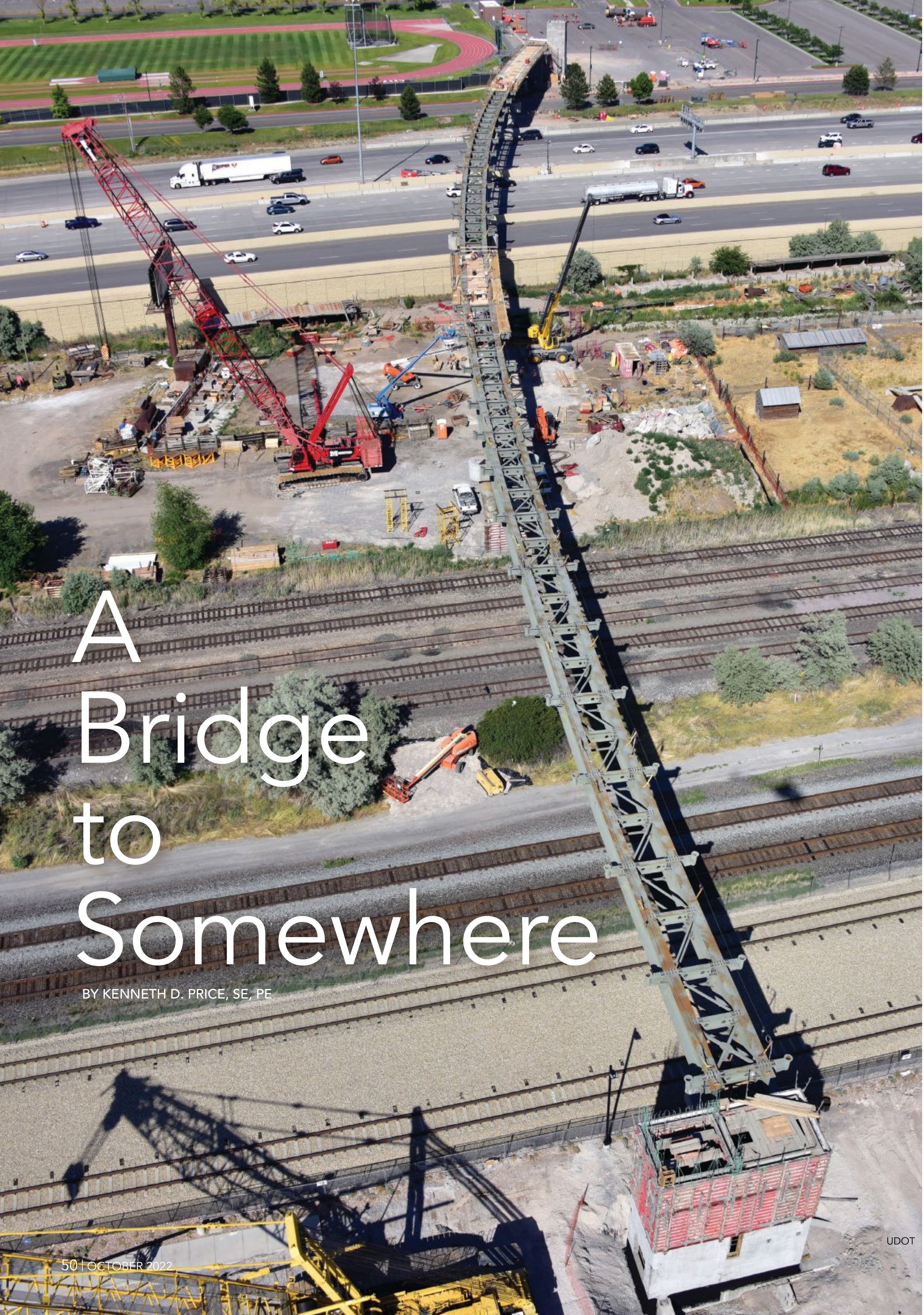
For the piers at Unit 9 that did not require a flared cap, the lower vertical dividing lines of the estuary pattern were replicated. The clean aesthetic theme not only creates visual interest but also reduces the visual mass of the concrete substructures. The closed section of the trapezoidal box girders and the full-depth diaphragms at the piers and quarter points reduces clutter and provides a streamlined appearance.

Ramp D.

Courtesy of AECOM

Spans 3 and 4 of Unit 9.

Courtesy of AECOM

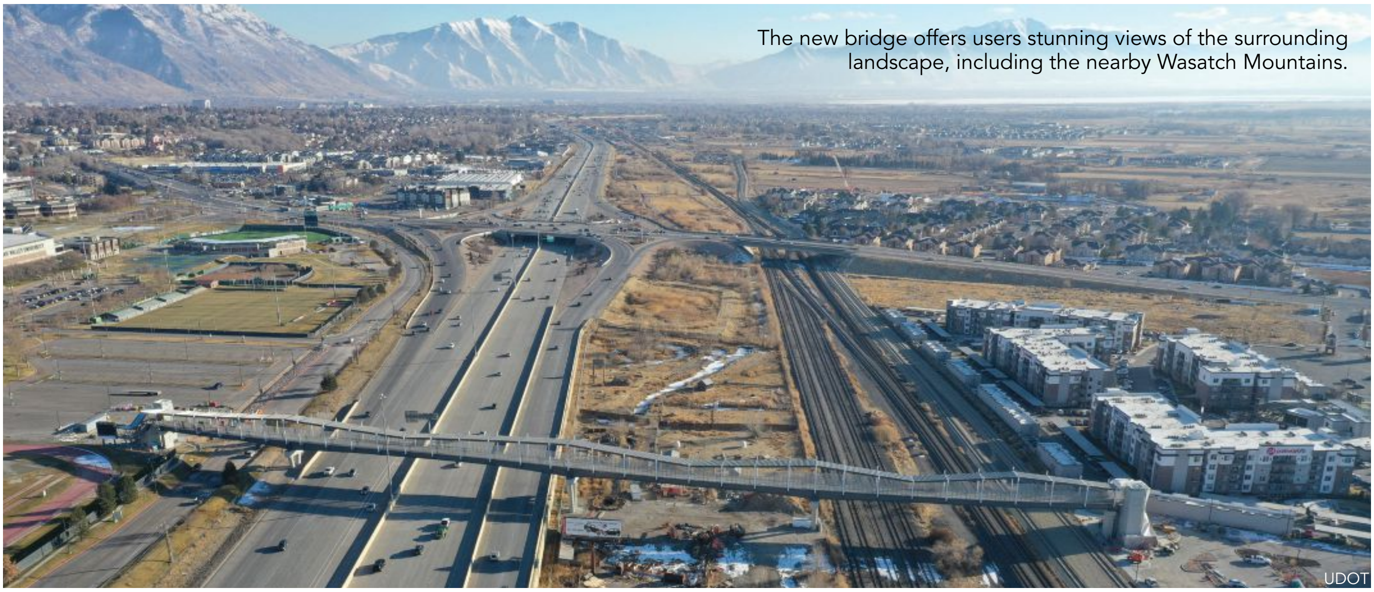


A Bridge to Somewhere

BY KENNETH D. PRICE, SE, PE

UDOT

Utah's longest pedestrian bridge lets users take in the scenery as they cross over a major Interstate and railroad tracks. It also cuts considerable time and risk for commuters to Utah Valley University's main campus.



The new bridge offers users stunning views of the surrounding landscape, including the nearby Wasatch Mountains.

UDOT

THE UTAH VALLEY UNIVERSITY (UVU) Pedestrian Bridge in Orem, Utah (just south of Salt Lake City) isn't just a way to get from Point A to Point B. It's also essentially a nearly 1,000-ft-long observation deck.

This steel-framed crossing, which opened in late 2021, spans 965 ft (bearing to bearing) across Interstate 15 and a series of railroad tracks to link the Orem Intermodal Center and the UVU Residential Campus on one side with the UVU Main Campus on the other. And it offers its users stunning views of the surrounding landscape, including the nearby Wasatch Mountains, every step of the way. It also includes several features that are not common on pedestrian bridges: a fully functional stair and ADA-compliant elevator access at each end, a dramatic roof structure, and a heated deck.

Overview and Stakeholders

The bridge reduces congestion at the University Parkway interchange by eliminating vehicular trips between the intermodal center and campus, improves connectivity for FrontRunner commuter rail users (making commuter rail a more attractive option and further reducing congestion on I-15), and reduces vehicular traffic and parking demand on the UVU Main Campus. As part of the university complex, the bridge design needed to complement campus architecture and provide a pleasing aesthetic appearance. The custom peaked roofline, controllable lighting, delta pier supports, heated deck, and sleek steel superstructure were all designed to provide a distinctive-looking bridge the community could enjoy and be proud of.

opposite page: The steel-framed Utah Valley University Pedestrian Bridge spans 965 ft (bearing to bearing) across Interstate 15 and a series of railroad tracks.

The peaked roof, designed to simulate the adjacent Wasatch Mountain profile, provides a distinctive look but is also functional, with continuous lighting and protection from the weather. The deck features a heating system, facilitating a safe and dry walking surface, and the side enclosure is partially open, offering open views while providing air circulation but at the same time blocking noise and weather. The entire bridge and landing areas have cameras and safety phones, providing additional safety for users.

Three primary owners provided funding and direction in the project's design and construction: UVU, the Utah Department of Transportation (UDOT), and the Utah Transit Authority (UTA). The strategic connection point between a transit hub and a university with more than 40,000 students provided significant value to all three major stakeholders as well as several others, including the Union Pacific Railroad (UPRR), the City of Orem, and the surrounding community.

Architecture

From an architectural perspective, the bridge was designed to tie the UVU campus to the community and the UTA Intermodal Center and was envisioned to provide an enhanced user experience, making the journey feel safe, comfortable, and welcoming over its nearly 1,000-ft span. It was also designed with mountain and lake views in mind, thanks to its curved pathway, semi-transparent perforated aluminum side enclosure, and peaked roof form working in unison to provide a variety of framed views and a spatially dynamic user experience.

The upper elevator and stair landings double as viewing platforms to provide panoramic scenes of UVU's campus with the mountainous background to the east and Utah Lake to the west. Custom details were designed and developed throughout

UDOT

Utah Pacific Bridge & Steel created a full sub-assembly of the entire superstructure in its yard to simulate the erection sequence in the field using a "no load fit" detailing assembly. This extra effort under controlled conditions ensured a close-to-perfect geometry and a seamless erection sequence during the Interstate closure windows.

Rachel Cullen/WSP

UDOT

the project to create streamlined integration and detailing of lighting and drainage systems, and the roof support columns and connections were also designed with sleek refinement in mind. The concrete elevator towers, aluminum panels, and lighter color tones of the main bridge structure share the architectural character found on UVU's campus, effectively making the bridge a natural extension of the campus. And the landscape design buffers and provides a refinement around circulation and seating areas, welcoming all users.

Structure

As the bridge was designed for heavy pedestrian traffic between the transit center, the university residential complex, and the main campus, the team provided a walking space of 15 ft between the side enclosures (the average total width is 21 ft out-to-out) and also implemented horizontal and vertical curvature to accommodate the north-south offset between the eastern and western terminus points.

The overall structural system is a variable-depth curved plate girder solution, employing a two-girder approach, with floor beam and K-bracing diaphragms at the roof column and intermediate locations with a typical spacing of 15 ft. This design approach resulted in a flowing, variable-depth soffit profile using a total of 900 tons of structural steel (including the roof). For the coating, the team specified a standard three-coat acrylic, vinyl, and zinc primer system, per UDOT.

UDOT required an increase in statutory vertical clearances over the Interstate to 17.5 ft to reduce the risk of over-height vehicles potentially impacting the bridge and compromising user safety. But due to site geometry and the chosen bridge profile, the actual minimum vertical clearance was 22.6 ft.

After researching available framing systems and proprietary solutions for adaptation to the roof system, the design team decided to develop a customized solution from scratch. Working closely with the steel detailer, Tensor Engineering, and the fabricator, Utah Pacific Bridge & Steel, structural engineer WSP developed a framing system that accommodated the architect's visual concept, merged effectively with the bridge structure for strength and dynamics, and was carefully detailed for the required visual demands and utilitarian functions such as drainage, lighting, and security. The steel framing system uses a mix of rolled and bent plate shapes, requiring careful detailing to accommodate cross fall, horizontal and vertical curvature, and the "peaked" effect, and the "fish-belly" shape was developed to accommodate the lighting and security systems and natural wood finish. All the primary girder and floor beam members are welded wide-flange shapes.

The railing system consisted of a partial enclosure using a perforated aluminum plate solution, which addressed safety and weather protection and provided visibility. This element is an important part of the aerodynamic response of the structure and was included and analyzed in an RWDI wind tunnel for aerodynamic response. In addition, a vibration study was conducted to ensure pedestrian comfort and safety and confirmed that no secondary tuned-mass dampers would be required.

Although pedestrian bridges are generally not susceptible to fatigue and redundancy issues, this is an ongoing matter of national concern and statutory requirements. With this in mind, a redundancy analysis was completed to ensure the safety and serviceability of the bridge without collapse under a defined limit-state damage event. In the analysis, an exterior girder was completely fractured over a critical location above I-15, and a dynamic amplification factor of 1.5 was applied, along with LL and impact, including a 1.5 overload factor. Deflection in the damaged condition was limited to just over 5 in., which met the functional limit-state requirements and nullified any concern about Interstate clearances or emergency

Zach Stolarsky/WSP

UDOT

left: The bridge features a stair and ADA-complaint elevator access at each end.

above: The peaked roof was designed to simulate the Wasatch Mountains.

below: Structural steel totals 900 tons.

UDOT

access and provided for the continued functionality of I-15 and the bridge itself. Given the challenging site constraints, the bridge's arrangement employed longer, heavier, and more irregular spans to facilitate access and erection; the four individual spans measure 260 ft, 228 ft, 305 ft, and 172 ft.

This project was designed and built using the construction manager/general contractor (CM/GC) method, with the general contractor and structural engineer working under separate contracts with the owner. The target objective was "design-to-budget," and an independent engineer provided a third-party cost estimate to ensure that the target guaranteed maximum price was achieved. On the technical front, WSP, Utah Pacific Bridge & Steel, Tensor, and steel erector Olsen Beal (AISC certified) all worked in close collaboration at all stages of the design development and construction sequencing, resulting in very limited Interstate closures. As an example, Utah Pacific Bridge & Steel created a full sub-assembly of the entire superstructure in its yard to simulate the erection sequence in the field using a "no load fit" (NLF) detailing approach, which entails detailing the entire superstructure framing to a zero-gravity geometry and blocking the girder assembly to this geometry. This decision was based on the significant differences in the dead load cambers between the interior girder and the exterior girder, given the curvature, and required a limited amount of "force fitting" in the yard to accommodate web rotation under gravity loads in the field. Making this extra effort under controlled conditions ensured a close-to-perfect geometry and a seamless erection sequence during the Interstate closure windows, and the team was able to erect the bridge, including its multiple 120-ton-plus elements, over a busy commuter line, a Class 1 freight line, an environmentally sensitive watercourse, private property, and one of the busiest stretches of I-15 in Utah without a hitch.

As the longest pedestrian bridge in the state, the UVU Pedestrian Bridge has the equally large job of providing a vital connection over a busy Interstate and multiple railroad tracks and connecting a town, a university, and a transit center. Since its completion, it's made mass transit, biking, and walking much more appealing to university students, staff, and visitors while improving the integrated transportation system in Orem–all while providing an iconic new crossing as well as stunning views for its users. ■

Owner/Funding Agencies
Utah Department of Transportation, Utah Valley University, Utah Transit Authority

General Contractor
Wm Kraemer NA, Castle Rock, Colo.

Architect
Method Studio, Salt Lake City

Structural Engineer
WSP USA, Salt Lake City

Steel Team

Fabricator
Utah Pacific Bridge & Steel (AISC CERTIFIED FABRICATOR), Lindon, Utah

Steel Detailer
Tensor Engineering (AISC DETAILER), Indian Beach Harbor, Fla.

Kenneth Price (**kenneth.price@wsp.com**) is vice president and manager of the Complex Bridge Group – Central Region with WSP USA.

Bridging the BIM Gap

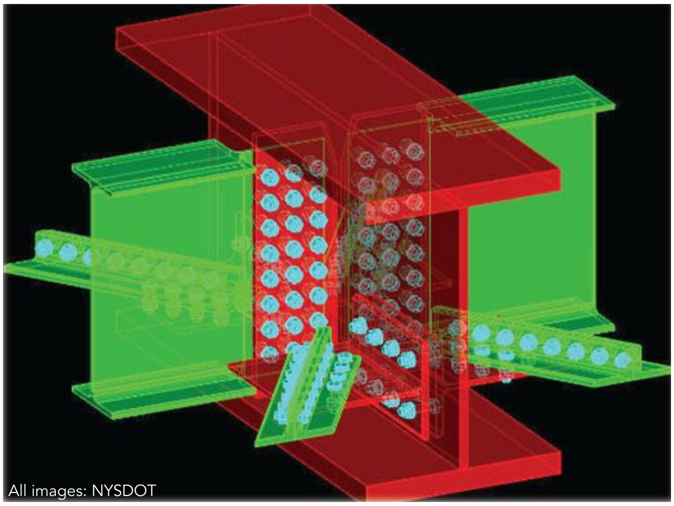
BY BRENDA CRUDELE, PE, AND JULIANNE FUDA, PE

Model-based contracting for steel bridge projects, while still in the early phases, is showing promise for the future.

BUILDING INFORMATION MODELING, better known as BIM, has been around for decades in the building industry.

When it comes to transportation projects, however, the model-based approach is still in its infancy.

But it's growing. And the bridge construction industry is now on the verge of a paradigm shift in terms of how information is exchanged. Designers are no longer limited to just 2D flat views; they can now design and visualize in 3D, bringing a visual and spatial aspect to the work that cannot be conveyed using only 2D plan sheets. More importantly, and sometimes forgotten among civil engineers, is the informational modeling aspect. Not only does the 3D model physically represent the actual component, but metadata is also associated with each piece of the model, making it a complete information model. Size, shape, materials, specifications, and contractual pay information can all be tied to the model. And many DOTs across the country are now considering this approach to capture the full benefit of 3D and information modeling.



A typical steel connection detail where entering and tightening clearances can be easily visualized in 3D.

Implementing a New Approach

The New York State Department of Transportation (NYSDOT) is one such entity and has been pioneering the effort to bring the benefits of 3D modeling into the bridge construction industry. NYSDOT started down this path in 2018 with the formation of its model-based Contracting Committee. The committee consisted of staff from all facets of the agency: design, structures, construction, contracts, and legal. The committee benchmarked what other states had done, determined the issues NYSDOT would have to overcome to make the change, developed goals, and then obtained executive approval to move forward with its first pilot projects.

Before we go into the details of those projects, it's important to note that model-based contracting requires a significant change in the workflow process, which can be especially challenging for DOTs. The challenge is twofold. First, individual staff members may struggle with change if they don't see a direct benefit to their specific portion of work. Second, the overall agency must deal with the considerable amount of time and effort required to develop a new workflow that is beneficial to all stakeholders. There is no benefit to change for the sake of change, but well-thought-out transformation can prove immensely beneficial. NYSDOT set the following goals for its own model-based contracting implementation:

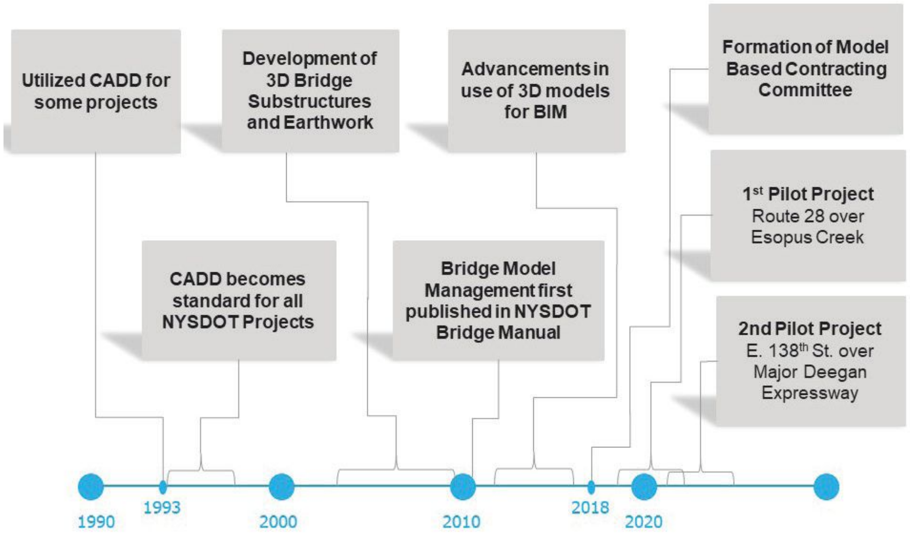
- Increase efficiency for data exchanges over the life of the project and bridge assets
- Reduce or eliminate the need for data reentry
- Increase data integrity
- Decrease initial and long-term costs
- Increase contract plan accuracy
- Steer the future direction of bridge technology and software

It quickly became clear that developing the required standards and workflows for model-based contracting at NYSDOT would take time and could only be improved through experience. It also became clear that the only way to get that experience was to dive in and employ the process on real-life projects.

And NYSDOT did just that, embarking on two pilot projects using the model-based contracting approach. Final design for the first project, which involved replacing a Route 28 bridge over Esopus Creek in the Catskill Mountains, began in late 2018. Construction started in early 2020 and was completed last year. Final design for the second project, the replacement of the East 138th Street Bridge over the Major Deegan Expressway in New York City, was initiated in March 2020 and construction commenced in the summer of 2021. The two projects are similar in that they are both multi-girder steel bridge replacement projects—but they could not be more different in every other aspect. Choosing these very unique and challenging projects to test model-based contracting not only exposed the true benefits of 3D modeling but also provided NYSDOT with the "lessons learned" that are crucial for future projects.

Route 28 Pilot Project

For the Route 28 project, the existing steel bridge was 336 ft long and carried a critical roadway through the rural mountainous region that is prone to flooding. The project intended to improve the local hydraulics by replacing the existing bridge with a much longer 800-ft bridge on an adjacent alignment. Given that this was the DOT's first pilot project, the required workflow was only theoretical and likely to require frequent revision. To avoid the complexities of writing a scope of services for a designer when all the required steps were not yet well defined, a decision was made to design the project using in-house staff from the NYSDOT Office of Structures and Office of Design. The in-house design team had been modeling bridge and highway components for many years, but the purpose of the models was always to create 2D plan sheets. Using 3D models as legal contract documents necessitated the creation of a new design, modeling, and QA process, along with the in-depth learning of improved modeling software.



A timeline of NYDOT's experience with model-based contracting.

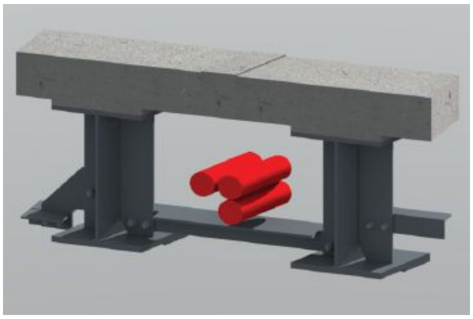

A 3D model of the proposed Route 28 Bridge, roadway embankment, and culvert.


The Route 28 project was successfully let with five bidders competing for the award. NYSDOT bridge replacement projects typically have two to six bidders, so this number verified that there was no significant apprehension from the contracting community concerning model-based contracting for this substantial replacement project. Even more impressive was that the top three bids were within 0.1% of each other, another indication that the scope of work was successfully depicted using 3D models in lieu of 2D plans.

Through trial and error, a workflow was ultimately developed that met the needs of the agency and the contractors.

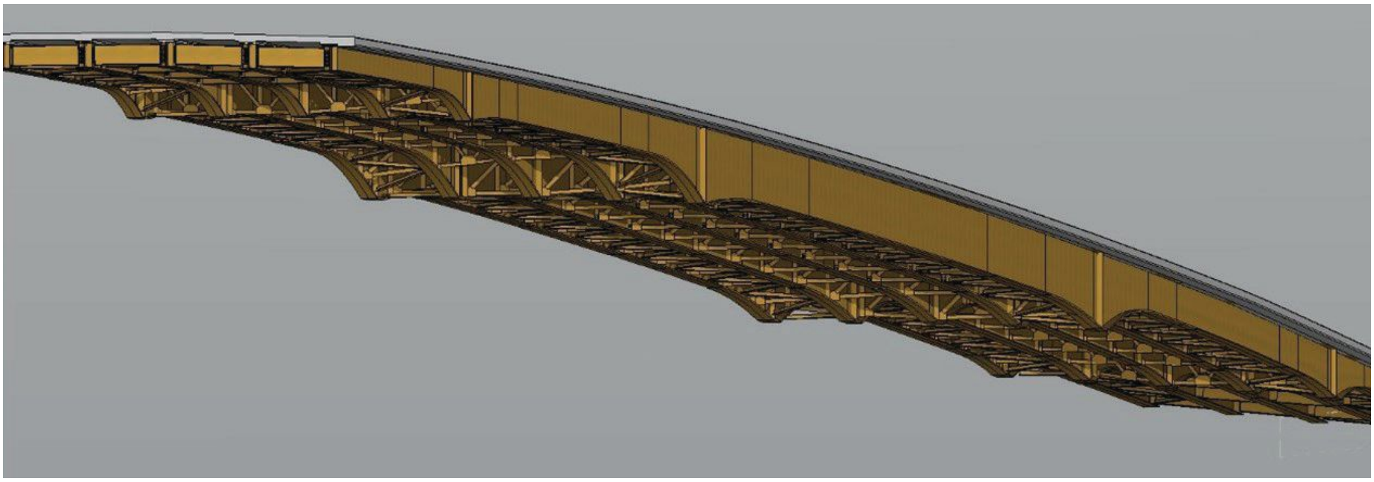
In the end, the team employed a hybrid approach. Not only were 3D models and other electronic files provided as contract documents, but traditional 2D plan sheets were also used for certain elements, with NYSDOT picking the best approach to take based on return on investment. For example, there were certain bridge elements, such as H-pile splice details, pedestrian fencing, and chamfer details, where the effort required to produce a full 3D model yielded little to no discernable benefit compared to simply providing 2D plans. By using the hybrid approach, the design team was able to choose the best method to convey the design intent to the contractor. This allowed for flexibility and efficiency while still maintaining the model-based contracting ideology.

One of the main lessons learned during the construction of the Route 28 bridge was that it is very important for both the field staff and the contractor to have experienced staff members who are familiar with navigating and using 3D information models. The more experience the staff had, the more useful the models were. It also became evident that different fabricators use different software packages.



above: A prefabricated unit for the East 138th Street Bridge with utility support modeled in 3D.

below: The proposed superstructure for the Route 28 Bridge with weathering steel girders haunched at each pier.

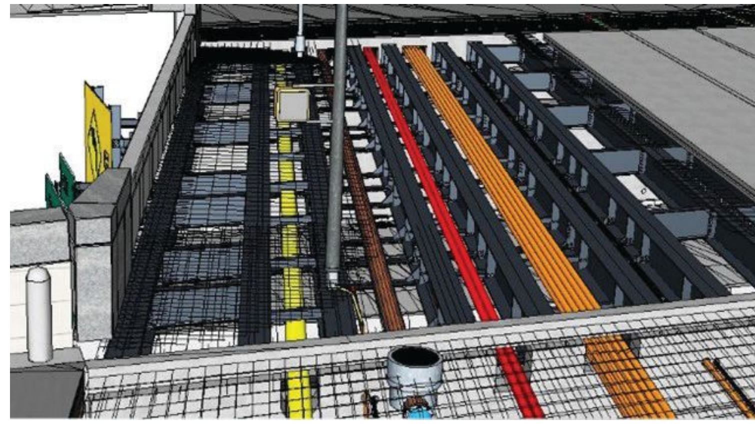


Converting the 3D model between two software packages was feasible, but it was not seamless, and NYSDOT is looking forward to software developers improving IFC import/export functionality in the future to alleviate this issue.

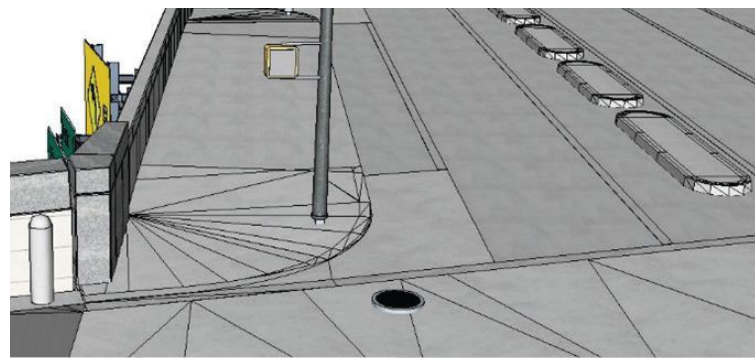
Overall, the 3D model approach was deemed a success for the project. In a few instances, it allowed the construction staff to determine conflicts in a virtual environment prior to the components being built. This saved time and money since the issue could be resolved prior to actual construction. The model was also used for outreach to local landowners whose driveways were being reconstructed as part of the project, and it was very easy for members of the public to visualize what the finished driveway slopes would look like. Getting this public buy-in would have been very difficult with conventional 2D plans.

In the end, the team employed a hybrid approach for the Route 28 project, using a combination of 3D models and traditional 2D plan sheets.

An photo of the existing East 138th Street Bridge and a rendering of the proposed replacement.



3D models showing the completed steel framing and utilities as well as the completed bridge deck.



East 138th Street Pilot Project

The second and ongoing model-based contracting project is the replacement of the East 138th Street Bridge over Major Deegan Expressway in the Bronx. The existing bridge, a two-span multi-girder steel bridge built in 1938, has limited vertical clearance over the expressway and has been hit numerous times. East 138th Street is a heavily traveled roadway on the approach to the Madison Avenue Bridge, which is one of the few free crossings from the Bronx to Manhattan. There are several utilities in the project area, including those being carried on the structure, under the East 138th Street roadway, running along the expressway, and crossing beneath the abutments on East 138th Street under the expressway. There is also a very strong pedestrian and bicyclist presence on the bridge that had to be accommodated during design and construction. The project's goal was to replace the existing bridge, eliminate the pier, and increase vertical clearance—all while providing for pedestrian access, keeping all lanes on the bridge and abutting intersections open during construction, limiting impacts to the various utilities, and providing aesthetics that tie into the historical character of the surrounding area. Like the Route 28 bridge, this project was also designed in-house by

A bird's-eye rendering of the completed East 138th Street Bridge.

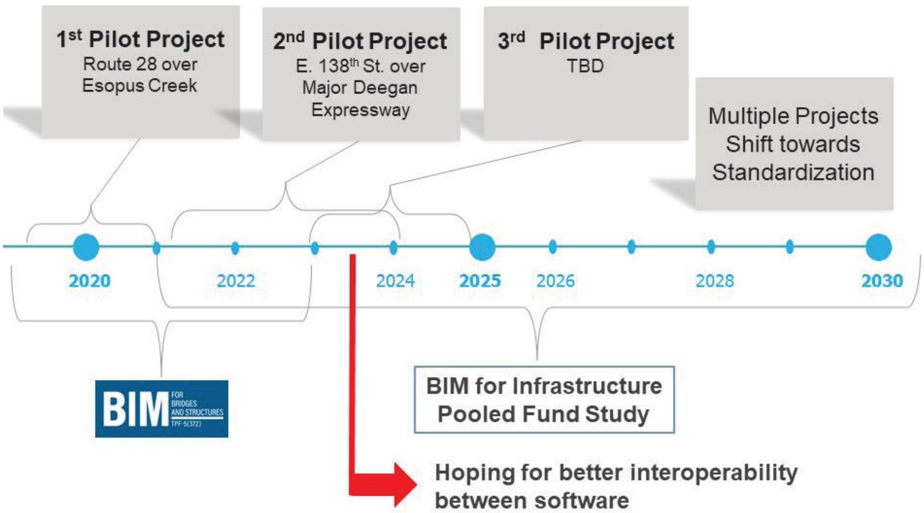
above: A 3D model showing the steel beam system located beneath the abutments of the East 138th Street Bridge.

below: A 3D model showing utilities underneath the bridge.

NYSDOT's Office of Structures and Office of Design, with the addition of an outside consultant for utility-related design tasks. It was an ideal candidate for model-based contracting, given the amount of coordination and clash detection that is necessary for a project that came with so many site constraints and strict geometric controls.

The new bridge is 147 ft wide with a single-span length of 81.5 ft. The superstructure is comprised of prefabricated bridge units, each unit consisting of two steel beams topped by a precast deck. Contrary to the first pilot project, the contractual information for the structural steel for the East 138th Street bridge was conveyed using spreadsheets. The structural steel was also modeled in 3D and provided to the contractor as supplemental information, a change in methodology that resulted from lessons learned from the first pilot project. The steel fabricator indicated that it was not easy to obtain steel dimensions solely through the 3D model, and there was hesitation that some geometry might be missed or not properly measured. The use of spreadsheets for the second pilot project was deemed an acceptable temporary work-around, but the team recognized that employing IFC files would greatly enhance the transfer of steel information from the 3D model to the steel fabricator.

The letting process for the second pilot project used the "best value" procurement process, where the bidder is selected based on its bid amount in addition to its scored proposal for certain criteria. For this project, NYSDOT solicited bids based on the following criteria: the contractor's previous experience using 3D models in construction, its plan for using the electronic files provided as contract documents, the overall schedule, and how it would address the logistical challenges to completing the bridge replacement on time and on budget while minimizing disruptions to the traveling public and surrounding neighborhoods. Construction is ongoing for this second pilot project, but NYSDOT is hopeful that the success evident in the design phase will translate through to completion.

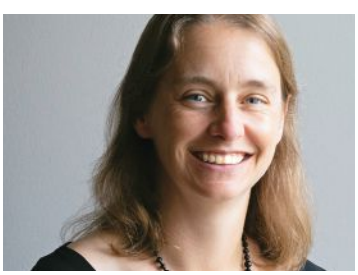


NYDOT's model-based contracting plan, looking forward.

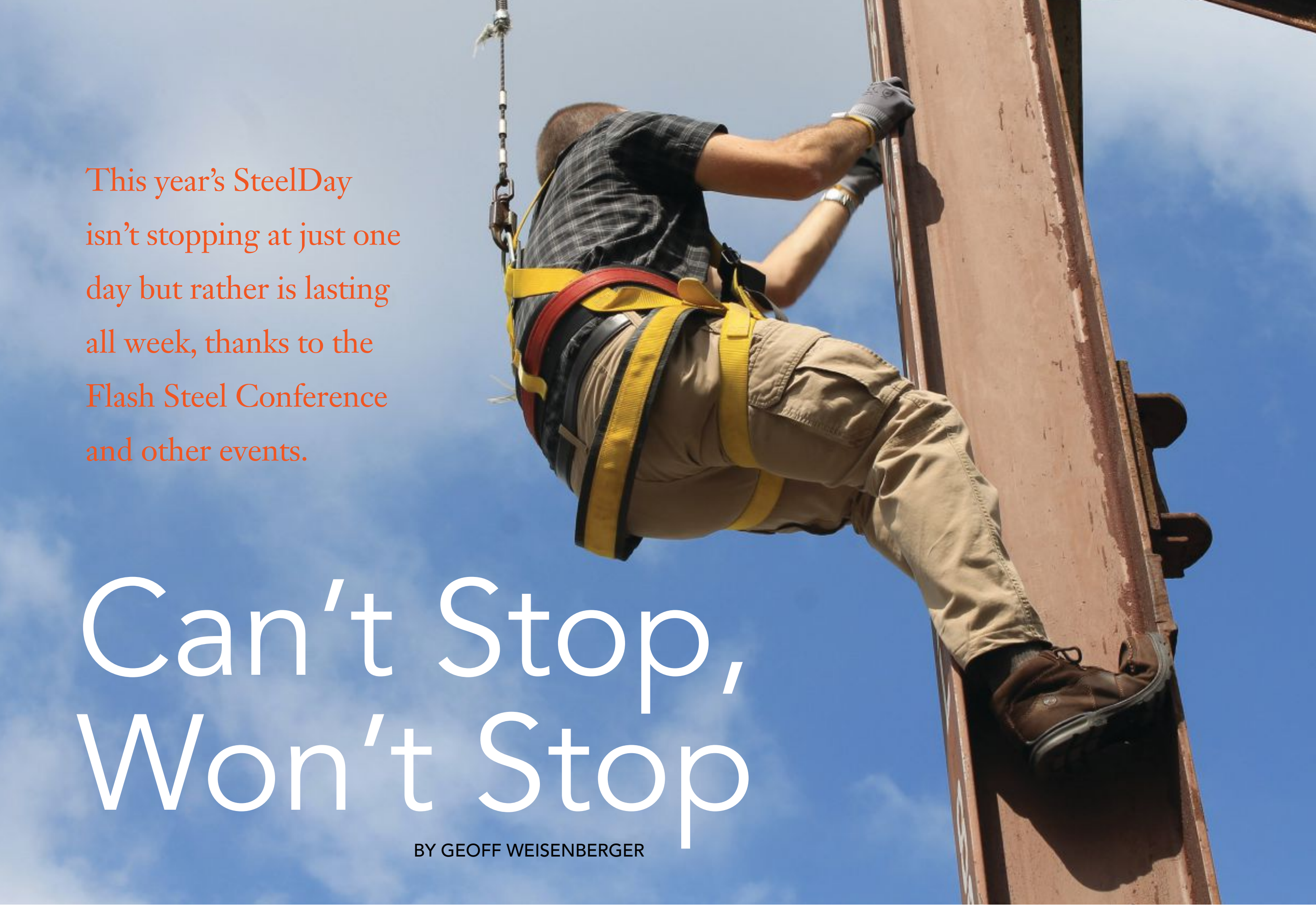
What's Next?

NYSDOT has been using model-based design for decades and is currently leading the way for model-based contracting, but we have yet to tackle the ultimate challenge of model-based asset management. From design to construction to operations, and ultimately back through planning and design, a bridge's life cycle should transfer data from one milestone to the next. But without BIM, data and asset management is siloed, with each group operating independently. This hinders productivity and efficiency and is, frankly, an obsolete approach in today's world of technology.

NYSDOT is currently focusing on the exchange of data from design to construction, and incorporating BIM into the overall bridge life cycle is the next phase. With hopes that the design and modeling software can catch up with the construction field technology and that field staff will continue to be trained in model-based construction and asset management, this can become a reality. Only then can a BIM approach for bridges come full circle, where 3D information models can be used to build, operate, maintain, and rehabilitate bridges—and NYSDOT is eager to lead the way. ■



Brenda Crudele (**brenda.crudele@dot.ny.gov**) is the director and **Julianne Fuda** (**julianne.fuda@dot.ny.gov**) is the assistant director, both with the Structures Design Bureau within the Office of Structures at the New York State Department of Transportation.



This year's SteelDay isn't stopping at just one day but rather is lasting all week, thanks to the Flash Steel Conference and other events.

Can't Stop, Won't Stop

BY GEOFF WEISENBERGER

WHAT ARE YOU DOING the week of October 17–21?

It's likely that you'll be working, although there's the possibility that you'll be taking a fall vacation (in which case, good for you).

But if you have some free time that week, even just a few hours, you can take advantage of fun, educational events that can enhance your work going forward—in some cases, even from the comfort of your office (whether that means your house or a more traditional office setting).

shop tours

welding demos

networking

free webinar

Flash Steel Conference

How is this possible? Because October 21 is SteelDay. And this year's edition is preceded by the Flash Steel Conference (more on that in a bit), which takes place October 18–20. Sponsored by AISC and various partners, SteelDay is the annual celebration of the structural steel industry that gives AEC professionals, faculty and students, and the public a firsthand look at the vibrant U.S. structural steel industry. You'll learn about the industry's latest technologies (ranging from improvements in the properties of steel to better equipment and new communication and design tools), see what's going on today with structural steel, and network with people advancing building and bridge design and construction.

Several in-person events are set to take place on or around SteelDay, including the following:

Lancaster, Pa. AISC member fabricator High Steel Structures is holding a full-day event, which includes a morning technical session, guided facility tours, and welding demos.

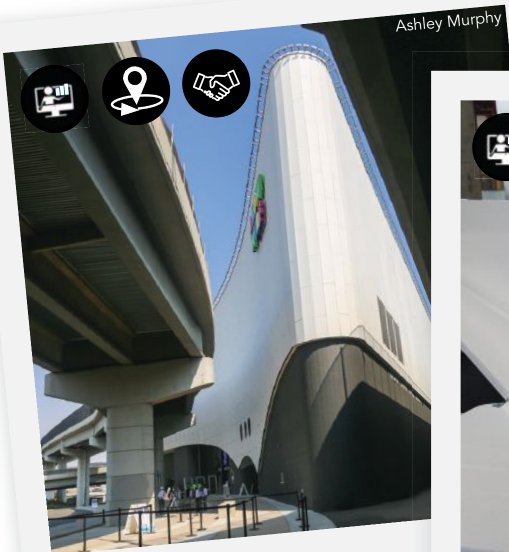
Owego, N.Y. If you want to see the galvanizing process at work, you can attend a plant tour of the newest addition to AISC member V&S Galvanizing's family: V&S NY Galvanizing. (Note that this event is scheduled to take place the week before SteelDay.)

Ridgefield, Wa. Another fabricator, AISC member Alpha Iron, is also holding an event where visitors can see how the company converts plans and specs to 3D models and how its robots and CNC machinery convert these models into steel components that can be used to build your projects. Attendees will also learn how technology can improve quality and schedule and reduce cost and reduce labor on a project and identify how other trades can be integrated into fabrication, including MEP and architectural connections.

Eau Claire, Wis. AISC member fabricator Veritas Steel will provide presentations on innovation and quality, followed by shop tours. (Note that this event is scheduled to take place the week after SteelDay.)

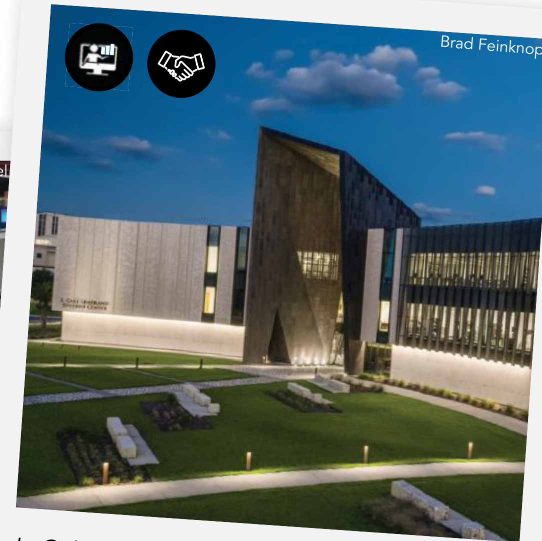
Tuscaloosa, Ala. AISC member producer Nucor Steel's Tuscaloosa facility will host DOT representatives for a presentation on the steelmaking process, followed by a tour.

Daytona Beach, Fla. This event takes the form of an IDEAS^2 Award presentation for one of this year's winners, the



Meow Wolf, Denver
presentation and tour

High Steel Structures, Lancaster, Pa.
presentation, shop tour, and welding demos



L. Gale Lemerand Center
Daytona Beach, Fla.
IDEAS^2 Award presentation

L. Gale Lemerand Center at Daytona State College. (To read about this project and the rest of the 2022 winners, see the related article in the May 2022 issue, available in the Archives section at **www.modernsteel.com**.)

Denver. Meow Wolf will host a presentation from the engineer and architect, followed by a tour of this surreal, inspiring museum experience that was built between two elevated highways near downtown Denver. (You can read about the project in "Immersive Installation" in the June 2022 issue.)

Seattle. Representatives from AISC member Metals Fabrication company (located in Spokane, Wash.) will give a presentation on constructability, which follows an AISC presentation on economics.

Butler, Ind. AISC member New Millennium Building Systems will provide a shop tour, giving attendees an up-close look at how a joist-manufacturing facility operates.

Across the country. Several Ironworker Management Progressive Action Cooperative Trust (IMPACT) facilities will be hosting tours throughout the week involving a variety of different training stations that allow you to experience what an ironworker does on a daily basis, including welding, flame-cutting, rigging a beam, or climbing a column. As of this printing, there are events scheduled in Atlanta, Orlando, New York, Boston, Washington, Dallas/Ft. Worth, Las Vegas, Los Angeles, San Diego, Sacramento, and Portland.

If online learning is more your speed, AISC's new vice president of engineering, Chris Raebel, will present an online webinar, "Bridging Research and Practice to Go Beyond the *Specification*," where you will learn how designers can work with educators to go beyond what's included in AISC's *Specification for Structural Steel Buildings* (ANSI/AISC 360); view case studies on successful collaboration between researchers, engineers, and fabricators to solve problems and confirm innovative design solutions; and get tips on developing your organization's future by scoping out new talent and introducing students to your work and opportunities.

Another online opportunity is the Flash Steel Conference. Now in its third year, the three-day online conference is comprised of 30-minute sessions and is geared toward providing a lot of information in a short time frame. The Connection Design track will provide practical connection tips and tricks, the Design and Construction Challenges track will focus on four recent IDEAS^2 Award-winning projects and examine the innovative solutions that engineers, fabricators, erectors, and others used to overcome specific challenges, and the Future of Steel track will feature sessions that look forward to areas of increasing importance. In addition, AISC's Steel Solutions Center (SSC) advisors and consultants will present some of the most intriguing and useful questions and answers from recent years on a variety of useful topics. And there are also two keynote speakers: Robert Otani of Thornton Tomasetti will discuss the concept of artificial intelligence (AI) and its role in design and construction, and Michel Bruneau of the University at Buffalo will speak about designing for resilience. You can register and learn more at **aisc.org/flash**.

And to view a list of events, register for one, and learn more about SteelDay, visit **aisc.org/steelday**. We hope to see you on or around October 21! ■

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

This month's New Products section is all about bridges and includes high-strength shoring, inspection vehicles with long-reach capabilities, and a decking system that meets your needs, both planned and unforeseen.

Acrow Superprop Shores

Available for rent, heavy-duty Superprop® Shores are suitable for a diverse range of applications. The shores are fabricated from Acrow bridge components using high-strength steel and can be installed within hours in even the most restricted staging areas. The system can also be hydraulically preloaded with ease using the infinitely adjustable Superprop system. A single Superprop Shore can safely support up to 256 tons, and by bracing Acrow shores with Acrow panels, a shoring system of superior strength and simplicity in design can be used in any vertical shoring application. Simple in design and rugged enough to support the heaviest loads, the modular, adjustable system provides an economical, efficient, and safe solution to the most critical shoring needs. For more information, visit **www.acrow.com**.

Paxton-Mitchell SNOOPER Trucks

The Paxton-Mitchell PM260 series of SNOOPER® Trucks provides the most extensive reach capabilities for a wide variety of bridges, trestles, and viaducts. The fully hydraulic, easily mobile crane allows operators to be positioned exactly where they need to be to perform any type of under-bridge task, including inspection. Once in position, as many as three operators can work. The hydraulically extendible second boom allows the platform or basket to be deployed over tall fences or under deep girders. Workers are placed right at their work, up in the structure, or along the bottom of beams. For more information, visit **www.paxton-mitchell.com**.

D-MAC Accelerated Steel Bridge Form

When you partner with D-MAC to provide the stay-in-place steel bridge form for your project, you are teaming up with the only manufacturer that uses two roll-forming lines dedicated to producing only steel bridge deck. This means that you get the metal bridge decking materials on time per your schedule—and more importantly, you get the materials that you were *not* planning for in hours or days, not weeks or months. Unforeseeable project delays caused by weather, pedestal elevations, girder camber, girder sweep, installation errors, or even a drunk driver trying to cross a bridge under construction (this has happened!) can be costly, but since 1988, D-MAC has been ready to respond immediately to such circumstances. D-MAC also provides the widest bridge form sheets in the industry, reducing installation time and costs. For more information, visit **www.d-macindustries.com**.

FORGE PRIZE

Emerging Architects: Show the World What You Can Do—And Win $15,000!

What will the future look like? Let's explore the possibilities with structural steel—from the imaginations of the emerging architects who will build tomorrow's real world!

AISC is now accepting entries for its fifth annual Forge Prize competition. The Forge Prize, established by AISC in 2018, recognizes visionary emerging architects for design concepts that embrace steel as a primary structural component and capitalize on steel's ability to increase a project's speed.

"The future belongs to those who will build it, and structural steel will continue to empower those who push the boundaries of sustainable, efficient, and captivating design," said Houston-based AISC senior structural steel specialist Alex Morales. "The Forge Prize provides a unique opportunity for emerging architects to dream big, then collaborate with an expert structural steel fabricator to explore how the real-life advantages of steel could help bring that vision to life faster, more economically, and with elegance."

Three finalists will each win $5,000 and a chance to highlight their work before the steel and AEC industries. They'll work with a steel fabricator to refine their concept before stepping into a global spotlight to present their concepts live to the judges—and to the public—on YouTube.

The winner will take home an additional $10,000 and be invited to present his/her design to the industry at the Architecture in Steel conference, which is incorporated in NASCC: The Steel Conference, in Charlotte, N.C., next April.

U.S.-based architects who are either currently seeking licensure or have been licensed for fewer than ten years may enter online at **www.forgeprize.com**. Entries are due by November 30, 2022.

THE STEEL CONFERENCE

Recordings from the 2022 NASCC: The Steel Conference Now Available Online

Remember that presentation you meant to attend this past March in Denver? The one that just didn't fit into your busy conference schedule no matter how you arranged your day? Now you can find that session—all sessions, in fact!—from the 2022 NASCC: The Steel Conference for free online! Though you won't earn any PDHs, you'll gain a ton of inspiration and insight into the latest innovations in American structural steel. You can access the sessions at **aisc.org/education/continuingeducation/education-archives/nascc-2022-all**.

People & Companies

AISC is proud to welcome **Christopher H. Raebel, SE, PE, PhD**, as its new vice president of engineering and research. He succeeds Larry Kruth, PE, who is retiring later this year.

Raebel will oversee all AISC technical activities, including the development of AISC's standards and technical publications, research programs, and technical assistance through the AISC Steel Solutions Center.

"Steel is the fastest, most cost-effective, highest quality, and sustainable structural material, and I'm thrilled to be part of the team working to make it the material of choice on every project," Raebel said. "I look forward to working with AISC's staff, members, and our hundreds of fantastic volunteers."

Raebel has been active in AISC committees and as a local and national leader in the broader engineering community for several years. He served as chair of the Department of Civil and Architectural Engineering and Construction Management at Milwaukee School of Engineering (MSOE), where he was also director of the Architectural Engineering Program. His areas of expertise include structural engineering, structural mechanics, structural steel design, steel connection analysis and design, robustness in steel-framed structures, floor vibrations due to occupant activities, and engineering education. In 2016, he was one of the first recipients of AISC's (Terry Peshia) Early Career Faculty Award.

BRIDGES

Speed Up Steel Bridge Fabrication with New NSBA Guide

When it comes to increasing the speed of steel fabrication, cutting, fitting, welding, drilling, cleaning, and coating are only part of the equation.

You can also make steel fabrication faster by optimizing what goes on outside the shop, like getting materials, facilitating routine procedures, and coordinating inspections.

The key to accelerated steel bridge fabrication is seamless teamwork between the fabricator, owner, engineer, and contractor—and NSBA's brand-new guide is designed to help you do just that.

Accelerated Steel: Achieving Speed in Steel Bridge Fabrication describes how each of these roles affects critical shop support activities, which can make or break the fabrication schedule. This guide describes the ideal schedule for every step of fabrication as well as the responsibilities of owners, designers, and general contractors.

Download the guide today to learn how to immediately speed up the steel bridge fabrication process: **aisc.org/nsba/design-resources**.

HSS

Steel Tube Institute Resource Approved as Standard Guide for Checking HSS Tolerances

The Steel Tube Institute's (STI) technical guide *Methods to Check Dimensional Tolerances on Hollow Structural Sections* has been approved as the standard guide for measuring tolerances according to the American Society for Testing and Materials (ASTM). This new resource makes it easy for producers, service centers, and fabricators to measure hollow structural section (HSS) tolerances.

Available on the STI website at **steeltubeinstitute.org/resources/hss-tolerances**, the guide details and illustrates the latest methods to correctly measure HSS tolerances. It also summarizes the dimensional tolerances allowed by ASTM A500, A847, and A1110, which is helpful for engineers and architects in detailing HSS projects.

The guide also assists professionals in verifying compliance with ASTM specifications. While it is approved for the A500, A847, and A1110 Specifications, it may be used for verifying tolerances for A1085, A1065, and other similar tubular specifications. The resource outlines instructions for checking tolerances for outside dimensions, wall thickness, length and straightness, squareness of sides, radius of corners, and twist of the member.

Letters to the Editor

Sound Judgment

I wanted to thank you for your marvelous coverage of the Student Steel Bridge Competition (SSBC) in the August issue ("Building Bridges in Blacksburg," August 2022, available at **www.modernsteel.com**). This type of exposure and your narrative brings the competition to life for many who were not previously familiar with it. Hopefully, your article encourages greater participation by stakeholders to support the SSBC by volunteering to judge or funding the costs of participating schools. I also want to thank you for your kind words about me. I have truly enjoyed my time and still marvel at how this competition has grown over the years.

—John Parucki
SSBC National Head Judge

Second Opinion

Thank you for comprehensive coverage of the 2022 SSBC and the précis of John Parucki's contributions as head judge. I was involved with most of the National Competitions over which John presided, so I can attest to his remarkable dedication, energy, focus, fairness, and good humor. Although his tenure began in 1995, that was not the first National Competition. The first was in 1992, hosted by Michigan State University, and the 1993 and 1994 National Competitions were hosted by Southern Tech (now Kennesaw State) and San Diego State, respectively. These three competitions were judged by whomever the host university recruited. From 1992 to 1995, participation boomed from 13 student teams to 31, and AISC correctly concluded that a single national head judge was needed to assure year-to-year continuity and uniformity in organizing, conducting, and judging the competitions. John Parucki was the fortuitous choice, and much of the competition's development, popularity, and educational impact are due to his 27 years of outstanding service. Also, thank you, Geoff, for editing *Modern Steel Construction*, my favorite magazine!

—Frank Hatfield, Professor Emeritus
College of Engineering
Michigan State University

advertiser index

Lovely and Long-lasting

MONTANA'S LONGEST AND TALLEST BRIDGE might also be its most durable.

The Koocanusa Bridge, located in the northwestern portion of the state, is 2,437 ft long and rises 270 ft above the bottom of Lake Koocanusa. The lake was created in 1972 by damming the Kootenai River with the Libby Dam, and the bridge, which was completed by the U.S. Army Corps of Engineers in 1971, spans the lake's width near Rexford.

Due to the concrete deck not holding up to the area's cold climate and freeze-thaw cycles, the entire deck was reconstructed in 1983. The original paint system involved some of the last lead-based paint used in Montana, so the steel was pressure washed, locations with severe paint peeling were spot painted, and then the entire bridge was overcoated with moisture-cure urethane paint, which encapsulated the remaining lead-based paint.

Late last year, DJ&A performed a routine fracture-critical inspection in conjunction with the U.S. Forest Service, Region 1. During the inspection, Brad Miller, PE, a senior structural engineer and lead inspector with DJ&A, documented the process with his Canon PowerShot camera, capturing this view.

The inspection revealed that the steel superstructure remained intact and in good working condition, with the experience reaffirming the longevity, as well as beauty, of structural steel bridges. ■