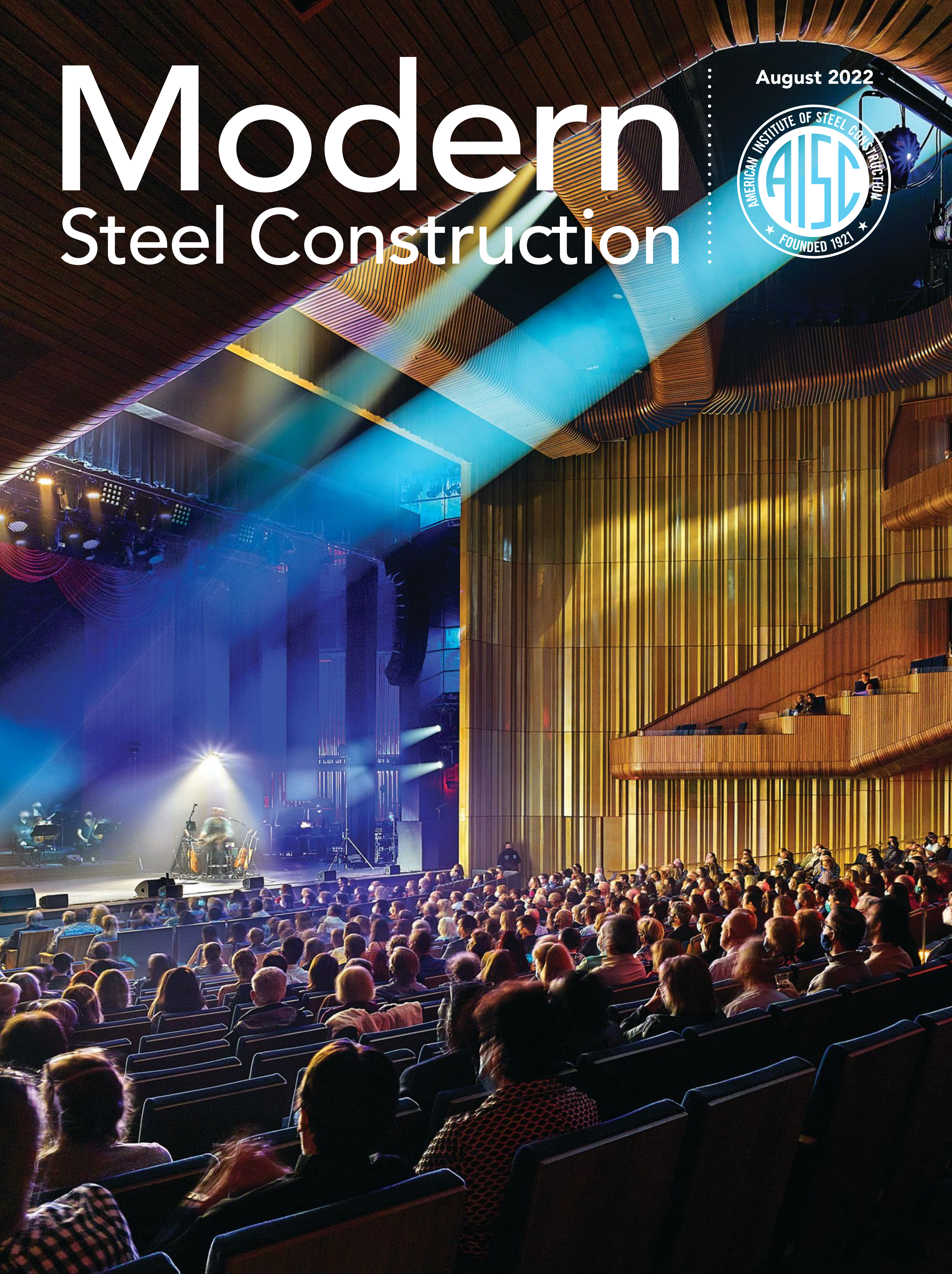
Modern Steel Construction

August 2022

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editor's note

Have you ever had to work or live through ongoing construction at your home, school, or workplace?

While it can be… challenging, it's also kind of fun. And educational!

My first experience with this was in Austin, back in the late 1990s. A friend had just moved down there from Iowa and was living with a couple who was basically doing a gut rehab of their house—while living in it. I spent a couple of nights there, and the room I slept in was basically untouched. But when I walked out the door in the middle of the night, it felt like I was getting a behind-the-scenes look at a movie being made. Like the house was being built around me. There was a very clear and present element of danger—several, in fact. (And who doesn't *love* that!) But to my untrained (at the time) eye, it was a fascinating look at the various components that are inherent in any building. The parts you don't see.

I bring this up because AISC is wrapping up its own HQ renovation project—which, by the way, is progressing according to schedule. Of course, we all know that many construction projects, whether new or retrofit, aren't completed on time. But AISC is working to make sure that steel is doing *its* part to keep projects on track and on schedule.

As you've probably heard (perhaps even in past editor's notes), we've been working on a Need for Speed initiative, which aims to increase the speed at which a steel building or bridge can be designed, fabricated, and erected by 50% by the end of 2025 (visit **aisc.org/needforspeed** to find out more about it). There's no magic button for achieving this goal. Rather, reaching it is the sum of many parts, and there are opportunities at every link in the steel supply chain to make incremental changes.

Why am I bringing this up? Because I want to give you a heads-up about our December issue, which will include write-ups from software developers and product manufacturers on how their offerings can help contribute to this goal. But this opportunity isn't just limited to them. If you're reading this and you have a steel success story involving speed, I want to hear about it. I'm not asking for every reader to submit an article (though, honestly, that would make my job a lot easier). Rather, I'm looking for a brief anecdote or testimonial about how a steel project you've worked on went faster than usual and how it happened—case studies, if you will. I'd even welcome your pie-in-the-sky ideas that stretch the imagination a bit.

And speaking of imagination, to see examples of cutting-edge concepts that hold some promise to speed up future steel projects—specifically in the form of steel connections that can help facilitate faster erection of framing elements—check out "Facilitating Faster Framing" on page 44 to read about the winners of AISC's SpeedConnection challenge.

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

Vertically Curved Members with H/L_s < 0.1

I am designing some vertically curved steel members. My designs have a large radius and a relatively short span, so my H/L_s (see Figure 1) value is less than 0.1. AISC Design Guide 33: *Curved Member Design* states that an H/L_s less than 0.2 is a higher risk for snap-through buckling. However, I don't see any information for an H/L_s less than 0.1. Is there a lower limit to where a beam acts more as a cambered beam than a curved beam, and the recommended procedures in the design guide are no longer relevant?

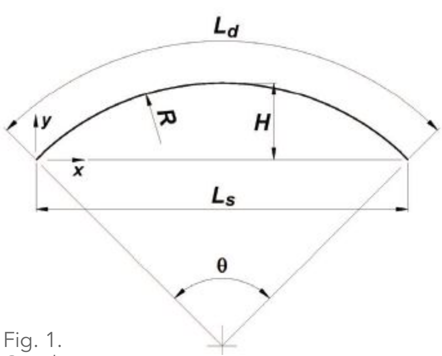
It is always safe to neglect any horizontal translational restraint and design vertically curved members as beams. This can be accomplished in the structural analysis model by releasing the horizontal translational restraint at one end of the member. If the member is designed as a beam, snap-through buckling (see Figure 2) is not an applicable limit state. For many vertically curved members in buildings, designing as a beam rather than an arch results in the most efficient structure because the large horizontal forces and the horizontal translational rigidity requirement at the member ends (to prevent snap-through buckling) are not required for beams.

Although the end support condition for one end of a vertically curved beam is idealized as a roller, actual structures will have some horizontal translational restraint. This will cause horizontal forces in the connection and support that are dependent on the connection and support stiffness. A primary concern for the supports and end connections is the ductility required to accommodate the horizontal translation of the member when loaded. Many end connections are ductile enough to accommodate the horizontal deformations without rupture; however, this should be verified. For example, if a large I-shaped curved member with a long span is welded directly to a rigid support with small fillet welds, the arch action will cause significant horizontal forces in the welds that may result in weld rupture. If a more ductile connection is used (for example, a bolted end plate), some deformation can be accommodated in the bolts and connection elements. For larger deformations, the connections can use slotted holes with finger-tight bolts.

For long-span members, such as those in arenas and arch bridges, it is usually efficient to design vertically curved members as arches. An advanced analysis that considers the effects of support stiffness, geometric imperfections, and inelastic material behavior (including residual stresses) is typically used to evaluate these members. The advanced analysis models must consider the snap-through buckling limit state. The design guidance for snap-through buckling in Design Guide 33 is intended to provide a simpler design (and potentially more conservative) method for shorter-span members typically used in building structures. Advanced analysis is highly recommended if a member is designed as an arch and the snap-through buckling requirements in AISC Design Guide 33 cannot be satisfied. This is especially the case for H/L_s < 0.10 because the support stiffness has a significant effect on the strength.

In addition, AISC's member bender-rollers are happy to assist with curved steel inquiries. You can view a map of them, with contact information, at **aisc.org/benders**.

Bo Dowswell, PE, PhD



where:
H = rise, in.
L_d = arc length (developed length), in.
L_s = chord (span), in.
R = radius, in.
θ = subtended angle, radius

Fig. 1.
Circular geometry.

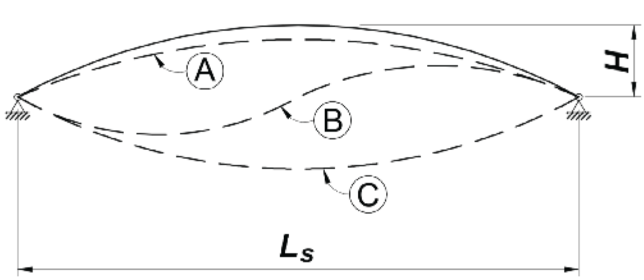


Fig. 2. Shape A shows the deflected shape at imminent buckling. Shapes B and C show snap-through buckling that can occur in a symmetric mode or asymmetric mode.

All mentioned AISC publications, unless noted otherwise, refer to the current version and are available at **aisc.org/publications**.

Special Moment Frame Connection to the Weak Axis of a Wide-Flange Column

Is there any design and detailing information on special moment frames (SMFs) connected to the web of a column?

I am not aware of any design or detailing resources for an SMF with the beam connecting to the column web as you describe. I am also not aware of any specific section of the AISC *Seismic Provisions for Structural Steel Buildings* (ANSI/AISC 341) that expressly prohibits the column orientation you describe. However, there are provisions that would make this condition impractical.

The *Seismic Provisions* govern the design of structural steel members and connections in seismic force-resisting systems. An SMF is a seismic force-resisting system that meets the requirements of Section E3 of AISC 341. Section E3.2 states: "SMFs designed in accordance with these provisions are expected to provide significant inelastic deformation capacity through flexural yielding of the SMF beams and limited yielding of column panel zones, or, where equivalent performance of the moment-frame system is demonstrated by substantiating analysis and testing, through yielding of the connections of beams to columns… Design of connections of beams to columns, including panel zones and continuity plates, shall be based on connection tests that provide the performance required by Section E3.6b, and demonstrate this conformance as required by Section E3.6c."

Part 4.3 of the AISC *Seismic Design Manual* (third edition) provides additional background information, stating: "Current requirements for SMF and IMF systems are the result of research and analysis completed by various groups… These requirements include prequalification of the connections used, per AISC *Seismic Provisions* Section K1, or qualification through testing in accordance with Section K2. Design and detailing requirements for moment connections prequalified in accordance with AISC *Seismic Provisions* Section K1 may be found in AISC *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* (ANSI/AISC 358)."

Prequalified Connections does not have any configurations where a connection of a beam to column web has been prequalified. Section 2.1 states that prequalified connections in Table 2.1 are for beams connected to column flanges. However, Section 1.1 states: "Nothing in this Standard shall preclude the use of connection types contained herein outside the indicated limitations, nor the use of other connection types, when satisfactory evidence of qualification in accordance with the AISC *Seismic Provisions* is presented to the authority having jurisdiction."

NEHRP Seismic Design Technical Brief No. 2 – *Seismic Design of Steel Special Moment Frames: A Guide for Practicing Engineers* (second edition), referenced in the *Seismic Manual*, is also a useful reference and provides a good summary. Section 3.5.3 of that publication states: "In some cases, the prequalifications available in AISC 358 and evaluation service reports may not be adequate to cover the design conditions for a particular project… Other reasons this may occur include using connections in geometries other than those for which prequalfications exist, such as connections to the minor axis of wide-flange columns or skewed connections. If no prequalified connection meets the requirements of a particular design condition, AISC 341 Section E3.6c(c)(2) permits project-specific testing… Because of the required size of specimens needed to comply with the AISC 341, Chapter K requirements can be quite large. Often, only a limited number of university laboratories have the capability to perform such testing. Therefore, whenever possible, using framing configurations that will enable the use of prequalified connections should be considered."

Yasmin Chaudhry

Bracing Members with Skewed Braces

Can I rely on skewed beams to brace columns?

The required resistance of column bracing is defined in the 2016 AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360-16), Appendix 6 Section 6.2. Both the strength and stiffness requirements for the bracing system must be met. The bracing system consists of all elements connecting the brace point to a rigid support, including the braces, struts, and connections.

Because the braces are skewed relative to the principal axes of the columns, the equations in Section 6.2 can be used to determine the required resistances (strength and stiffness) perpendicular to the buckling axes. The loads in the bracing system must also consider the effect of the brace angle (angle between the buckling axis and the bracing plane) and, depending on the angle, it could lead to the required strength and stiffness being several times the required values calculated with the equations in Section 6.2.

Bo Dowswell, PE, PhD

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STEEL SOLUTIONS CENTER

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

steel quiz

This month's quiz focuses on recently released updated version of Design Guide 27: *Structural Stainless Steel.*

What do you call it when a thief steals something without leaving any clues behind? A stainless steal. On that topic, did you know that AISC recently released the second edition of AISC Design Guide 27: *Structural Stainless Steel* (**aisc.org/dg**)? If so, congratulations, you already got one question right! Now let's see what you really know. The questions and answers were developed by Yasmin Chaudhry, staff engineer in AISC's Steel Solutions Center.

1 **True or False:** The latest version of Design Guide 27 contains shape dimension and property tables and many design aid tables that complement the new AISC *Specification for Structural Stainless Steel Buildings* (ANSI/AISC 370-21, **aisc.org/specifications**).

2 **True or False:** Stainless steel exhibits linear-elastic behavior up to the yield stress and a plateau before strain hardening occurs. (Hint: This would be similar to the behavior of carbon steel.)

3 **True or False:** Austenitic stainless steels are generally selected for structural applications that require a combination of high strength, corrosion resistance, and/or high levels of crevice and stress corrosion cracking resistance.

4 How many specifications should be referenced for most common product forms when specifying stainless steel?
a. One **b.** Two **c.** Three **d.** Four

5 **True or False:** Selecting an appropriately resistant stainless steel for the given environment is the *most* critical step in preventing corrosion problems when designing for corrosion control with stainless steel.

6 The design strength for stainless steel is taken as what percentage offset yield strength?
a. 0.1% **b.** 0.3% **c.** 0.2% **d.** 0.5%

TURN TO PAGE 14 FOR THE ANSWERS.

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 **True.** The Design Guide functions similarly to the *Steel Construction Manual* for the new *Stainless Steel Specification*, which the guide is based on. Major topics are material behavior and selection, cross-section design, member design, connections, and fabrication. Dimension and property tables are included in Chapter 4, design tables covering available strength for flexural members in Chapter 7, compression members in Chapter 6, and connections in Chapter 10. Design examples are also included.

2 **False.** While carbon steel typically exhibits linear-elastic behavior up to the yield stress and a plateau before strain hardening is encountered, stainless steel has a more rounded response with no well-defined yield stress. This is the most critical difference in the stress-strain behavior of stainless steel compared to carbon steel. See Chapter 2 of Design Guide 27 for information on the basic stress-strain behavior of stainless steel.

3 **False.** Austenitic stainless steels are generally selected for structural applications that require a combination of good strength, corrosion resistance, formability, excellent field and shop weldability, and excellent elongation prior to fracture (for seismic applications). Where high strength, corrosion resistance, and/or higher levels of crevice and stress corrosion cracking resistance are required, duplex stainless steels are most suitable. See Chapter 3 of Design Guide 27 for guidance on stainless steel selection.

4 **b.** Two. The specification of stainless steel is different from that of carbon and alloy steel. For most common product forms, two specifications should be referenced. The chemistry and mechanical property requirements are listed in one specification, while the general requirements, such as finish, tolerances, testing, condition, shipping, and handling, are within a separate specification. Table A3.1 in the *Stainless Steel Specification* summarizes the relevant ASTM standards required to specify stainless steel products. See Chapter 2 of Design Guide 27 for information on the specification and ordering of stainless steel.

5 **True.** The most important step in preventing corrosion problems is selecting an appropriately resistant stainless steel with suitable fabrication characteristics for the given environment. Because stainless steel is typically used for its corrosion resistance, the choice of the correct alloy is of paramount importance. See Chapter 3 of Design Guide 27.

6 **c.** 0.2%. Whereas carbon steels typically exhibit linear-elastic behavior up to the yield strength and a plateau before strain hardening is encountered, stainless steel has no definite yield point, shows an early departure from linear-elastic behavior, and exhibits pronounced strain hardening. For metals that demonstrate these characteristics, the design strength is taken as the 0.2% offset yield strength given in the ASTM product specifications. See Chapter 5 of Design Guide 27.

Composite Beam Possibilities

BY J.R. MUJAGIC, SE, PE, PhD, AND CHRISTINA HARBER, SE, PE

The soon-to-be released 2022 version of the AISC *Specification* brings flexibility and innovation to composite beam design with the introduction of a performance-based alternative for shear connections.

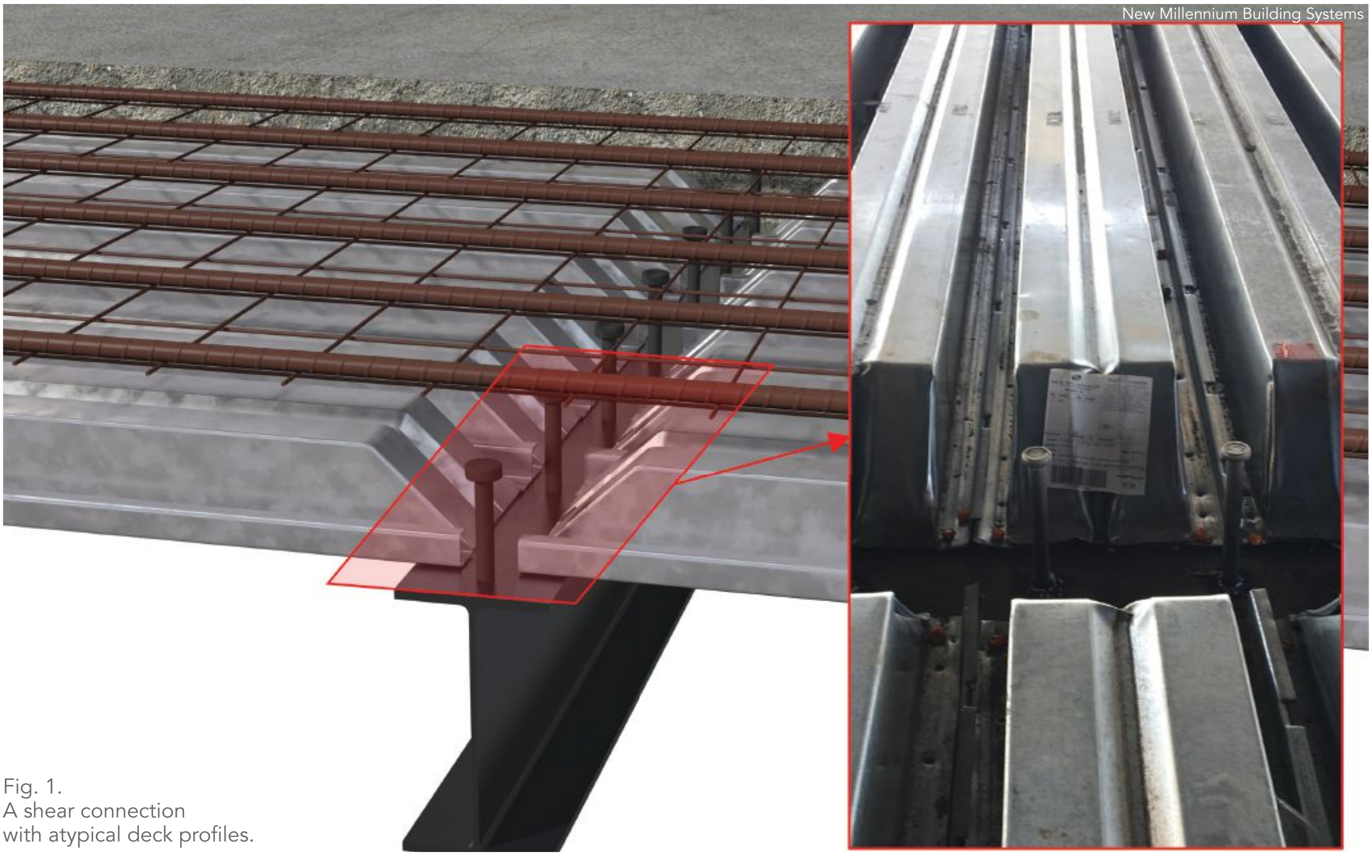

Fig. 1.
A shear connection with atypical deck profiles.

FOR A LONG TIME, DESIGNERS faced limited options when designing composite beams.

Until now, per the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360), they could only design composite beams with a limited range of steel deck, concrete slab, and shear connector geometries and material properties. This was an issue in situations where, say, a company wanted to create an innovative new composite deck system (such as the deck profile shown in Figure 1) or an engineer needed to check an as-built condition that didn't meet the required conditions.

But that's about to change. The 2022 version of the *Specification*, scheduled to be released this year, will give the building industry a performance-based alternative for composite beams.

Why

Designing shear connections between a concrete slab and structural steel member in composite beams was first made possible with the 1961 version of AISC *Specification*, which included tabular design values based on testing at Lehigh University. Based largely on the same test program, the first strength prediction model appeared in the 1986 edition of the *Specification*, and this model experienced substantial revisions in the 2005 *Specification*, resulting in what we use today.

The computational model used to determine the shear strength of an anchor embedded in a solid concrete or composite slab with decking, Q_n, is subject to several strength and dimensional limitations. These mostly stem from the confines of the test program leading to its development. Examples of dimensional limitations include the requirements of maximum deck rib height (h_r), the minimum height of headed shear anchor above the formed deck profile (H_s–h_r), anchor spacing requirements, shear anchor diameter, and the minimum width of the deck rib (w_r), as shown in Figure 2. The type of shear connector is limited to channel anchors or headed stud anchors. Component material strength parameters, such as tensile strength of the shear anchor material (F_u), are limited as well. Finally, the strength prediction model does not capture the effect of other contributors, such as mild reinforcement and strength, thickness, and embossment patterns of formed steel deck.

A comprehensive modification of the strength prediction model in the *Specification* involves lengthy and costly physical testing protocols, the specification consensus process, and a six-year specification development cycle followed by the subsequent adoption of the *Specification* by the applicable building code. Finding a fast and economical way to implement innovative deep deck profiles (see Figure 1), larger-diameter or higher-strength materials in shear connectors, or alternate forms of shear connectors is certainly attractive when striving to meet the demands of a specific project.

Section 104.11 of the *International Building Code* provides a venue for using alternate materials, designs, and construction methods, provided they are deemed equivalent in performance to their counterparts prescribed by the code. This process typically involves the pursuit of a code approval report through a third-party evaluation agency. A recent example of such implementation related to shear connectors in flexural members is Ecospan Shearflex shear connectors by Vulcraft.

Recognizing the benefit to design practitioners—and the construction industry in general—of employing a prescribed mechanism to quickly evaluate and implement specific shear connection configurations not covered by the scope of the current *Specification*, the 2022 version incorporates newly created provisions in Section I8.4 that outline the performance-based alternative for designing shear connections.

What

The new requirements in Section I8.4, Performance-Based Alternative for the Design of Shear Connection, serve as a set of performance thresholds that any particular shear connection must meet in order to be deemed equivalent to the shear connection currently covered by the *Specification* without affecting how flexural strength is determined.

To that end, the 2022 edition identifies four key performance criteria: strength, reliability, ductility, and stiffness. The process of executing a performance-based alternative entails determining these four performance criteria for a specific configuration of the connection and comparing them to the performance thresholds provided in Section I8.4. If these thresholds are met, the shear connection may be employed in the design and deemed equivalent in performance to the shear connection methods provided in Section I8.2.

Designers must determine these performance characteristics through push-out testing. For this purpose, the 2022 edition stipulates using the newly published *Test Standard for Determining Strength and Stiffness of Shear Connections in Composite Members* (AISI S923). The scope of this standard is general in terms of the ability to evaluate connector types and geometric and strength variables. Additionally, the commentary provides examples of alternative testing standards aimed at connections featuring specific types of shear connectors.

Strength and reliability. The nominal shear connector strength, Q_{ne}, is determined as 85% of the average test strength per shear connector from the testing protocol. The value of Q_{ne} doesn't need to be similar or identical to any particular value of Q_n determined in accordance with Section I8.2. Q_{ne} may be viewed as the direct design parameter to be used in lieu of Q_n for determining the flexural strength of a composite beam.

To assure the level of reliability necessary in conjunction with the value of Q_{ne}, the 2022 edition of the *Specification* limits the coefficient of variation (COV) to a value between 0.09 and 0.15, depending on the number of replicate tests conducted. Effectively, the larger the number of tests, the smaller correction needs to be applied to the COV. COV limits are meant to be conformant to those of conventional shear studs so that an additional resistance factor is not needed; the resistance factor remains embedded within the flexural design of the beam.

Given the nature of the composite beam design process, a designer may be interested only in the nominal strength of shear connection, Q_{ne}. However, where the design context requires available strength, $f_v Q_{ne}$ or Q_{ne}/Ω_v, such as for force transfer

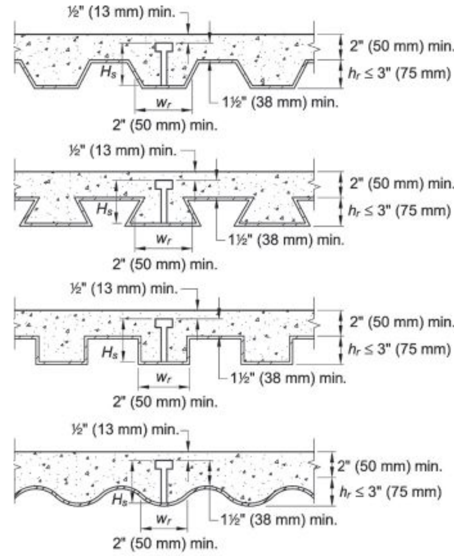

Fig. 2. Steel deck geometries and limits.

from the diaphragm to the seismic force-resisting system, available strength can be determined using the strength reduction and safety factors given in Section I8.3, provided that the statistical performance benchmarks outlined above are met. Alternatively, the user can establish the available strength directly using the approach provided by Chapter K of AISI S100: *North American Specification for the Design of Cold-Formed Steel Structural Members*.

Ductility. Shear connection ductility, or slip capacity, is defined as the ability of the shear connection assembly to displace (slip, *s*) at the interface of the steel beam and the concrete slab while maintaining its strength. To avoid significant underestimation of ductility on account of a minor loss of strength in ductile shear connection assemblies, the 2022 edition of the *Specification* defines the ductility as the slip recorded at 95% of the ultimate load (tested strength) captured on the declining end of the load-slip curve, as shown in Figure 3 on the following page. The shear connection ductility can be readily determined through the AISI S923 testing protocol. The nominal slip value is defined as the arithmetic average of the slip capacities obtained from the push-out tests used to obtain Q_{ne}. AISC 360-22 sets the passing performance threshold at 0.25 in.

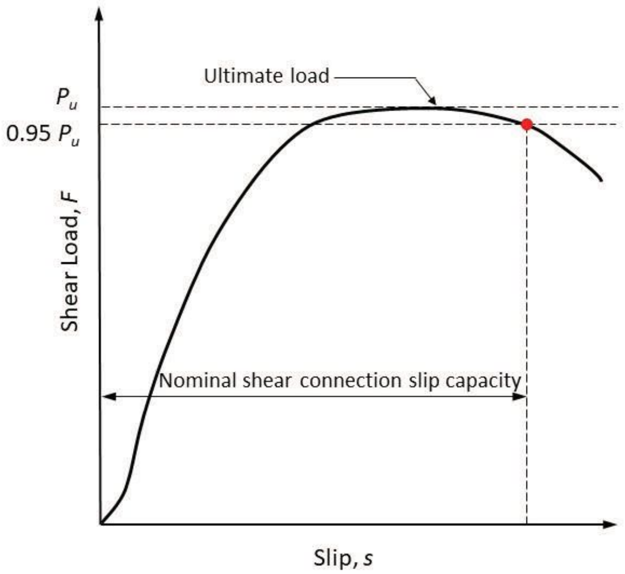

Fig. 3. Shear connection ductility.

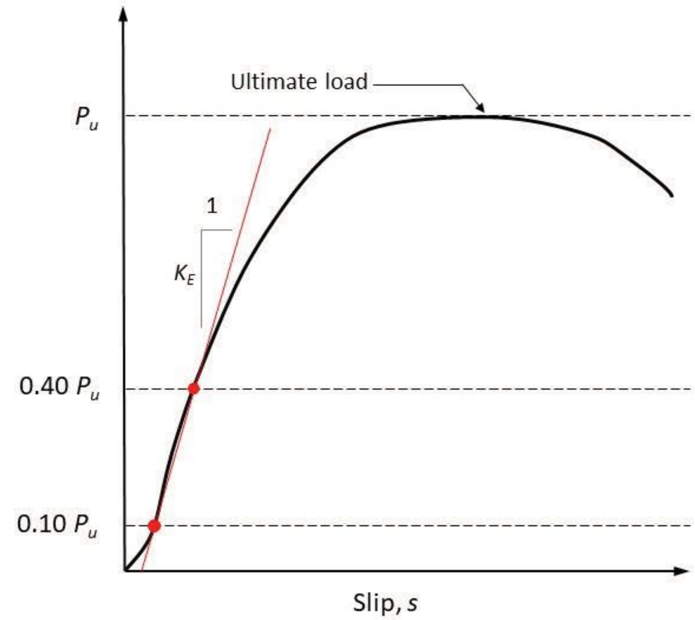

Fig. 4. Shear connection elastic stiffness, K_E.

It is important to recognize that the performance threshold of 0.25 in. does not remove the responsibility to consider the effect of shear connection ductility at the steel beam-concrete slab interface in design per Section I.3. Instead, the specified passing performance mark of 0.25 in. merely establishes the equivalence with the prescribed methods of shear connection and restores the validity of the guidelines provided in the commentary for considering shear connection ductility. When the flexural strength of a member is limited by the ability of the shear connection to supply adequate ductility, the performance-based alternative has the advantage of identifying potentially higher slip capacity for a particular shear connection that can be employed directly in the design and used to overcome ductility limitations in critical configurations, such as longer members.

Stiffness. While the slip capacity of 0.25 in. incorporates the total displacement a shear connection is capable of absorbing, it is important to limit the displacement component within the elastic range of the load-slip curve. Specifically, an overly flexible connection could cause early discontinuities in the strain diagram of the composite section and consequently invalidate the assumptions made in the determination of the composite section flexural strength or section and member stiffness used for analysis and serviceability checks.

The shear connection elastic shear stiffness, K_E, is defined for this purpose as the slope of a straight line connecting the points on the load-slip diagram corresponding to 10 and 40% of the ultimate load (see Figure 4). The offset of 10% accommodates potential initial displacements in the test assembly that aren't related to the behavior of the shear connection itself. The passing performance mark of 2,000 kip/in. can be assessed as the arithmetic average of the values obtained through the same testing protocol used to obtain Q_{ne}. While K_E is not a parameter typically directly employed in design, it is used to establish equivalence with the traditional forms of shear connection in Section I8.

The user of the performance-based framework can also take advantage of another provision of Section I8.4d. Specifically, in lieu of reliance on the acceptance pass/fail threshold of 2,000 kip/in, the user may also assess the impact on the composite section directly by employing another testing standard: AISI S924: T*est Standard for Determining the Effective Flexural Stiffness of Composite Members*. Therewith, the user may derive the effective flexural stiffness of the composite section to be used in analysis and serviceability checks, regardless of whether the shear connection stiffness meets the 2,000 kip/in. performance minimum. When AISI S924 is used, the nominal stiffness of the composite section is defined as the arithmetic average of those obtained from at least three tests.

How

Although users can assess countless shear connection design parameters with these new provisions, it is important to understand that Section I8.4 should not be used to validate, compare, or replace the strength parameters produced by the strength prediction model presently provided in Section I8.2. In contrast, the strength prediction model in Section I8.2 provides a continuous solution within the range of dimensional and other parameters discussed above, while each application of Section I8.4 is intended to address a single case of use—i.e., one specific configuration of a shear connection—rather than a method of interpolating other solutions. In short, the performance-based alternative cannot be used for developing strength prediction models rivaling those currently in the *Specification*.

Using the performance-based alternative is straightforward and can be summarized as follows:

1. Define the specific shear connection of interest—e.g.:
   - Composite steel deck: 6 in. deep, 0.05 in. thick, F_y =50 ksi, and w_r = 6 in.,
   - Concrete: normal weight, f'_c = 4 ksi, 10.5 in. total slab thickness with #5@12 in. E.W. reinforcement 1 in. above the deck profile
   - Steel-headed stud anchor: 1 in. in dia. by 8 in. long, F_u = 80 ksi,
   - 2 studs per rib in a strong position with $e_{mid\text{-}ht}$ = 4 in.
2. Identify an accredited testing facility acceptable to the authority having jurisdiction (i.e., typically an ISO 17025-compliant laboratory)
3. Perform a minimum of four replicate

tests. If the COV relative to Q_{ne} exceeds 0.09, perform additional tests until a COV not exceeding 0.09 is achieved relative to the mean tested strength, or perform a minimum of 9 tests with a COV not exceeding 0.15.

4. Obtain a test report recording the values of COV of Q_{ne}, s, and K_E.
5. Provided the performance thresholds of Section I8.4 of the 2022 edition are met, obtain approval of the authority having jurisdiction, as required (i.e., through an evaluation report or another applicable mechanism).
6. Apply the parameters of s, Q_{ne}, $f_v Q_{ne}$, or Q_{ne}/Ω_v, as applicable, in design. Specify the configuration from Step 1 in the construction documents.
7. If opting to evaluate effective section stiffness through AISI S924, follow the above steps before applying the stiffness in design. Effective section stiffness could be determined if K_E < 2000 kip/in., as determined from the application of AISI S923, or due to voluntary application of AISI S924 to attain a value of effective section stiffness in lieu of guidelines provided in the commentary.

Looking Ahead

The current scope is primarily aimed at the applications of shear connections used for achieving flexural strength in composite beams, as well as available strength of shear connection used for purposes of load transfer—i.e., from the diaphragm into the lateral force-resisting system. The protocols used to derive the performance-based parameters can also yield useful constitutive models of shear connection assemblies that can be employed in advanced modeling techniques.

The upcoming 2022 *Specification* is flexible. It does not stipulate the custodian of the data stemming from the application of the performance-based alternative. For example, the data could be published in the catalog of a manufacturer of a deep deck profile, or it could be used on a single project. The *Specification* furthermore does not stipulate a preference towards or against the proprietary nature of the components or the entirety of the shear connection assembly designed using the performance-based alternative. Simply put, it provides a framework enabling innovation and a faster path to implementation of specific shear connection configurations, which will serve to benefit the structural steel industry. ■

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Historic Rhythms

BY JOE DARDIS

As GDP recovery goes, so typically does construction—12 to 18 months later—making it a useful, if not perfect, economic indicator to keep an eye on.

HISTORY DOESN'T REPEAT ITSELF EXACTLY— but it often rhymes.

The correlation between GDP and nonresidential construction spending is a great example of this (see Figure 1) and a good indicator to monitor when it comes to anticipating projects.

Historically, a drop in GDP immediately triggers a drop in nonresidential construction spending. The magnitude of the drop in construction spending is typically dictated by three things: the magnitude of GDP drop, the length of time GDP is depressed, and the magnitude of GDP rebound. There is no "golden equation" to calculate which of these factors has the greatest impact, but Figure 1 implies that they all have significance.

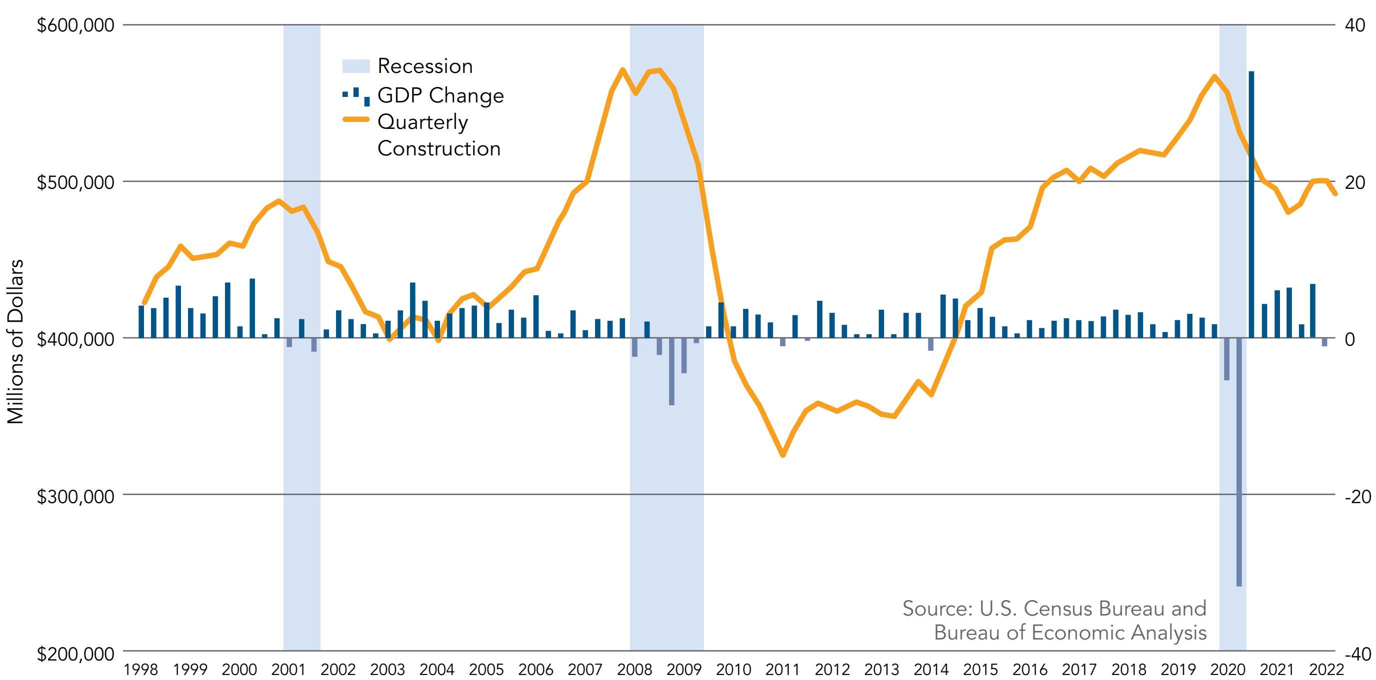
This can be observed from past recessions. The moderate drop in spending during the onset of COVID correlated with a huge drop in GDP but also a huge rebound over a relatively short period of time. Conversely, there was a huge drop in spending during the great recession but a modest drop and rebound in GDP over a longer period of time.

Perhaps the best "rhyme" from this example is that unlike the immediate drop in construction spending following a drop in GDP, the rebound of construction spending typically lags the rebound of GDP by 12 to 18 months. This observation holds true for the last three recessions, in which construction spending immediately began to drop when GDP turned negative but continued to drop well after GDP recovered.

Most recently, we saw construction spending begin to dip in the first quarter of 2020 and continue dipping until momentum was reversed in the third quarter of 2021 (18 months after GDP rebounded). However, the first quarter of 2022 saw a reversal in construction spending as GDP reversed its momentum.

So what happened? Does this mean construction spending will decrease for another year or two before it rebounds? Not necessarily. Remember, history tells us there are three contributing factors: size of drop, size of rebound, and length of time. The drop size was relatively small, and history also shows that there have been one-off quarters in the past with small GDP drops (2011 and 2014) with only minor and short-lived drops in construction spending.

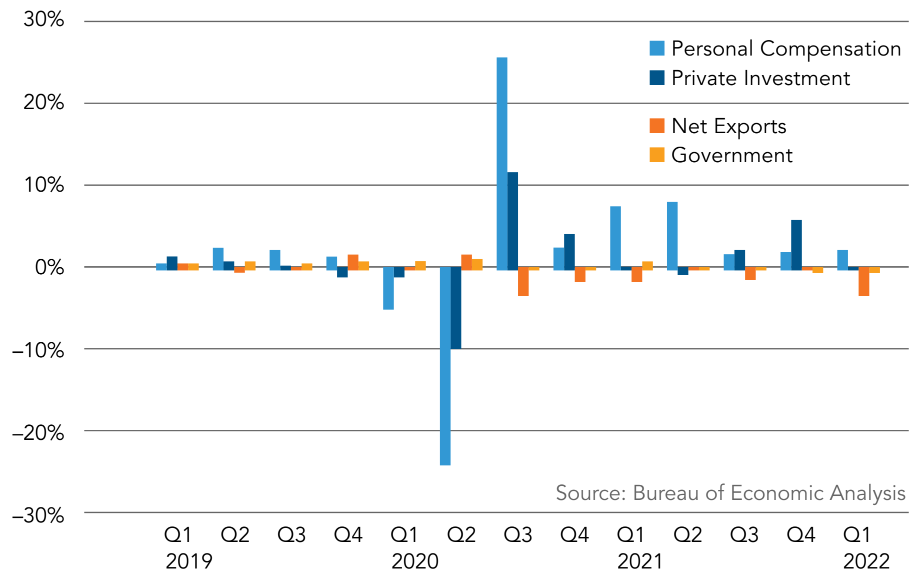
Fig. 1.
Nonresidential Building Spending (Inflation Adjusted) and GDP



But why did this drop occur after the economy was performing so well following the COVID rebound? Figure 2, which shows the contributions to the change in GDP, gives us a closer look and reveals that there are a few factors at play. The first of which, personal consumption, accounts for about two-thirds of the economy and saw only modest growth in the first quarter of 2022 as inflation caused materials and goods prices to rise. The larger factor here is the trade deficit, or "net exports." Importing goods into the U.S. means that U.S. dollars are going to other countries, which has a negative effect on GDP (again, see Figure 2). With a constrained supply chain, wholesalers and retailers have been seeking imports to rebuild inventories. More recently, however, many retailers are reporting inventory surpluses, indicating that the imbalance in the trade deficit could be eased in the near future.

Ultimately, history has rhymed again and GDP is still one of the most reliable indicators that we have about future construction spending. While a recent drop in GDP is not a great sign, it is important to remember the three factors that have historically dictated how construction spending reacts (again, magnitude of GDP drop, length of time GDP is depressed, and magnitude of GDP rebound) as well as the lag between GDP recovery and construction recovery. Since changes in nonresidential spending will affect almost all AISC member fabricators, it's important to keep a close eye on GDP movement and the reasons behind that movement. ■

Fig. 2.
Contributions to Percent Change in Real Gross Domestic Product



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

The Sky's the Limit

INTERVIEW BY GEOFF WEISENBERGER

This year's Forge Prize winners discuss their Common Sky concept, which has the potential to take urban housing projects to new heights, both figuratively and literally.

VINCENT YEE FOO LAI AND DOUGLAS LEE came to the University of California, Berkeley, via different paths. But the two share a common background of growing up in cities known for high-rise living, as well as a love of buildings.

Vincent has since moved to New York, where he works as an architectural designer at Adjaye Associates, and Douglas recently finished his master's in architecture studies at Berkeley. But they have maintained a coast-to-coast connection via their design collective, Temporary Office, where they developed their winning design for this year's AISC Forge Prize competition.

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**.

You both attended and met at the University of California, Berkeley, but where are you from originally?

Vincent: I was born and raised in Malaysia, and I immigrated to Singapore at the age of 12, so I spent the formative 24 years of my life in Southeast Asia before I came to Berkeley for grad school.

Douglas: I was born in Vancouver and raised in Hong Kong until I was 16 and moved around a little bit after high school, but I eventually ended up doing my undergraduate studies in London. And then I moved to Berkeley for graduate school in 2017. And that's where I met Vincent.

A lot of dense, vertical cities in your backgrounds! Everyone has an origin story. How did you both become interested in designing buildings?

Vincent: It's funny. A lot of people ask us this question, as well as whether we were interested in drawing. My story's a little bit atypical in the sense that I always liked assembling things. When I was young, we moved a lot, and my dad always wanted me to fix things like furniture here and there, so I was naturally drawn to putting things together, and it didn't have to be something that I'd created. Rather, it was more about figuring out how things come together. And when I was in Singapore, which is a very young nation, there was a mixture of public housing and private housing. And my whole life has always been in this environment where buildings constantly just pop up from out of nowhere. And five years later, you just see a building that's completely done. So I was very interested in contributing to that process of the built environment.

Douglas: For me, I don't think there was one defining moment that got me into architecture. I think it was mostly small observations that slowly got me interested in the built environment. Similar to Vincent, I grew up in megacities, and so I think urban infrastructure was always a fascination. Hong Kong is built vertically in a very steep landscape with very limited buildable space. And I think my urban planning degree allowed me to tap into the world of design from a more macro-perspective. But then I thought that it was intangible enough for me in terms of knowing what was actually getting built. And that ultimately led me to become more interested in design on a more granular level and at an architectural scale.

Two fairly different origin stories! Can you tell me how you joined forces to form Temporary Office?

Vincent: Currently, it's very much a speculative collaborative, meaning that we are not taking on any commissioned work yet. The inception was back when we were in school. We've always wanted to do competitions and test ideas. The collaborative doesn't have a certain dogma; there is no certain structure to how we approach a design. It's more of a fun way of creating a process and sticking to that process all the way to completion.

Douglas: I think the word temporary is a way to debunk the myth of how we practice. Designers are not limited to just working full-time in the office. We always encourage people to go out and seek inspiration, and then the office itself is just the place where we meet, or we meet over Zoom, to consolidate ideas. So it's a framework for what we want to build for the future practice.

We started back in 2020 when COVID had just begun, and "temporary" is a reflection of that state where we didn't really know what was going to happen in the future. But we're also open to trying new things, working collaboratively on different continents, working with different people, so there's this sense of just open-mindedness behind the name.

Very good point about how the name reflects our current reality. Can you tell me about your winning Forge Prize design, Common Sky?

Vincent: I think the point of departure for this project was that we saw that a lot of shared amenity spaces in these social housing projects were really underutilized, under-maintained, and somewhat uninviting, and we saw a good example of that in London and also at Riverton Gardens in Harlem, where the design is based. And we also see that a lot of these spaces are actually drivers for social interaction. So I think the focus of the project becomes how we find a way to celebrate this by thinking of new ways to create a dynamic, shared space where people would want to spend time—to create this very vibrant environment between people's housing units. Common Sky is a big common space with a lot of really exciting amenities like shared libraries, cafes, urban gardens, and urban farms where people can come together whenever they want to.

I understand you worked with an AISC member fabricator, Steel, LLC, to bring the whole thing together. Can you talk a bit about that experience?

Douglas: It was a super enriching experience. We started off with a lot of dialogue and building mutual consent around what we had in mind for a design direction. Rob Williams, our mentor from Steel, LLC, was very quick to respond to the design vision and try to assimilate his suggestions to what we were trying to do, and it moved quickly into a collaborative process where we tried to adapt the "old world" techniques that have been used on steel buildings for years, and there was a lot of back and forth in that process. Often, you hear about architects saying what they want, and then the structure engineer tries to solve it, but in this case, it was the other way around.

When it comes to the project's location at Riverton Square in Harlem, was there a personal connection to this particular development, or did you just see it as a good place to implement the design?

Vincent: We looked at Harlem because it has a history of gentrification and has gone through a great transformation. After the 1980s, with this new incoming infrastructure and a lot more unaffordable luxury housing coming in, that situation didn't necessarily appeal to the local community, and that top-down strategy left many Harlem residents feeling disempowered. So we thought about this as an opportunity to create a new type of ecology that could recalibrate this polarizing environment—an opportunity to create a scaffold for the Harlem community to build for themselves and something they can call their own.

Douglas: And in New York specifically and also the United States generally, there's a lot of social housing going into decay but also a lot of opportunity to invigorate those buildings to serve as a scaffold, as Vincent mentioned, for this new kind of housing. So we're taking that history and reinvigorating it so there's new life in this old building. We chose Riverton because of the strict geometry and the simple built form that provided a good canvas for us to design the first iteration. And after this first step, our view is to adopt this method for other housing projects.

The repeatability is a good approach. On that note, have you worked with modular construction before?

Douglas: I haven't really worked with modular construction before, but it was always a recurring theme for us. I think it started out on an architecture paper that we first worked on together that focused on the modularity of the Pompidou Center in Paris. And I think modularity becomes a very timely topic for us, because at a time when architecture as a field is called upon to think more sustainably and there's a focus on readapting existing buildings, it becomes a much more popular theme and makes more sense than just tearing down and building new.

Vincent: Modularity is also this rudimentary concept of an envelope that encompasses, say, one person living in one unit or one module. How do you maximize the volume in a given footprint? And so the idea is that modularity is part of the DNA of New York housing since it's so efficient. But how do you create different nuances in modularity to spark new life, new community engagement, and new community growth? I think that's what's interesting to us. It's not just about adding to the existing units but also the in-between spaces. ■

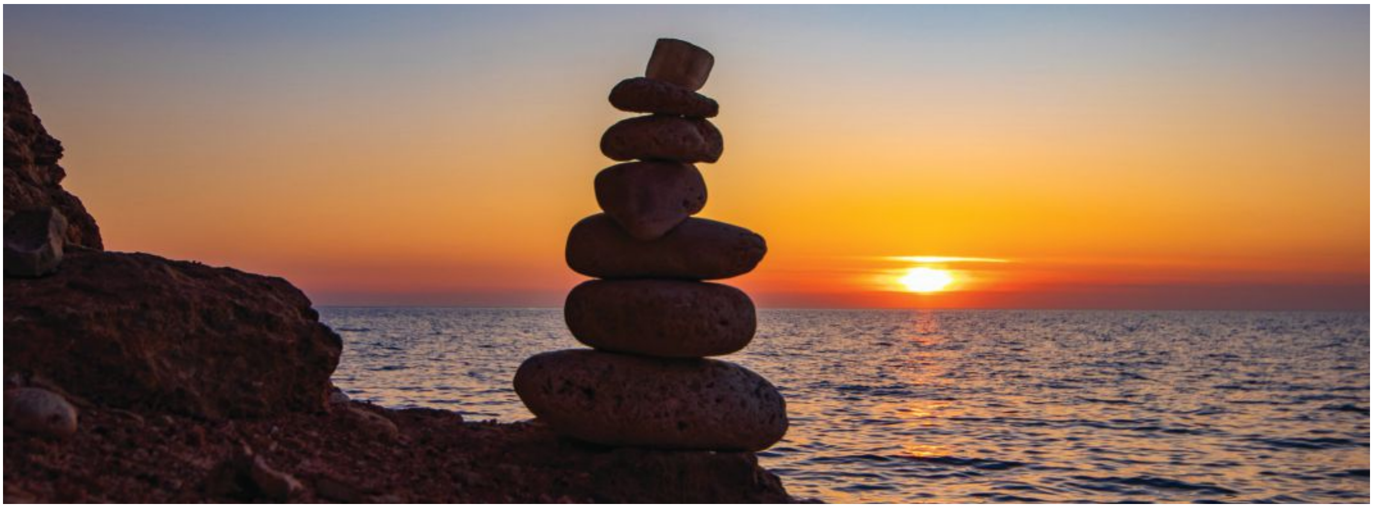
To hear more from Vincent and Douglas, including their thoughts on Berkeley and New York, check out the full podcast in the Field Notes section at ***www.modernsteel.com****. And you can read about their winning Forge Prize design, Common Sky, in "Shared Space" on page 56.*

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

The Inner Journey

BY DAN COUGHLIN

Achieving long-term success as an organization is sometimes a matter of looking inward.



WHEN STRIVING for excellence in work, life, or anywhere, it helps to look inward.

But that doesn't just apply to individuals. Organizations as a whole can follow the same path, and all of the same steps can be used:

- Establish the importance of your (organization's) inner journey
- Define your terms
- Surrender selfishness
- Embrace virtue
- Live up to your morals
- Have deep discussions
- Clarify a higher purpose
- Contribute
- Achieve excellence

This journey is not meant to immediately produce greater revenue and profits or to strengthen your organization's brand or strategy. Rather it is meant to strengthen your organization for the long term from the inside out.

Since you likely spend as much or more time in your work as you do anywhere else, the health of your organization is a very important aspect of your and your fellow coworkers' lives. Doing the work of organizational renewal is just as vital as going on your own inner journey. Let's walk through the steps as they apply to your organization.

Establish the importance of your organization's inner journey. This is an odd topic. Instead of rallying employees around a sales goal or gaining new customers, you're talking about a quest for excellence. People may have a hard time wrapping their heads around that one. It only becomes important to the degree that you make it important.

Write down why it's important for your organization to surrender selfishness, embrace virtue, and contribute toward a higher purpose. If you don't clearly see the value in doing this, then you won't be able to communicate this value to your employees with any real conviction.

Define your terms. Since words mean different things to different people, I suggest you define what you mean when you use words like integrity, conscience, character, selfishness, virtues, morals, higher purpose, and so on. For many organizations, this type of conversation will be uncharted territory. It may very well become uncomfortable for people. The more you reduce the vagueness of these topics, the more you will be able to turn them into practical conversations that help improve the organization.

Surrender selfishness. In my opinion, the most important step to making any real progress on this inner journey is to see and surrender selfishness. Selfishness is what ruins relationships. It keeps people—and organizations—from becoming what they are capable of becoming. Selfishness is primarily about immediate gratification.

Growing revenues and increasing profits are not acts of selfishness. They are how organizations become capable of paying salaries and investing in improvements that can add more value to customers. If organizations attempt to charge customers more than is reasonable, then the market has a way of punishing those companies through competition.

Selfishness can rear its ugly head in many ways inside an organization:

- Managers berate employees for their own immediate gratification and get away with it, at least for a while, because of their authority over other people
- People gossip inside the organization about fellow employees and damage reputations because it feels good in the short term
- In employees pad expense reports—or in extreme cases, steal from the company—for their own immediate gratification

By taking time on an individual basis and as an organization to reflect on and discern the ways in which selfishness occurs in your organization, you can begin to surrender those behaviors. People will only change their behaviors if they really believe that the value of changing is greater than the value of staying the same.

Embrace virtue. Think of virtues in this sense as the way you want to live your life or your company to operate.

I encourage you to have regular conversations with employees about the virtues they want to see in the organization. Don't hide away from the word virtue. Put it out in the open. Virtues are behaviors to aspire for. They get to the very character of your organization. They are noble. They are important. What virtues do you want to be displayed in your organization? Talk a lot about this. Listen to other people. Get them talking to each other about virtues. The more you make this an important topic, the more it will be discussed and discerned.

Live up to your morals. Morals are what a person believes is the right thing and the wrong thing to do. It's possible for an organization's culture to produce behaviors that are consistently the wrong thing to do, and over time people may not even realize that what they are doing is wrong because it has become so ingrained in the culture.

I certainly can't and won't tell you what the right and wrong behaviors for your organization are. These are decisions you will have to make as an organization. What I can tell you is that living up to your morals is crucially important to strengthening the character of your organization. This is a huge step on the road to excellence as an organization.

Have deep discussions. Obviously, these are serious topics. They are not the kind of thing people can cover while rushing through their many activities. These topics require reflection, discernment, and deep discussions with other people. The only way that will happen is if you take them with a high degree of seriousness. I encourage you to set aside a few hours at a time with small groups of people to really dig into the importance of each of these steps.

Clarify a higher purpose. Surrendering selfishness, embracing virtues, and living up to your morals are the building blocks of a healthy organization. Clarifying a higher purpose is what moves you deeper as an organization toward excellence.

So what is the higher purpose of your organization? This is about more than just surviving and thriving as an organization. What is the bigger goal that your organization is striving to fulfill? This is not a topic for day one on your inner journey. You need to work your way up to this question. It's a very, very important topic.

Contribute. Once an organization has clarified its higher purpose, I encourage managers to meet with employees to discuss how they can contribute toward fulfilling this higher purpose. This sounds easy but can be quite hard to do. Contributing to a higher purpose doesn't mean the employee will get a bigger title or income. It might even mean they'll invest a lot of hours without a lot of recognition. It can be a hard idea to sell to another person.

However, in contributing to a higher purpose, people can feel more meaningful in their work. This is an extraordinarily important non-financial aspect of work. If a person works 40 hours a week for 50 weeks a year for 40 years, that's 80,000 hours. If the person feels that all they did was earn a lot of paychecks, then they might experience burnout and a lack of purposefulness—which is especially discouraging on a long-term basis.

Achieve excellence. Whether for one organization or multiple ones, the vast majority of us will work for decades. This inner journey to excellence as an organization is not a one-time deal but rather an ongoing journey to be readdressed over and over again.

I encourage you to use a "Monthly Review" (or biweekly or whatever time frame seems reasonable) as an organization. This can be a one-page document for every employee to fill in on their own. It should include a few questions:

- What selfishness do I want to surrender?
- What virtues do I want to embrace?
- What morals do I want to live up to?
- What higher purpose am I trying to fulfill?
- How will I contribute?

The "Process for Continually Raising Your Bar" is another one-page document for every employee to fill in on their own a few times a year. It could simply say:

In terms of surrendering selfishness, embracing virtues, living up to my morals, clarifying a higher purpose, and making a contribution:

1. What did I do that worked well and why did it work well, and what did I do that did not work well and why did it not work well?
2. What lessons did I learn or relearn in each of those areas?
3. What will I do the same and what will I do differently over the next two weeks, and why will I do that?

You could also discuss those same three questions in small groups throughout your organization and work together to raise the bar of the company.

Suggestions for Success

Remember: These steps don't constitute a rigid formula or process; they're merely a set of suggestions. That said, I do believe these topics are very, very important to consider when attempting to fortify an organization for long-term success. The way in which you make these ideas into a working reality is up to you. While intangible and non-financial, I think they get to the very heart and soul of a healthy organization—and a healthy organization is much more likely to be a profitable one in the long term. ■

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."

Capital One Hall takes the stage in suburban D.C. with a signature sawtooth façade supported by long-span steel trusses.

Center Stage

BY JENNIFER GREENAWALT, SE, PE, AND MICHAEL CROPPER, PE

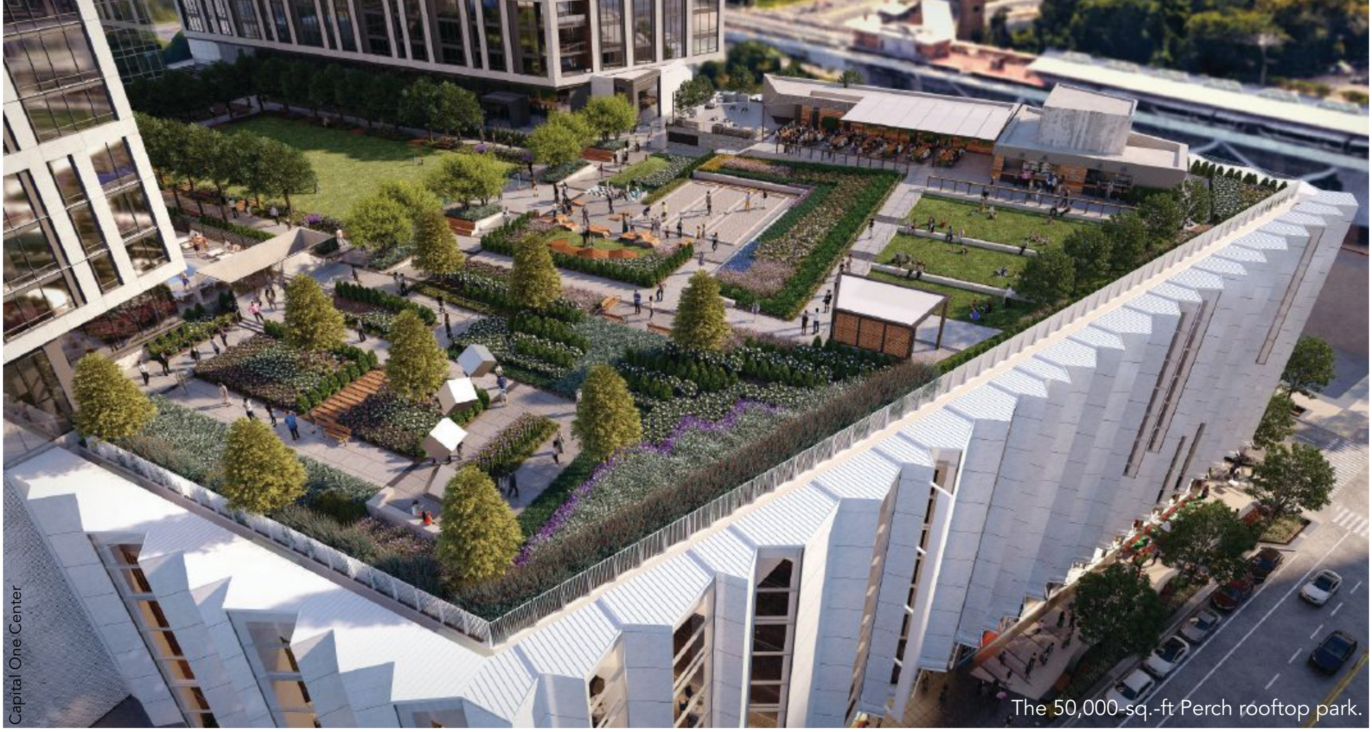
The new Capital One Hall in Tysons, Va.

Photo © Alan Karchmer

PERFORMANCE VENUES are typically known for what's inside, but a new theater in suburban Washington, D.C., demonstrates that what's on the outside also counts.

Capital One Hall, a high-end corporate event and performing arts center in Tysons, Va., just a few miles west of Washington, is topped by a sprawling landscaped public park and wrapped in a signature sawtooth marble and glass façade. The new venue, which opened this past October, houses a 1,600-seat main theater, a 225-seat black box theater, and a large atrium. As part of the larger Capital One Center development, it shares a block—along with a parking and loading-dock facility—with a grocery store and hotel tower. In addition to Broadway shows, concerts, and other entertainment acts, it hosts an extensive series of local arts groups through a partnership with ArtsFairfax, giving up-and-coming performers a world-class stage on which to showcase their talents.

The building, framed with more than 3,000 tons of structural steel, sits atop an 18,000-sq.-ft shared loading dock and is topped by the sprawling landscaped public park, called the Perch, just above the main performance theater. The project presented a series of complex challenges for architect HGA and structural engineer Thornton Tomasetti, including supporting the heavy, active rooftop park over the column-free atrium and theater spaces, ensuring patron comfort at the aggressively cantilevered seating balconies, and supporting the sawtooth façade. On top of that, the main theater was constructed as an independent "box-in-box" to keep unwanted noise and vibration away from the performance space. Thornton Tomasetti consulted AISC's Design Guide 11: *Vibrations of Steel-Framed Structural Systems Due to Human Activity* (**aisc.org/dg**) to address vibration due to walking excitation on the floors outside of the hall and also vibration of the cantilever seating balconies.


Capital One Center

The 50,000-sq.-ft Perch rooftop park.

Take it from the Top

The 50,000-sq.-ft rooftop Perch park is sloped and terraced, changing in elevation by more than 13 ft across its span, and the supporting roof structure consists of a composite slab on metal deck supported by a series of 17 steel trusses, with spans ranging from 25 ft up to nearly 150 ft, made from web-horizontal W14 shapes. Due to the sawtooth ceiling below and slope of the roof above, the truss with the longest span (again, approaching 150 ft) was held to the tightest span-to-depth restriction, weighed 80 tons, and was limited to 10 ft in depth from center of chords. In addition to the rooftop park, the truss also supports two hung balcony floors below, which overlook the atrium. For the largest truss, the design team specified W14×455 chords and W14×176 web diagonals to meet the strength demands and limit deflections under the high rooftop-imposed loading.

The trusses were shop-assembled in three sections each, and final assembly was completed in the field for each truss to be set in place as one piece. Due to the size of the trusses and their locations in the building, each truss pick required a critical lift plan, with the largest (80-ton) truss being at 92% of the crane chart. The two balconies are hung with 1-in. by 2.5-in. Grade 50 architecturally exposed structural steel (AESS) steel bar hangers. These assemblies were specified as AESS 3: Feature Elements in Close View (for more details on the various AESS levels, see "Maximum Exposure" in the November 2017 issue, available at **www.modernsteel.com**). Since the balconies were required to be level at a specified elevation and because the hangers and connections were exposed, Thornton Tomasetti developed a recommended construction sequence during design that allowed the

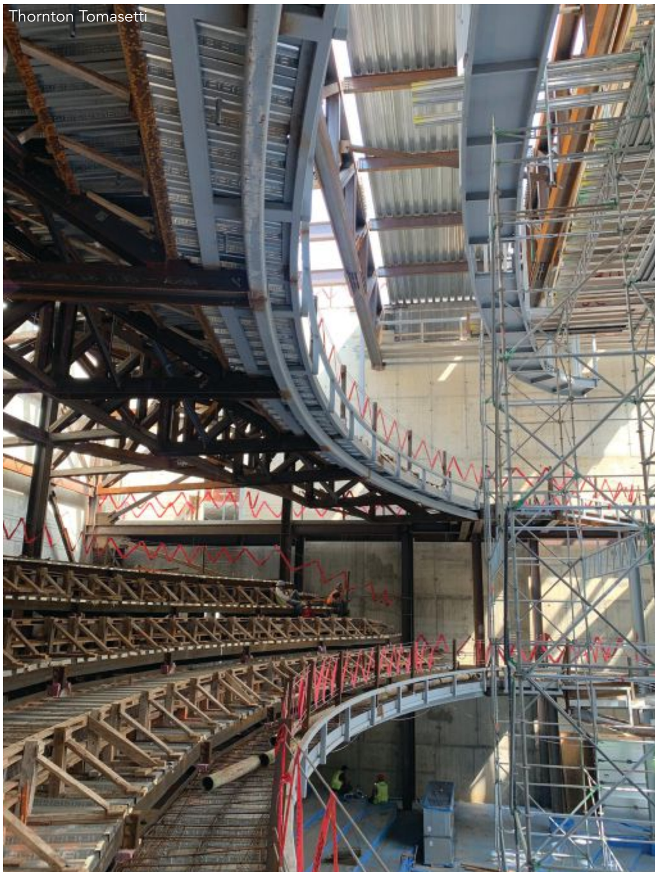

Thornton Tomasetti

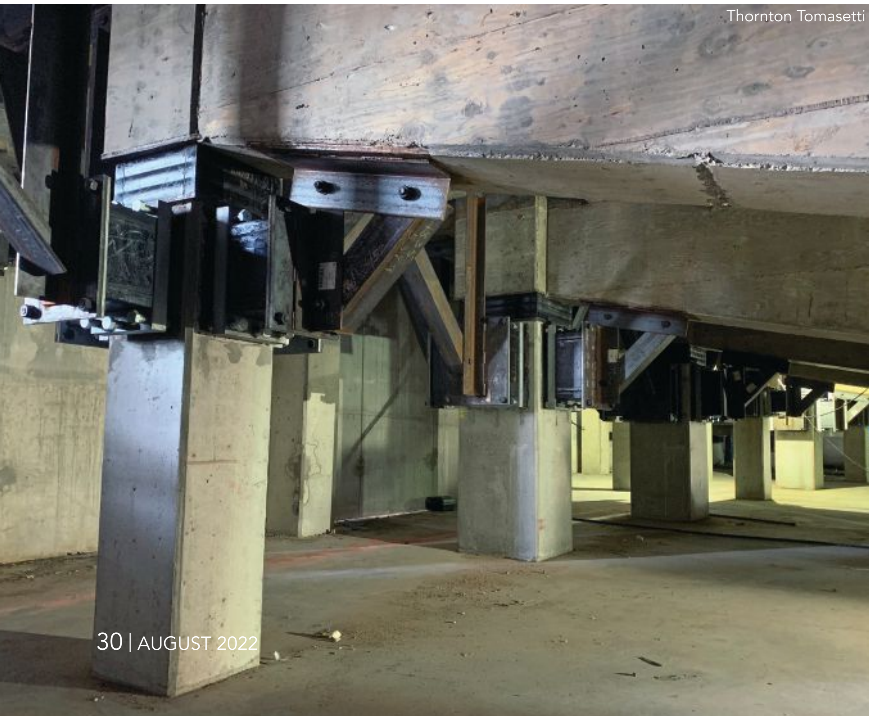
Erection of the project's largest steel truss.

above: The main theater gives the audience unobstructed views from every seat and brings them closer to the stage.

right: Cantilevered steel trusses frame the seating balconies.

below: Isolation pads provide acoustic isolation below the performance hall.





balconies to be constructed while they were supported on temporary columns. During construction, the design team worked with contractor Whiting-Turner, steel fabricator SteelFab, and the steel erector to implement the construction sequence. By coordinating with these parties early on, unwelcome surprises were kept to a minimum and the team achieved the final product as envisioned by HGA.

Along the edge of the atrium, built-up steel plate columns span over 65 ft unbraced to deliver loads from the roof trusses to the support structure below. Since the venue is positioned over a vertical combination of retail, loading dock, and parking, column locations could not remain consistent over the height of the building. Built-up steel transfer beams, varying from 36 in. to 80 in. deep, support the columns as they are transferred to the below-grade grid. The largest transfer is made by a two-span girder stretching over 80 ft to support the longest roof truss; this girder is 80 in. deep, weighs 44 tons, and is built from 4-in.-thick by 18-in.-wide Grade 50 flange plates.

Up Close and Personal

Sandwiched between the busy loading dock and the active rooftop park is the state-of-the-art main theater. Already host to some of the world's top performers, the main theater had to be isolated from external noise and was therefore designed as a box-in-box structure to attain the necessary acoustic performance. The stage and audience seating are completely separated from the rest of the structure and are supported on a series of acoustic isolation pads. Lateral isolation pads were also required to mitigate effects from sidesway. Since the lateral pads needed to be compressed to specified amounts to isolate the required frequencies, Thornton Tomasetti designed an adjustable steel frame assembly that could be uniquely detailed to each location. The assembly implemented variable-sized embed plates with headed studs into the piers and slab above. The lateral frame assembly consists of single angles and WTs bolted together and welded to a mounting plate whose slotted holes allowed for adjustability when mounting the isolation pads. A sequence was established for installing the frames and pads and then jacking the load into the pad. In total, more than 150 vertical isolation pads and 200 lateral isolation pads were installed below the theater.

In theater terms, a "tight" venue brings patrons closer to the action on stage and creates better views from more seats. Capital One Hall achieves this by hiding support columns in back-of-house walls and by cantilevering the seating balconies more than 25 ft toward the stage, thus bringing the audience closer to the action and creating excellent, unobstructed views from every seat. Since columns had to stay hidden, Thornton Tomasetti used a system of girder and transfer trusses made up of fully welded, web-horizontal W12 members to support the cantilevered steel balconies. The design team created a full SAP2000 model to analyze anticipated deflections and vibrations due to the complex framing arrangement; member strength was not the governing limit state, which is typical for these types of cantilevered seating balconies. Due to the long cantilevers coupled with short back spans, most of the trusses experience uplift at their back supports, which required a system of "hold-down" isolation pads to maintain the acoustic rating. After a constructability review with the construction team, the seating tiers were designed as steel angle frames with slab-on-metal-deck infill rather than with precast or cast-in-place concrete.

Thornton Tomasetti

Adding to the Drama

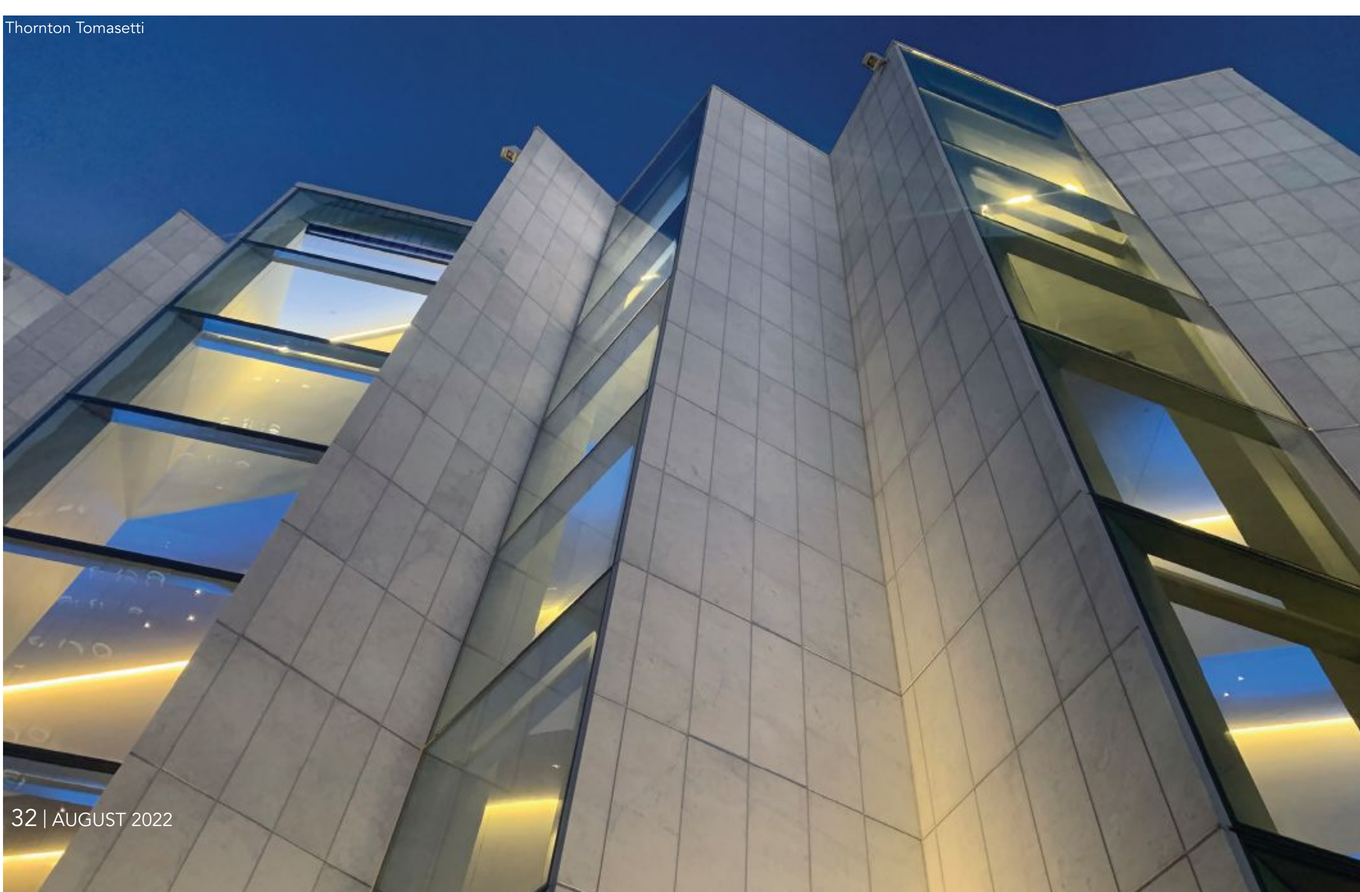
Visible from the busy Capital Beltway, the venue's façade has an irregular sawtooth form that introduces a dramatic component to the building's aesthetics. The glass and Carrara marble façade (consisting of 7,000 slabs) is supported by a series of vertical steel trusses spanning up to 80 ft between supports. The façade encloses the building's north side and then turns the corner to the diagonal slab edge along the west wall and the curved slab edge along the south. The façade includes a framing concept with a consistent slab edge and vertical trusses and frames that use two-way action between the different bays, which was required to stay within the limited depth available in the architectural enclosure. This system allowed for varied façade bay angles and spacing while minimizing the number of support conditions. Thirty-seven shop-assembled trusses were strategically placed at the perimeter of the building, with infill framing installed in the field to provide continuous backup support for the façade. This approach simplified fabrication, which saved time and money.

Each façade bay is at a different angle from the next, some having large windows with light support frames consisting of horizontal

left: The hall's main entrance on opening night, October 1, 2021.

below: The sawtooth marble and glass façade is supported by a two-way continuous steel frame.

Thornton Tomasetti



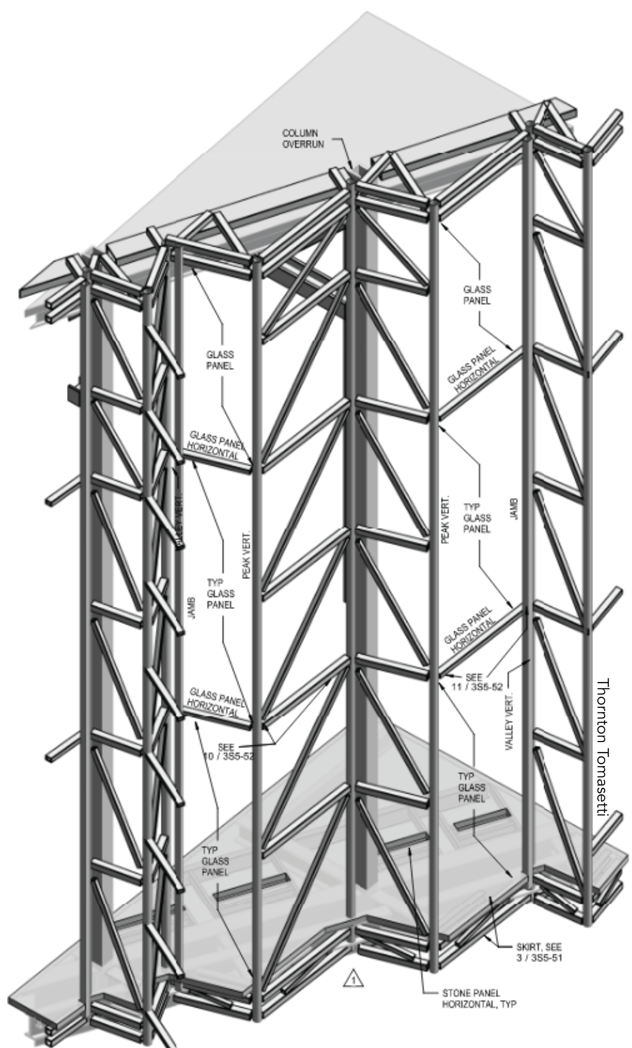
Thornton Tomasetti

above: The steel frame at the start of building enclosure construction.

right: A 3D image of typical façade support steel.

tubes and others covered by marble, which allowed for a stiffer structural frame behind the opaque construction. The stiffer structural frame includes round hollow structural section (HSS) horizontals and diagonal braces between HSS6 circular posts and hangers at the peaks and valleys of the frames. These façade trusses include out-of-plane braces with HSS20×8 and HSS12×8 horizontal members connected to the main building columns. The base of the façade, referred to as the "skirt," is hung from the lowest level of framing, while the top portion of the façade coping cantilevers above the main roof level. The south façade includes a large window for the black box theater that interrupts four vertical trusses with HSS12×12 horizontal members to frame out the opening for the large windows.

The façade steel framing system reduces the number of different support conditions at the base of the trusses. The bottom connection is detailed to prevent fixity of the frames, allowing them to behave as simple trusses per the design intent. The top of the façade includes a lateral connection to transfer the strut forces to long side horizontal HSS tubes to resist the wind load on the façade. The lateral brace connections between the façade valley posts and main building columns include slip connections to be consistent around the entire façade. In addition, all the façade valley posts were labeled, and the maximum deflection under five different loading scenarios was reported. There were no issues with steel deflection after construction, and all this complex geometry, the multitude of HSS tubes, and intricate detailing were able to be conveyed on just three structural sheets that included plans, elevations, 3D isometric views, a table of deflections, and details.



Thornton Tomasetti


Capital One Center

Curtain Call

The striking marble façade, which is visible to a myriad of commuters every day, and the assortment of fun activities on the rooftop public park make Capital One Hall memorable even before considering the variety of artists and events that it hosts. And it wouldn't have been possible to bring the various components together within one building without structural steel. It's

above: The main atrium features soaring ceilings.

below: The steel-framed grand stair wraps around the edge of the performance hall.


Thornton Tomasetti

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13. **Tee Stem Up** — MEAN DIA. — 22" x $142\frac{1}{2}$# Tee
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15. **Angle Heel Out** — OUTSIDE DIA. — 8" x 8" x 1" Angle
16. **Angle Heel Up** — MEAN DIA. — 8" x 8"x1" Angle
17. **Square Tube** — INSIDE DIA. — 24" x $\frac{1}{2}$" Tube
18. **Rectangular Tube The Easy Way (Y-Y Axis)** — INSIDE DIA. — 20" x 12" x $\frac{5}{8}$" Tube
19. **Rectangular Tube The Hard Way (X-X Axis)** — INSIDE DIA. — 20" x 12" x $\frac{5}{8}$" Tube
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the long-span roof trusses that allow the column-free atrium and the built-up steel plate columns that support a full landscaped park on the roof with long unbraced spans. The cantilevered steel balcony seating provides fantastic views in the main theater, and steel supports the sawtooth façade and makes up the built-up transfer beams over the loading dock. While these steel elements may be hidden from view, their impact is felt by all who use the space, from the delivery driver being able to turn a tractor-trailer around underneath a ballet performance to the audience watching it in the main hall and all the way up to the workers enjoying happy hour in the rooftop park. ■

Owner
Capital One

General Contractor
Whiting-Turner

Architect
HGA

Structural Engineer
Thornton Tomasetti

Steel Team

Fabricator
SteelFab (AISC Certified Fabricator), Charlotte

Detailer
Prodraft (AISC Detailer), Chesapeake, Va.

Jennifer Greenawalt (jgreenawalt@thorntontomasetti.com) is a senior project engineer and **Michael Cropper** (mcropper@thorntontomasetti.com) is a vice president, both with Thornton Tomasetti.

High Gear

BY KERRI MOLITOR

Early fabricator and erector involvement help a steel-framed vehicle performance and electrification facility navigate heavy traffic on a congested job site.

FORD MOTOR COMPANY isn't throwing caution to the wind when it comes to increasing the performance of its products and preparing for vehicle electrification.

The auto manufacturer's new Vehicle Performance and Electrification Center (VPEC), situated on a 14-acre campus in Allen Park, Mich., was built to test passenger and motorsports vehicles to achieve even greater fuel efficiency, as well as to perform battery research and testing for future vehicle electrification. The 210,000-sq.-ft facility includes three attached buildings featuring the most technologically advanced wind tunnel of its kind in the world, capable of speeds of up to 200 mph. It also includes a state-of-the-art rolling road system, a traversing measurement system, a cutting-edge frontal area measurement system, a variety of battery cyclers and environmental chambers, and multiple offices and work areas.

For speed of installation, as well as structural integrity, steel was the clear choice for the battery lab and support facility buildings, as well as for the architectural stairs for all three buildings. The majority of the more than 1,800 tons of structural steel was incorporated into the two-story battery lab building and attached support facility, one of the largest steel projects ever for steel fabricator Aristeo. The company, a major contractor for the facility,

Ford's new 210,000-sq.-ft Vehicle Performance and Electrification Center (VPEC) was built to test passenger and motorsports vehicles to achieve even greater fuel efficiency, as well as to perform battery research and testing for future vehicle electrification.

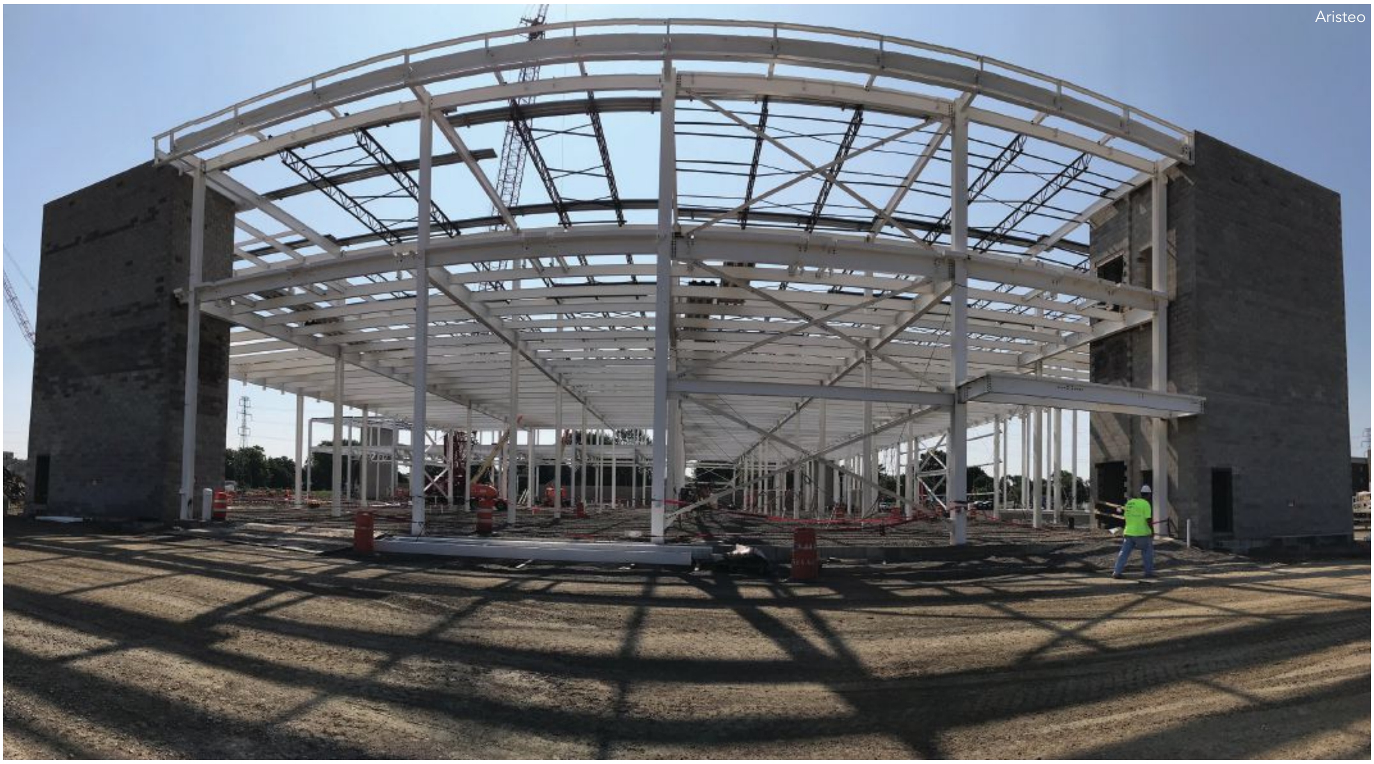
Aristeo

performed multiple trades throughout the project, including steel fabrication and erection, and carefully coordinated the sequencing and scheduling of multiple crews and erection cranes across the job site, allowing the building to be erected on multiple fronts and preventing conflicts with the large, ongoing concrete pours.

Bringing Solutions to the Table

Aristeo, a long-time supplier for Ford Motor Company, worked closely with the entire project team to develop a number of solutions to the challenges that the project presented. These came in the form of detailed schedules, LEAN on-site construction practices, on-site preassembly of steel elements, strategic laydown areas, detailed logistics plans, and a just-in-time delivery mindset. The team also built flexibility into the job site's layout and allowed for the relocation of roads and laydown areas as the project's needs changed. In addition, Aristeo's fabrication facility is located within 20 miles of the site, allowing steel deliveries to be made and scheduled quickly.

Right off the bat, the most significant challenge was that the project required the simultaneous construction of three distinct, albeit attached, facilities within a limited footprint. A significant amount of space was needed for large concrete pours and



The project used GPS-controlled equipment to help maximize time and material by only moving the required amount of material, helping to minimize material overruns, fuel usage, and trucking costs for import and disposal charges.

formwork assembly, which Aristeo also self-performed, as well as ongoing structural steel erection activities with large laydown areas. These all occurred alongside other activities, including underground utility installation, primary power feeds and electrical infrastructure, equipment installation, carpentry, miscellaneous utilities, and more.

An additional challenge was an expansion of the project scope after the project had already begun. What was originally a wind tunnel project quickly expanded to include the battery lab facility, and much of the existing 14-acre space would soon be covered by the new structure. In order to ensure that the new facility met both customer requirements and regulatory needs, the space was reprogrammed and a series of updates were made, including upgrades to the site-wide fire-protection system.

The team also proactively ensured that materials would arrive as needed on the job site and without taking up much-needed laydown space. For example, specialty materials for the wind tunnel process equipment were sourced from vendors across the globe (the wind tunnel fan itself is made up of components sourced from every continent except Antarctica). Another specialty item was a steel rack in the battery facility. Traditionally, electrical components for the battery chamber would be routed through the ceiling, but this method would have made it too difficult for the customer to access the necessary controls. Instead, Aristeo fabricated a rack to link all of the battery chambers' electrical components, providing easier access while eliminating the risk of accidental connection or disconnection.

During the development of the wind tunnel, Aristeo teams managing both steel installation and concrete placement were able to use steel embeds in tandem with multiple concrete pours in order to keep the concrete in place. Hundreds of precision weld plates were cast into the concrete walls, floors, and ceiling of the wind tunnel structure during construction. These plates were later used to support the steel turning vanes in each corner of the wind tunnel, in addition to the stainless steel honeycomb strainer, flow conditioning screen, steel flex nozzle, collector flaps, and traverse system. The turning vanes, which were fabricated through a partnership with fabricator Merrill Steel, were successfully installed by Aristeo ironworkers in compliance with the tight customer-required tolerance of $\frac{1}{32}$ in.

Proactive Involvement

Perhaps one of the most proactive solutions implemented on the project was the early involvement of Aristeo as a key trade partner, which introduced advantages into the schedule. For example, while structural steel was being fabricated for the battery lab building, Ford provided direction to redesign certain elevations to facilitate a future expansion. Aristeo was able to quickly and efficiently revise its fabrication and erection sequences to allow for design and foundation changes to be made while maintaining the project schedule and limiting cost impacts. The early involvement approach also allowed Aristeo's ironworkers to coordinate efficient assembly at the site, where they assembled bar joist and bridging sections on the ground, which were then flown up and set in place. The planned expansion to the battery lab is now underway, and Aristeo is managing the project as the general contractor and is self-performing key trades, including steel fabrication and erection.

An additional process that boosted efficiency was Aristeo's use of Trimble RealWorks, SDS/2, and Navisworks for 3D modeling and scanning. These technologies provided highly detailed, as-built 3D models of the project, resulting in higher-quality project layouts, more accurate job-site surveys, and higher tolerance compliance.

The project also used GPS-controlled equipment to help maximize time and material by only moving the required amount of material,

above and below: The majority of the more than 1,800 tons of structural steel was incorporated into the two-story battery lab building and attached support facility, one of the largest steel projects ever for steel fabricator Aristeo.

above and below: Ford presented significant redesign plans during steel fabrication, and Aristeo was able to quickly and efficiently revise its fabrication and erection sequences to allow for the changes to be made while maintaining the project schedule and limiting cost impacts.

all photos on the page courtesy of Aristeo

Jason Keen

left: The wind tunnel's steel turning vanes, fabricated by Merrill Steel, were successfully installed by Aristeo ironworkers in compliance with the tight customer-required tolerance of $\frac{1}{32}$ in.

below and right: The facility features the most technologically advanced wind tunnel of its kind in the world, capable of speeds of up to 200 mph.

Aristeo

The design and construction team built flexibility into the job site's layout and allowed for relocation of roads and laydown areas as the project's needs changed.

helping to minimize material overruns, fuel usage, and trucking costs for import and disposal charges. With this equipment, teams were able to input the project blueprint into the onboard machine telematics, including design surfaces, grades, and precise location of infrastructure and building coordinates. This solution saved the customer time and provided a higher quality product on this project, preventing over-digging, backfilling with extra material, and reducing error.

Efficiency is the name of the game in the automotive industry, especially when it comes to research and development for new electrified vehicles. And it was equally applicable when it came to designing and building Ford's new VPEC facility. Thanks to engaging with an experienced fabricator and erector right from the get-go, the project was able to overcome spacing constraints, scope changes, and a busy job site with many activities taking place at once—and the new facility came together like a well-oiled machine. ■

Owner
Ford Motor Company Vehicle Performance and Electrification Center, Allen Park, Mich.

General Contractor
Stenco Construction, Livonia, Mich.

Architects
Ghafari Associates, LLC, Dearborn, Mich.
Jacobs Engineering, Bingham Farms, Mich.

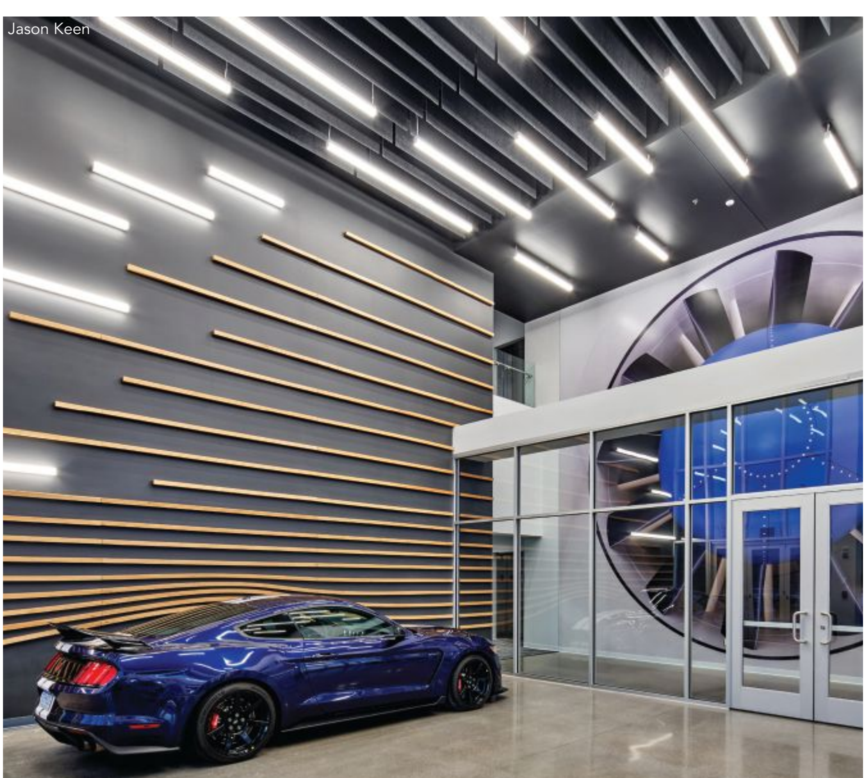
Structural Engineer
Ghafari Associates, LLC

Steel Team

Fabricator and Erector
Aristeo Construction, Livonia, Mich.

Fabricator (wind tunnel turning vanes)
Merrill Steel, Inc., Schofield, Wis.

Detailer
Lincoln Engineering Group, LLC, Naperville, Ill.



Jason Keen

Kerri Molitor (**kmolitor@aristeo.com**) is the marketing team lead with Aristeo.

No Paint? No Problem

BY GEOFF WEISENBERGER

While supply chain shortages have affected paint and primer products for structural steel applications, there's no need to panic—because a significant portion of structural steel doesn't *need* to be painted or primed.

FOR A WHILE NOW, the headlines about supply chain issues and their subsequent delays and price increases have become as frustrating as they are ubiquitous.

And the steel industry hasn't been immune, especially when it comes to paint and primer.

But there's good news. And also even better news.

First, the good news: You probably don't need to paint steel as often as you think you do. In fact, Section M3.1 of the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360, **aisc.org/specifications**) indicates that shop paint isn't required unless it's specified in the contract documents. On top of that (pun intended), AISC, for nearly seven decades, has recommended against painting or priming steel that will be enclosed by a building finish, coated with a contact-type fireproofing, or in contact with concrete. (In fact, this point was recently reiterated in a technical advisory, which you can read at **aisc.org/paint**.) The advisory lists exceptions for this advice when the enclosed steel is (1) in an area where the critical relative humidity level is expected to be above 70% or (2) in industrial structures where corroding chemicals are present.

In addition, there is little if any value in removing mill scale and applying a primer to steel that will be enclosed in a ceiling, wall, or other interior space that will not be visible, as the mill scale will adequately protect the steel due to the absence of any appreciable electrolyte (such as water). And when it comes to primers, it's also important to keep in mind that they are not to be used as finish coats and frequently aren't capable of providing long-term protection anyway.

Here's the even better news: By eliminating unnecessary paint and primers, you also eliminate unnecessary costs, delays, and negative environmental impacts (such as volatile organic compounds found in many coating systems). So those supply chain issues? They don't affect steel projects as much as you might think. And AISC member fabricators have been instrumental in spreading this message.

"Over the past five years, we've seen fewer instances where paint is specified and adds no inherent value to the project, where historically, owners might request their steel painted, even if it's covered up with finishes," said Derrick Fitton, PE, director of operations with Drake-Williams Steel's structural division. "We've been proactive with educating our local design and construction community on when painted material brings value but will also suggest the removal of primer when suitable. As raw materials prices have continued to increase, I believe owners are looking to cut costs in any area possible, so removing unnecessary primer has been a regular point of discussion to help drive costs down. Priming structural steel can add 10% to 20% more labor to a project, and when you combine that with the additional cost of the paint, the overall structural steel scope cost impact could be in the neighborhood of 3% to 5%. The reduction in labor can also reduce the overall production duration, which can flow downstream to an earlier project completion date."

That said, it can sometimes be difficult to get owners on board.

"For the most part, it seems like the owner and design team are set on what they want," said Jennifer Paisley, a project manager with Novel Iron Works. "We've never had much success in having paint removed from our scope once we get a project, even when we explain that the primer is a provisional coating and doesn't provide any long-term benefit to the steel."

In situations where paint or primer *are* required, fabricators recommend being proactive.

"When it comes to the paint raw material shortage we're all facing, Puma Steel has been trying to buy shop coat primer in bulk," said Bill Van Houten, a project manager with Puma Steel. "We have been unable to rely on local paint distributors to supply what we need 'just in time' for coating systems."

He added that his shop tries to offer discounts to customers if they don't request painting services and also that some paint providers have been able to suggest comparable products in their catalog if a specific coating isn't available.

Fitton said his company began seeing issues with paint availability and overall lead times in late 2021. "We were able to work with our vendors to order large quantities of our standard primer for 'stock,'" He explained. "We also worked with our customers on some projects to substitute readily available primers in lieu of the original primer specified. While we are not currently experiencing lead times with our standard primers, some paint systems and colors are not readily available, so we need to be proactive with our vendors and customers to ensure we can meet their expectations."

Owen Parrish, PE, vice president of operations with North Alabama Fabricating Company (NAFCO), agreed with the cost and schedule benefits but noted that projects with mixed paint requirements reinforce the need for early communication.

"We've seen some challenges on projects where the steel is not completely painted or unpainted," he said. "This mixed condition across an individual sequence requires clear communication and review from the detailer, engineer, and architect during the review process. All parties must be on the same page to avoid miscommunication that results in exposed members not being painted in the shop or unexposed members being painted unnecessarily."

"Painted/primed steel requires a fair amount of handling, which impacts cost and schedule," said Nat Killpatrick, president of Basden Steel. "There are also the potential environmental concerns and the peripheral waste: cleaning agents, barrels, towels, and cleaning up the paint bay. The other concern is making sure our painters have proper training and proper gear to help limit exposure to the paint systems being used."

"Primer and paint have a purpose and are very effective for corrosion control when needed," he continued. "That said, looking out in west Texas and seeing an old barn sitting out there for 50 years with hardly a speck of paint on it, standing tall, it seems to me that we could get by with priming a lot less steel if folks really understood steel's ability to perform uncoated in the right situations."

In addition to fabricators, designers are also working to minimize the use of unnecessary paint and primer.

"We often specify painting (and primer) with a clause that states, 'All steel shall remain unpainted, except…' noted Justin Smith, PE, a senior associate with Walter P Moore's (WPM) Houston office. "That way, anything outside of the exceptions receives no paint, and that is the default finish."

"There typically shouldn't be any need to paint interior steel that is not exposed to view and does not require corrosion protection," echoed Brian Lewis, PE, a principal with WPM's Washington office. "I typically don't require any coating for this unless the steel may be exposed to weather for long periods of time during construction."

Lewis suggests considering galvanizing in lieu of paint for corrosion protection, especially where aesthetics aren't as high of a priority, or weathering steel when the steel is exposed to view and when corrosion protection is required. He also encourages blast cleaning or wire brushing in place of paint to achieve slip-critical faying surfaces when corrosion protection isn't required.

Ryan Curtis, PE, a senior structural engineer and project manager with LEO A DALY, noted that he has become increasingly less likely to specify paint, though he did acknowledge that it may be necessary in situations where steel is unexpectedly left exposed for long periods of time.

"Typically, we don't require primer for steel when it will be within the building envelope and behind a wall finish," he said. "Over the course of time, I have grown to not require it. However, a very large project may require steel exposed without the envelope installed for up to a year, or sometimes longer. Also, with COVID starts and stops, we saw some projects start construction, stop for a year, then start back up, which put unprimed steel at risk of natural corrosion and exposure to the elements."

But fast-moving projects are a different story.

"For our Ambulatory Care Center on the Omaha VA Medical Center project (see 'Serving Veterans' in the August 2020 issue, available at **www.modernsteel.com**), I spoke with our contractor, and they said they had done many large projects with the steel left exposed and unprimed and experienced no issues," he explained. "That helped me with my decision to not prime the steel on the VA job, aside from locations where we had interior exposed steel."

"And when I'm in a pinch, I always call my local AISC certified fabricator for advice on topics like this." ■

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

Facilitating Faster Framing

BY ERIN CONAWAY, PE

The winners of AISC's SpeedConnection Challenge work to push the erection envelope and allow steel frames to come together faster.

A HANDFUL OF NEW CONNECTION CONCEPTS are showing promise in facilitating faster steel erection.

These concepts are the result of AISC's SpeedConnection Challenge, which aims to provide speed and performance improvements for how buildings can be erected related to connections. The project is part of AISC's Need for Speed initiative, whose goal is to increase the speed at which a steel project (either a building or a bridge) can be designed, fabricated, and erected by 50% by the end of 2025. (Check out **aisc.org/needforspeed** for more information.)

Structural steel buildings would not be possible without the connections that hold them together. The SpeedConnection effort's overarching goal is to develop a "game-changer" solution for steel connections, with the idea that developing faster and easier connections will benefit the structural engineering and construction community and potentially result in more projects designed in steel due to the increased speed of construction.

To kick off the initiative, AISC conducted a series of three crowdsourcing challenges with the goal of gaining perspectives from all areas of the design and construction industry—architects, engineers, construction professionals/tradespeople, structural steel fabricators and erectors, researchers, academics, students, entrepreneurs, and anyone else with a spark of inspiration. The challenges focused on three common connection types: simple, rigid, and column splices. Each challenge also considered the potential role of castings or other technologies (e.g., additive manufacturing), how automation could influence connection economics, fit-up issues, ease of design, and specific safety (OSHA) requirements for steel connections. Potential solutions needed to demonstrate a high feasibility factor, a high speed factor, and a high innovation factor.

The Challenges

From the three challenges, judged by a panel of steel industry experts, emerged six winning connection ideas that illustrated key concepts for increasing the speed and ease of erection.

The Steel SpeedConnection Challenge focused on developing a fast, easy, and economical connection for shear transfer between a beam and column and/or girder. The goal was to cause a paradigm shift in steel building construction by reinventing the way steel beams and columns are connected. Standard shear connections have long been used for the majority of steel beam and column connections, as they are viewed as easy and economical—and the submitters were tasked with creating connections that could take ease and value to the next level.

The winners were:

- Andrew Dolan's Team (Andrew Dolan, SE, PE, Associate, Gilsanz, Murray Steficek; Erica Fischer, PE, PhD, Assistant Professor, School of Civil and Construction Engineering, Oregon State University; Ramon Gilsanz, Partner, Gilsanz, Murray, Steficek; and Daniel Gleave, PE, Associate, Gilsanz, Murray, Steficek) for "Fire Protection and Composite Connection"
- Matt Eatherton, PhD, Professor, Virginia Tech, for "Hands-Free Speed Bracket"
- Anton Sherevenets, Mechanical Engineering Graduate of the National Aerospace University "Kharkiv Aviation Institute" in Ukraine, for "Using the Thermite Welding and Magnet Holders"

The Rigid SpeedConnection Challenge focused on developing a fast, easy, and economical way to make beam-to-girder shear connections into moment connections, which could potentially reduce beam sizes, deflections, and vibration problems. The current practice for typical steel floor framing is to use simple shear connections between beams and girders. While they have long been viewed as an easy and economical solution, shear connections are limited when it comes to floor framing—i.e., they allow the end of the beam to rotate. If the connections in a floor system can provide rigidity against rotation, floor deflections can be greatly reduced, paving the way for a lighter and stiffer floor system that is still easy and economical.

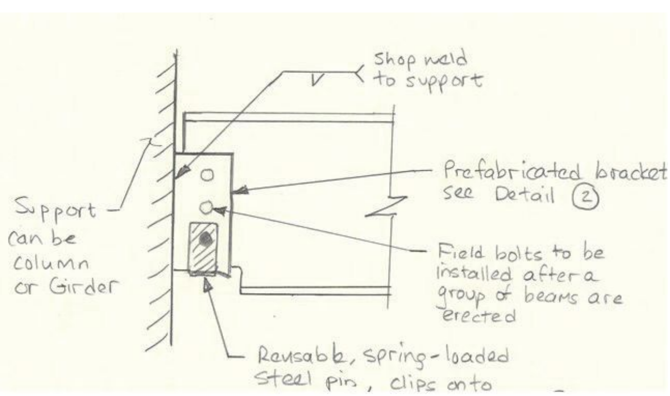
The winner was:

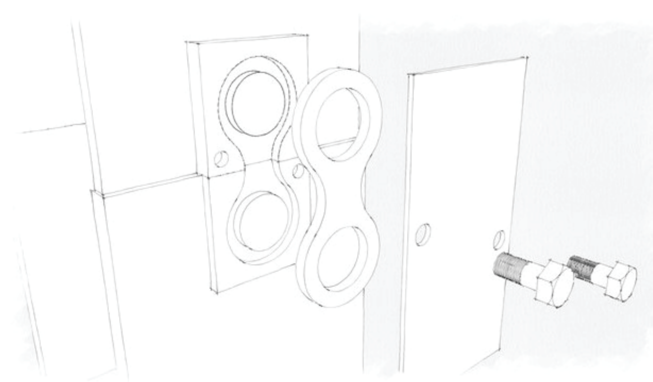
- Luis Fernandez, CSA Project Management Consultant, Senior Structural Design Engineer, for "Robot Clamp"

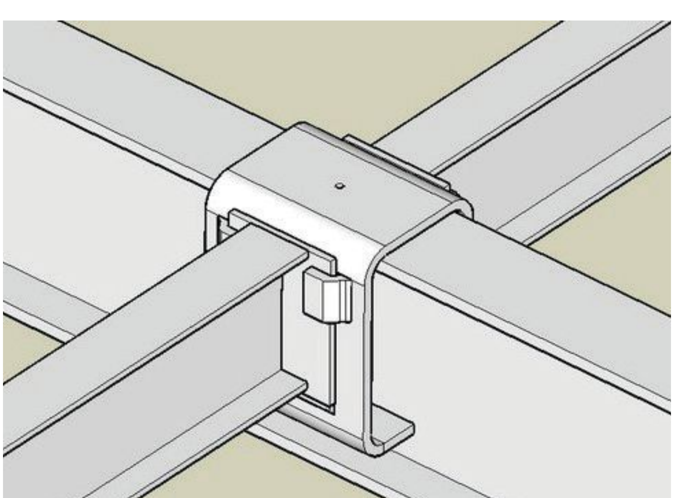
The Column SpeedConnection Challenge focused on developing a fast, easy and economical column splice connection. Column splices haven't changed much over time and typically employ bolts, welds, or a combination of the two. The goal was to determine a better way to splice a column.

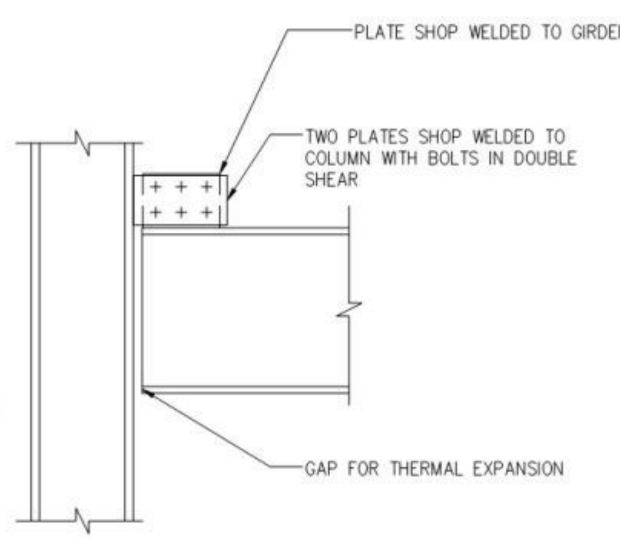
The winners were:

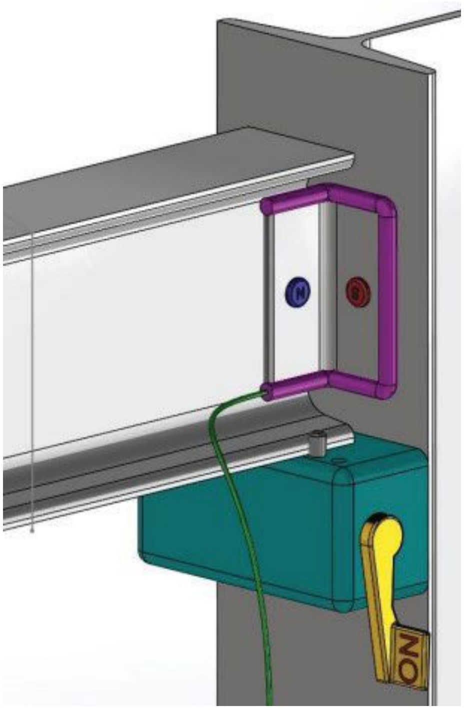
- Reid Zimmerman, SE, PE, Technical Director, KPFF Consulting Engineers, for "SnapLocX—The Fastest Column Splice Connection"
- Chantal Goldson, Lead Strategic Pricing Analyst, AT&T, for "Innov8 Connection"

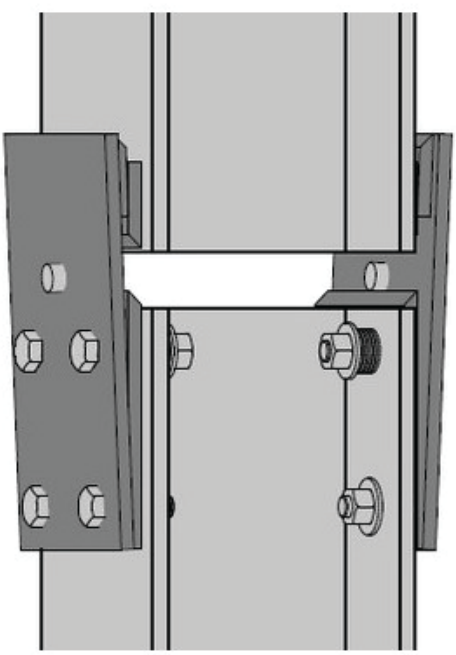












NEED FOR SPEED

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

Winning Perspectives

Each of the winners brought their own unique background and perspective to the challenge. Read on to learn about their designs and how they came to participate in the SpeedConnection challenge.

What motivated you to participate in the SpeedConnection crowdsourcing challenge?

Sherevenets: It was interesting because the challenge topic was new to me, but the principles used in steel construction are the same, so I had a chance to see the problem from a different angle. It was also a great opportunity to contribute to AISC.

Goldson: My fiancé convinced me to participate in the challenge since I am fascinated by the way different structures are built. I thought, "Why not? Maybe I could win!" Admittedly, I never thought I would actually win!

Zimmerman: Current column splice connections require relatively laborious field bolting or welding, often in conditions with heightened risk to ironworkers and on projects with compressed schedules. The motivation for the SnapLocX Connection was to transform the splicing of steel columns into a straightforward "snap and lock" operation that would dramatically reduce the time to perform a column splice, thus limiting the risk exposure for ironworkers and expediting erection of subsequent floor framing.

Fernandez: Frankly speaking, the prize was kind of the first spark of motivation, but while developing the idea I gained additional motivation to continue to develop and finalize the concept. I guess that motivation hits when you really start believing in your idea, thinking, ''This could really work," while you see the model spin on your computer's monitor.

Dolan: To improve the performance of steel buildings in fires, design professionals can increase the thickness of fire protection on critical members or components or design members and components to maintain load carrying capacity and structural integrity throughout a design-basis fire. Previous building fires have demonstrated the importance of gravity framing connections to the stability of a building during a fire. Therefore, the challenge of using exposed steel framing in a building is how to design these connections such that they have the capacity to resist the demands imposed and they are not vulnerable to failure.

Spray-applied fire protection is a wet trade and, therefore, the removal of this material from the project would be beneficial to the construction schedule of a project. However, how can structural engineers ensure that the connections remain protected from the fire? One option is to take inspiration from the steel joist industry and relocate the connection to the top of the beam such that it would be embedded in the slab on metal deck. This allows the connection to be protected during a fire event and for the reduction of fire protection throughout the building.

Eatherton: As an engineer, I always found connection design to be the most challenging and rewarding part of a project. I was inspired by the principal of the company where I was working (Kris Johnson), who was a genius when it came to connections and was always able to come up with an eloquent solution to even the most challenging problems. I enjoy challenges like these where the goal is to come up with a creative solution to a constrained problem.

How did you come up with your winning idea and/or what was your inspiration?

Sherevenets: I decided that improving the bolted connection is barely possible because all the useless steps and pieces have already been eliminated. But the welding process is limited only by the amount of energy supplied to the joint, and if we can concentrate and store it in some way and then deliver it to a joint, we will be able to speed up the whole process. I believed that chemical reagents looked very promising for that case. The Bengal fires concept inspired me to do some experiments with heating the metal without electricity and arc welding stuff.

Goldson: Initially, I thought of a track system that would slide and lock into place. However, that idea became quite complex and proved harder to put to paper than I hoped. This eventually evolved into the "figure eight" idea that I submitted. Although the insert can take many forms, I chose the figure eight as it reminded me of the infinity symbol. Circles also occur more frequently in nature than do many other shapes.

Zimmerman: The concept of the SnapLocX Connection was to create a solution in steel that was not unlike the clasp on a waist strap of a backpack. Steel plates, fillet welding, bolts, and steel disc springs (also known as Belleville washers, conical spring washers, etc.) are all that would be required to be assembled in the fabrication shop. The SnapLocX Connection would then be shipped to the site already attached to the lower column. The SnapLocX Connection is thus innovative in its use of conventional materials and methods in new ways.

Fernandez: For me, the most important was to propose something based on fabrication and installation speed, and of course that would also be feasible. Mechanized automated procedures were something that I thought about due to the wide variety of bent steel pieces that we can find in the market almost for any purpose, like door hinges, table stiffeners, scuppers, etc.

Dolan: Connections are one of the weakest components when the steel building is exposed to fire. If we were to remove the traditional fire protection from the beam, we wanted to know how we could find a unique way to still protect the connection from a fire event. Our result was to move the connection to be located within the depth of the composite slab. Also, on many projects, it is desirable for an architectural layout to have services run along column lines. If the connection is moved into the depth of the slab, it would be possible to notch beams where it is most desirable to run ductwork and sprinkler lines while reducing floor-to-floor heights.

Eatherton: I took my Steel 1 class to see the steel erection for a building on campus called the Creativity and Innovation District. We watched as the erection crew rigged up a beam, craned it into place, worked to get the connections to fit up, and then installed the bolts. As the students watched the beam being installed, I was watching the two erectors on the ground and the crane operator, all of which were idle and just waiting around for the crew up in the air to finish. Any time workers and equipment are standing by idle is lost time, and I thought to myself that there *has* to be a more efficient approach. When the SpeedConnection challenge came along, I was excited to try to come up with a solution.

What do you think is the most exciting thing about structural steel—now or in the future?

Sherevenets: I think it is currently quite exciting, but the future will bring us a lot of new solutions, and each time, the polishing of existing technologies plus adding some new ideas will give us something really cutting-edge in the use of structural steel.

Goldson: As technology advances, I believe the 3D printing of structural shapes on a large scale will become a possibility. This would allow for more efficient, unique, and customized designs.

Zimmerman: Steel is fascinating in its malleability to suit a design vision, from using standard shapes directly to building up cross sections from individual plates and standard shapes to creating an entirely free form by casting. As the saying goes, "There's always a solution in steel," limited only by what you can imagine.

Fernandez: For me, the most exciting thing about structural steel is the versatility it offers for construction. In essence, it allows you to build almost anything!

Dolan: Steel can come in all shapes and sizes, it can be cast steel, and it can be recycled. Steel provides ductility to almost all our buildings, regardless of material. It is a universal and adaptable building construction material that allows us to build in areas that are at risk of many different types of hazards.

Eatherton: Structural steel has the opportunity to be *the* sustainable material for the future. With more than 90% of the material coming from recycled sources and the use of electric arc furnaces that don't require burning fossil fuels, the steel construction industry is already environmentally conscious. If we can get the electric arc furnaces running on renewable energy sources, then there is the potential to create an industry that is truly sustainable and carbon-neutral in the long term.

To Speedier Connections—and Beyond

The SpeedConnection Challenges exemplified a diverse range of options that may have merit for various steel connection types in the future. AISC has proposed a research project that will further develop one of these winning connection ideas into a viable, real-world solution or develop a new connection idea that exemplifies the key concepts identified in the crowdsourcing challenges. Stay tuned! ■

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is AISC's senior director
of market development.


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Building Bridges in Blacksburg

BY GEOFF WEISENBERGER

The Student Steel Bridge Competition was back in full force at Virginia Tech, marking the first in-person National Finals since 2019.

AS WE APPROACHED the outskirts of Blacksburg, Va., and really, all along the roughly 40-minute drive from the airport in Roanoke, I was struck by the natural beauty of the area. Green, rolling hills that seemed to stretch forever in all directions.

Not a jarring, overwhelming beauty, but rather the comforting sort that makes you feel good to come home to. I couldn't help but think of "Take Me Home, Country Roads," which references West Virginia and less arterial roads than the Interstate we were on, but… close enough.

Our Uber driver, a jovial local, told us he regularly ushers passengers between the Roanoke airport and Blacksburg (home to Virginia Tech), sometimes making up to six back-and-forth trips per day. You could say—and I believe he did at one point—that he knows the route like the back of his hand.

The same could be said for the members of the 34 teams that qualified for and attended the Student Steel Bridge Competition (SSBC) National Finals when it comes to their bridges. You don't make the finals without knowing your bridge inside and out, thanks to the hours and hours spent designing, fabricating, and constructing it.

The competition, which took place over Memorial Day weekend and was the first in-person National Finals since 2019, was the reason for our trip to Blacksburg and the Virginia Tech campus, which is sprawling and lovely. (Did you know that the buildings are all clad with "Hokie Stone" dolomite from a nearby quarry that the university purchased decades ago? Well, now you do!) Sponsored by AISC and ASCE (American Society for Civil Engineers), the competition challenges collegiate teams to create 1:10 scale-model steel bridges, which are judged in several categories: aesthetics, construction speed, stiffness, lightness, economy, cost estimation, and efficiency. The overall rankings are based on these individual categories and expressed as cost.

"With this being our first National Finals in three years, many of the students were new to the competition," said Kristi Sattler, senior engineer with AISC's University Relations department. "Some of them had never competed at an in-person event until this spring. It is amazing to see what they have accomplished, and there was so much enthusiasm and excitement at the competition!"

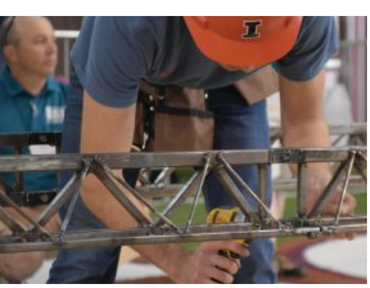
Passing Judgment

I've attended the competition in the past a few times, always as an observer and photographer, but this time I was there as… a judge! Specifically for the lateral load portion. "This will be exciting!" I thought. And it was. In a very, well, constrained way. More on that in a bit.

Training for the judges—broken up into the construction, weighing, vertical loading, and lateral load categories—took place Friday morning in the press box at Lane Stadium, the home venue for the Virginia Tech Hokies football team. (As an avid college football fan, I was grateful to cross another prominent stadium off the list.)

The competition's head judge, John Parucki—who has held this post for 27 years, nearly as long as the competition has been in existence—gave us instructions on how to judge our category and also provided tips to "keep the boat moving," as he put it. The most important bit was probably, "Don't give advice but also don't point out mistakes." The message was clear: We were there to judge, not make friends or enemies or act as advisors or coaches—especially the kind that screams at and belittles players.

"At the training, I recognized some of the judges as former students (from Missouri S&T and University of Puerto Rico Mayagüez) whom I met at the 2018 and 2019 National Finals," said Christina Harber, AISC's senior director of education. "AISC is so



fortunate to have such dedicated and passionate volunteers that want to give back to our current students and steel community."

Following our training, we made our way to the school's Beamer-Lawson Indoor Practice Facility, which was just across the outdoor practice field from Lane Stadium. Inside, all 34 teams' bridges were on display for the aesthetics judges to do their thing. This portion also allows the teams to check out and admire, analyze, and critique (ideally, silently) the other bridges. It's a wonderful, inspiring demonstration of how nearly three dozen teams interpret the parameters of the competition and present their own take on the assigned design. And really, there are a lot more interpretations than this. This year's competition involved 20 regional competitions and 139 teams in all. That is a ***lot*** of interpretations.

"The aesthetics portion is by far my favorite part of the whole weekend," exclaimed Harber. "I try to speak to as many teams as I can. Every year, I get to meet the best engineering students in the country and learn about their designs, as well as the challenges they faced and the fun they had during the entire process. If I see them again on stage as I hand them an award, I know what they've been through, and my congratulations are even more enthusiastic!"

The rules are modified every year, and this year's teams were tasked with creating bridges that spanned approximately 20 ft, included skewed piers and a cantilever on one end, had no above-deck structure, and could carry 2,500 lb without failing or experiencing excessive deflection. The "story" changes every year as well, and this year's scenario/challenge was for each team to build a hypothetical wildlife crossing over I-90 in Washington State that could support the weight of the green surface, wildlife, pedestrians, and

maintenance and park vehicles. And in an effort to limit the impact on traffic, no construction was allowed within the highway confines. In other words, during the construction portion, build team members weren't allowed to stand in the "highway" and instead had to work above it from either side (past competitions have involved other obstacles, such as rivers, that the bridges need to span over).

Fast but not Furious

Speaking of the construction category, that was the next portion of the competition and began Saturday morning. Along with the aesthetics portion—and all the rest of the Saturday categories—this portion also took place in the indoor practice facility. Unlike all other SSBCs I'd been to—which occur on concrete floors in gyms, basketball arenas, or convention spaces—the flooring for this year's National Finals was much more forgiving on the joints: field turf. That being said, the various building and loading stations were set on plywood to provide level surfaces (my first thought at seeing all of the "floating" platforms scattered about the competition area was that of a "the floor is lava" situation). There were five build "lanes" in all.

The construction portion is the exciting part (though not as exciting as LATERAL LOADING), where teams stage their individual bridge elements and connections and then assemble their bridges, some of them in jaw-dropping times. For example, the winner of the construction speed category, the Kennesaw State University team, assembled its bridge in 3.83 minutes, and the mean build time was around 13 minutes.

The Laser Doesn't Lie

The next—and best—series of (three) stations was, you guessed it, for lateral loading. (Did I mention I was a lateral loading judge?) Here's how it works: Once a team completes the construction portion and the judges assess it, they carry it to a lateral loading station. There, the team members must pass two lateral tests (unlike the build portion, these are pass or fail tests). The team applies 75 lb (in the form of three 25-lb angles) on one side of the bridge, with a grate serving as the platform. From there, a laser is attached to the bridge, as is a cord attached to a pulley. From here, a target is taped to the ground, with the laser calibrated to point exactly at the middle of the target. Once a judge is able to get the laser to stop swaying (I got very good at this), the team captain verifies that the calibration is acceptable, two team members are allowed to brace the bridge (either with their feet or a device, such as a wood block, that they've brought with them) without stepping on the footings (if there are any), and another team member applies weight (50 lb in all) to an attachment at the other end of the cord. Slow and steady is the name of the game here. The idea is to do all of this without the bridge being pulled too far laterally.

And too far isn't very far at all. If the laser moves beyond the 0.75-in. radius on the target, the bridge fails this portion of the competition (this is the constraint I mentioned earlier). If a bridge passes this test, it has to undergo a second lateral test, with the 75 lb and bracing applied at different locations of the bridge and the laser and 50 lb of lateral load attached to the end of the cantilever. Since there's a potential for more sway at the end of the bridge, it makes this final lateral test that much more exciting. It's like passing an increasingly more difficult series of bosses to defeat in a video game.

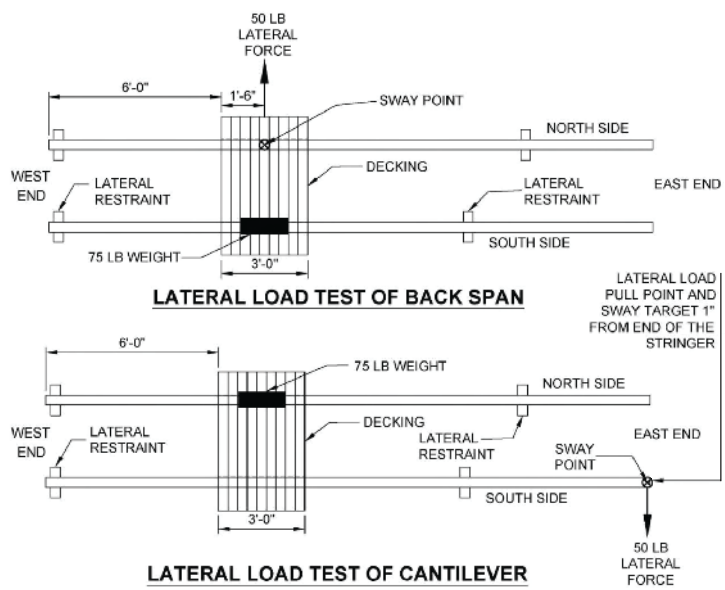
As an experienced judge told me, if a team makes it to the national finals, they've likely designed their bridge so it won't deflect past the limit. But variables such as late design changes, applying the lateral load too harshly, or even just bad luck (typically in the form of tripping) do create a bit of tension—as does the very, very tight tolerance of the target. Once the first weight is applied, the test is live and there's no turning back—and no second chance. There are no guaranteed wins, and the old sports adage "That's why we play the games" definitely applies here.

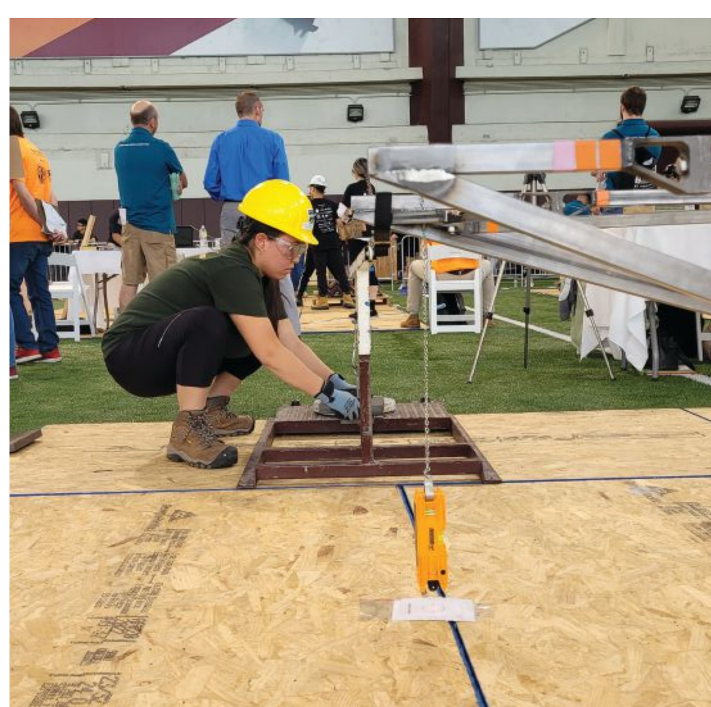
The good news: All 34 teams made it through the station unscathed (though some by mere millimeters).

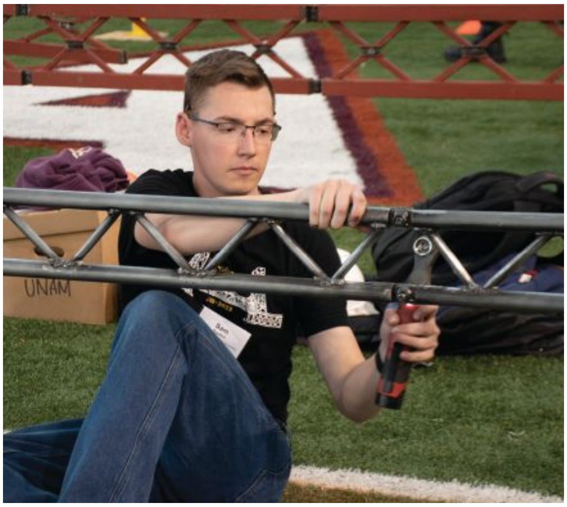
At one point, while taking a brief break from my judging duties, I ran into Sam Easterling. Sam is the James L. and Katherine S. Melsa Dean of Engineering at Iowa State University in Ames but before that, he spent more than three decades with Virginia Tech's Charles Edward Via, Jr. Department of Civil and Environmental Engineering. He recalled how Virginia Tech became the host school for this year's National Finals.

"Back in either the fall of 2018 or spring of 2019, Christina Harber asked if we were interested in hosting, and I certainly was but I wasn't going to commit without talking to the structures faculty and all the people that would have to do a lot of the heavy lifting," he said. "Matt Hebdon, now at the University of Texas at Austin, was also a faculty member here at the time. He was supervising the bridge team and agreed that it would be a great opportunity to host, and so we committed to it—and then

The lateral load testing station! Students brace their bridges (above). A diagram of the station (below). Another teammate applies lateral load to the cantilever and holds her breath while the laser makes its judgment (bottom).







Role Reversal

It's always challenging making it to the National Competition of the SSBC. And back in 2018, one team even braved a hurricane to get there.

In the late summer of 2017, Hurricane Maria nearly ended the University of Puerto Rico Mayagüez (UPRM) bridge team's run. Following the hurricane, it was more difficult for the team to secure sponsors and materials. So, they worked with what they had, harvesting components from past bridges and combining them with whatever new materials they were able to secure.

"We called our bridge 'Frankenstein,'" said Sofía D. Boscio, a member of that year's UPRM bridge team. "For a certain amount of time, we were in survival mode."

But the team persevered and advanced to the national competition, where they came in eighth place overall (out of 42 teams).

Four of the members from that team were back at this year's National Finals—this time as judges. All of them graduated in 2021 and are currently working in civil engineering jobs or have gone on to pursue advanced degrees. And in some cases, Hurricane Maria directly influenced their paths.

Boscio now works for the geotechnical section of the U.S. Army Corps of Engineers in the Huntington, W.V., District. In fact, she's currently on assignment in Puerto Rico to address flooding that occurred during Hurricane Maria.

Gabriela Yanez Gonzalez is working on her PhD at the University of Nebraska – Lincoln, focusing on functional recovery, prompted not only by her experience with Maria and other Caribbean hurricanes but also by earthquakes in the region. Her goal is to eventually work as a professor.

"The aim in the far future is to become a university faculty member to give back and teach new generations about engineering and make them fall in love with the profession as much as I did," she said.

Charmelis Reyes is currently pursuing a master's degree in urban planning, focusing on transportation planning, at the University of Texas at Austin. And Gilmarie O'Neill-Medina currently works as a transportation engineer with J2 Engineers near Washington, D.C.

The four were excited to be back at the competition and also to see this year's UPRM team make the National Finals again. As with the 2017–2018 squad, the current team also won the Robert E. Shaw, Jr. Spirit of the Competition Award.

"For us, being Puerto Ricans in civil engineering means bringing our unique, strong, and indestructible personalities to the world," said O'Neill-Medina. "So we encouraged this year's team to embrace our diverse cultural backgrounds because we have all developed a resilient perspective that can further help innovate and develop the industry."

End of an Era

Most may have missed the bittersweet moment of John Parucki finding his chair in Blacksburg at the 2022 SSBC National Finals.

It symbolized not just the end of this year's National Finals but also his retirement from judging after over 30 years of service.

As the national head judge for the SSBC, Parucki spent the day fluttering between the construction, loading, and weighing stations. He oversaw a crew of more than 40 volunteer judges, answered questions, opined on the rules, and strived to make it a fair and memorable experience for all teams. While doing so, he was completely *in the zone*, exuding a combination of laser focus and pure joy.

His keen eye for detail and intense commitment to a smoothly run event means that he has a tough time taking a break. He does not sit until the final bridge has completed the vertical loading station. Hence the significance of finding his chair at the end of the day.

Parucki is a former structural steel fabricator, and he started volunteering as a judge for the SSBC in 1991 in upstate New York. In preparation for the first-ever competition at the national level, AISC invited Parucki to serve as the national head judge in 1995. Little did he know that his role would grow and continue over multiple decades.

He has coached *every* National Finals host school through the planning process. He has trained and supervised *all* the judges at every running of the event, and he has also mentored head judges at the regional level. He has served on the Rules Committee, led efforts to standardize the competition equipment, and helped develop alternative competition formats for teams to safely participate during the COVID-19 pandemic. It is an understatement that Parucki has played a key role in the success and growth of the competition.

During the awards banquet at the conclusion of this year's National Finals, AISC senior director of education Christina Harber announced that the award for the first place overall winner was renamed the John M. Parucki National Champion.

Parucki has always announced the overall winners, and so it is especially fitting that he will forever have a presence at the pinnacle moment of each year's competition.

You can read about Parucki's experiences with the SSBC and life in general in the May 2020 Field Notes article "Judge and Jury" (in the Archives section) as well as listen to the related podcast (in the Field Notes section), both at ***www.modernsteel.com****.*

—Kristi Sattler, SE, PE, PhD
Senior Engineer
University Relations
AISC

several months later found out I would be leaving. And then COVID kicked it down the road until this year. With Matt Hebdon leaving, Matt Eatherton stepped in and has done a wonderful job of keeping the effort going here at Virginia Tech. And the new department head is Mark Widdowson, and he's been super supportive as well."

"I was most excited to show prospective graduate students from many other universities and colleges how friendly, welcoming, and helpful the graduate students in the Structural Engineering and Materials program at Virginia Tech are," said Zachary Coleman, a Virginia Tech graduate student and a co-director of the organizing committee. "By hosting the SSBC National Finals, I hope we've showcased this value to students who may be considering a graduate education here."

"We really wanted to provide a positive environment for the competition and all the wonderful competitors, advisors, judges, and volunteers who participated," said Eatherton, Virginia Tech's faculty advisor for the organizing committee. "The graduate student organizers did a tremendous job at making this goal a reality, and I cannot overstate how proud I am of our organizing team."

Running the Gauntlet

Of course, I'm talking up the excitement of the lateral portion because that was my judging assignment. (I was just a bit disappointed that I didn't get assigned to a construction lane because I wanted the opportunity to yell, "Bolt in the road. Bolt in the road! FOR THE LOVE OF GOD, BOLT IN THE ROAD!" Maybe next year.) But the truth is, the next station—vertical loading, which rates bridges on stiffness or vertical deflection—brought its own brand of excitement.

At that station, teams apply not 75 but 2,500 lb (!!!) of weight to their bridges, positioned in two locations determined randomly by the roll of a die at the beginning of the competition (a six-sided die, to clarify for those of you familiar with Dungeons and Dragons), and all teams load their bridges at the same locations. That 1.25 tons of weight also comes in the form of 25-lb angles, to be placed one at a time. Whereas the construction portion is (in many cases, literally) a sprint and the lateral station is more of a middle-distance race, vertical loading is a marathon. If a bridge deflects vertically too far, it fails. (This year, the limit was 2.5 in.) And unfortunately, three teams' bridges were disqualified at this stage—two due to excessive deflection or sway and one that collapsed due to a sheared bolt. Scenarios like this are part of the competition experience and provide harsh yet useful lessons for future projects, both at the SSBC and in real life.

From there, it's on to the weighing station, where scales are positioned under each of the four piers. The idea here is pretty straightforward: The lighter the bridge, the higher the score.

And that's it! Once a team has run the gauntlet of stations and judges, it's out into the sunshine to disassemble the bridge, decompress, and wait for the awards ceremony and results.

While the Saturday portion of the National Finals, which traditionally starts at 8:00 a.m., can often run past 5:00 p.m., this year's competition wrapped up by 2:00 p.m., a true exercise in efficiency. I like to think that the lateral judges played a big role in making this happen. (Did I mention that we got to use lasers? Lasers are neat.)

And the Winners Are

That evening, back at the practice facility, the top three teams in each category and the overall competition were announced, as were the winners of four special awards:

- Team Engagement Award: University of British Columbia
- Robert E. Shaw, Jr. Spirit of the Competition Award: University of Puerto Rico Mayagüez
- Frank J. Hatfield Ingenuity Award: University of Florida

Video Awards:

- First place: University of British Columbia
- Second place: Louisiana State University
- Third place: University of California, Berkeley

And the top three overall teams were:

- First place (John M. Parucki National Champion): University of Florida
- Second place: University of Alaska, Fairbanks
- Third place: Lafayette College

For the full results of the National Finals, as well as this year's rules and additional information about the competition, visit **aisc.org/ssbc**.

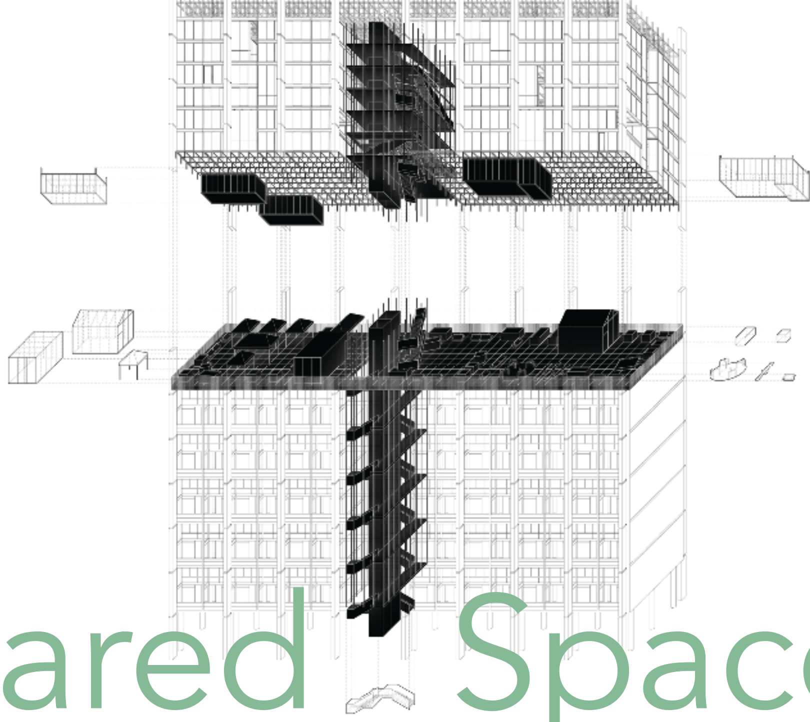
For Parucki, it was the end of the era, as he announced the overall winners for the last time as the competition's head judge.

"Over the 27 years I've been head judge, the rules have been modified from year to year, and the style of bridges allowed has also changed," he said. "However, the goal has always remained the same: Give students the challenge of designing, fabricating, and constructing a bridge. I still marvel at how each team solves the problem!"

The location for next year's National Finals was also revealed at the awards ceremony: the University of California, San Diego. As the home of one of the largest shake tables in the U.S., it gives me an idea for a new category in the competition…

For more images and videos of the competition, visit the Project Extras section a ***www.modernsteel.com***.

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



Shared Space

The winner of this year's AISC Forge Prize visualizes an attractive, ambitious new take on public housing.

A VISION OF A REINVIGORATED public housing community in Harlem has won AISC's 2022 Forge Prize.

The three finalists presented their projects live on YouTube in a stream that drew an international audience from as far away as South Africa. After tough deliberation, the 2022 Forge Prize jury rendered its verdict. Vincent Yee Foo Lai of Adjaye Associates and Douglas Lee of the University of California, Berkeley, took home the $10,000 grand prize for an inspiring concept to transform public housing in New York City's Harlem.

AISC thanks judges Alex Bachrach (Architectural Record), Evelyn Lee, FAIA (Slack Technologies), and Miles Nelligan (Diller Scofidio + Renfro) for their dedication to this program. The jury named Martin Miller's design for an iconic Silicon Valley structure first runner-up, followed by Levi Wall's concept to reimagine a site in Detroit.

The Forge Prize is unique in that it matches emerging architects with steel fabricators to brainstorm innovations that could make the three finalist design concepts easier and more economical to construct in the real world.

Lai and Lee worked with fabricator Rob Williams of AISC member fabricator Steel, LLC, to refine their concept in the second phase of the competition. One of the things that emerged from that partnership was a steel column with a tectonic train-track rail. That component of the steel structure would facilitate transporting materials up to the job site. The rail would also contain mechanical systems.

AISC's senior structural steel specialist for the Houston market, Alex Morales, noted that the challenge of practicing architecture is merging the romanticism of studio architecture with the reality of what it takes to create something tangible.

"What we see in the Forge Prize is a connection between those two worlds," he said. "Hopefully, after working with your fabricators, you are able to value the importance of that collaboration and what that looks like in practice—understanding things like how a fabrication shop operates, how many times you can repeat certain elements to reduce costs, the parameters of transportation, and other logistics that do help inform your design and ultimately contribute to a healthier project."

The judges praised the design for its creative approach to the demand for low-cost housing, deliberately fostering communities within communities, and using the modular options to introduce an element of agency that is missing from most current affordable housing schemes.

"We are extremely honored to receive the Forge Prize," said Lai and Lee. 'This recognition is a cherry on the cake for the fruitful three months of mentorship process. It has taught us to push the boundaries of the space-making and construction process with the versatility of steel. The work here is not done; we will be carrying this momentum to further unlock the potential of modular construction to house communities in need. To forge living spaces for the common good."

"I'm excited for Vincent and Douglas!" exclaimed Williams. "They put a lot of time and effort into the project. They did a great job coordinating their ideas and design with the functionality and constructability of the steel structure. It was a lot of fun for me in that I was able to get a glimpse into the future to see what types of projects we might be building five to 10 years down the road. I truly hope that Vincent and Douglas's design becomes a reality someday!"

Read on to learn about and see conceptual designs of all three finalists, and visit **www.forgeprize.com** to find out more about the Forge Prize competition. You can also learn more about Vincent at Douglas in this month's Field Notes column, "The Sky's the Limit," on page 22.

WINNER

Common Sky

New York and London
Vincent Yee Foo Lai, Adjaye Associates, and Douglas Lee, University of California, Berkeley

AISC Member Fabricator Partner:
Rob Williams, PE, Vice President of Sales Steel, LLC

Steel provides versatility and speed in construction, especially crucial in housing the homeless population. More importantly, we believe steel can be a driver to bridge the old and new communities by strategically weaving together the shared space. Previously, we took London as a testing bed for this vision. Now, we are looking to develop add-on communities on existing New York Public Housing estates such as Linden Houses and Boulevard Houses in East New York and Harlem River Houses.

The concept was inspired by London, which is blessed with a conglomeration of experimental post-war, high-rise social housing. It has successfully provided a quick rehousing for the population with its modern modular construction method. But many of these facilities are now facing the threat of demolition due to poor serviceability, safety, and community management, provoking many developers to flatten existing estates to construct new buildings to tackle overwhelming London's housing crisis.

In our proposal, instead of restocking housing by demolishing the current, existing estates will serve as a scaffold for building new communities. Existing community density and building proportions will guide the new housing density and structural composition, respectively. The proposed housing attachment will revitalize the community by creating a flexible common space between the new and existing in the sky. This space aims at recalibrating the social programs relevant for revitalizing the shared community between the current estate's residents and future tenants. We call this the "common-sky" typology. With Alton Estate in Roehampton, U.K., being used as a testing bed for this new typology.

"The work here is not done. We will be carrying this momentum to further unlock the potential of modular construction to house communities in need and to forge living spaces for the common good."
—Vincent Yee Foo Lai and Douglas Lee

The extended architecture is constructed using a rectilinear structural frame. Echoing a similar floor grid to the original building, the new space frame is made up of individual grids of 1.15 m (3.77 ft) and 1.2 m (3.94 ft), where it has a vertical capacity of 3 m (9.84 ft). With site deployment being a top priority, a gridded frame allows for maximum flexibility when adapting to a new estate across the U.K. and U.S.

The service structure core is a key component to regenerating existing buildings and supporting additional restocking of new housing units. The proposed service structure cores are made of 1,000mm (3.28 ft) × 500 mm (1.64 ft) aluminum-encased steel columns attached to the exterior of the building. Embedded within the vertical service structure core are four types of pipes (ventilation, soil, water, and electricity cables). To support the residential unit services, 1.64-ft gaps are uniformly created between all unit floors and ceilings for the horizontal insertion of service pipes.

Reflecting upon the modularization method from the original estate, a similar system of prefabricated and customizable units is used to provide high flexibility and adaptability to accommodate a constantly growing population and ever-changing demographics. With a base residential unit of nine base grids, the modular system could expand to cater to different demographic sizes, from a single person to a couple to a small family (three people) to a mid-sized family (four to five people), by offering a catalog of unique configurations.

FIRST RUNNER-UP

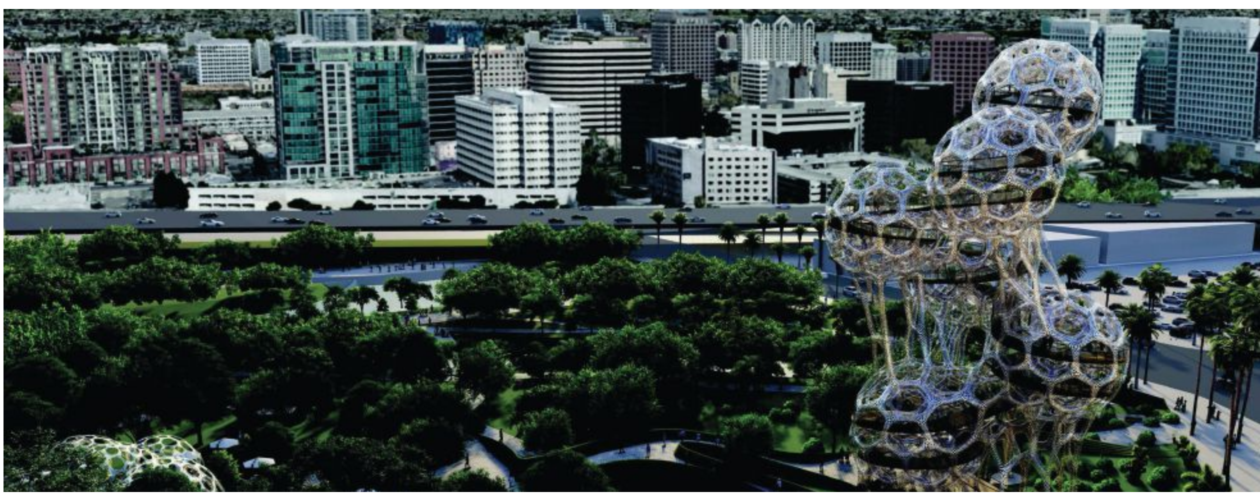
Accumulus/Woven Tectonics

San Jose, Calif.
Martin Miller,
Antistatics Architecture

AISC Member
Fabricator Partner:
Brett Manning,
Vice President of Engineering
(Western Region), Schuff Steel

Accumulus, a woven steel observation tower in San Jose, California's Arena Green Park, was designed to embody material efficiency, integration with nature, net-zero energy use, and public dialogue.

Made of tempered chromium steel alloy, the tower involves a series of steel trellises that come together to form multiple orbs as the structure rises.



Encapsulated in the tower is an ascending, curving pedestrian ramp that provides visitors with 360° views of the city.

The project is based on Woven Steel, a novel approach to the creation of lightweight and efficient structures, which has permitted several paradigm shifts to occur. By using customized computational tools for the prediction of material bending and, hence, the behaviorally determined placement of fasteners, we are able to create larger assemblies of steel lattice structures, which maintain continuity across members or laths while shifting the joints between structural components to occur at the midpoints of the linear connections, as well as maintain continuity through the structural nodes. This continuity provides greater resistance to moment forces while saving material that would otherwise be required to reinforce these positions ala gusset plates.

The diagrid structure of the grid shell precedents has been hybridized with the steel lattice structures of truss bridges of the Eiffel Tower or New York's Queensboro Bridge to create highly adaptable and efficient component-based structural systems. Leveraging high-strength spring steel strip to wrap around computationally generated minimal surface geometries, we have developed a method that further builds upon the work of famed architect Buckminster Fuller and his geodesic curves across doubly curved spheres, which we have adapted to apply to minimal variegated surfaces. The inherent and local straightness of the curve means that ubiquitous straight linear strips can wrap a doubly curved surface creating a counter torsional construction for highly efficient and lightweight elements.

The computational logic of the simulated material behavior has been tested and prototyped against physical studies and full-scale prototypes, creating formations in both spring steel strips as well as bamboo and other composite materials. The recyclable nature of steel and rigorous performance of the material as a proven structural material are most compelling to our team moving forward. However, the material studies and tests show that the viability of the computational material system is applicable to nearly all strip-based materials. Further compelling to the system is that it can be produced through automated processes. The only intervention within the strip required is the punching of precisely predetermined holes and labels, embedding the assembly logic in the material itself, thus reducing the need for complex shop drawings and instructions.

With an ever-increasing strain on available materials and increasing demands on the built environment, we believe it is through artificial intelligence and efficient material strategies—as well as looking to nature for inspiration—that we might solve many of the pressing issues facing the planet.

SECOND RUNNER-UP

Re-Adaptation

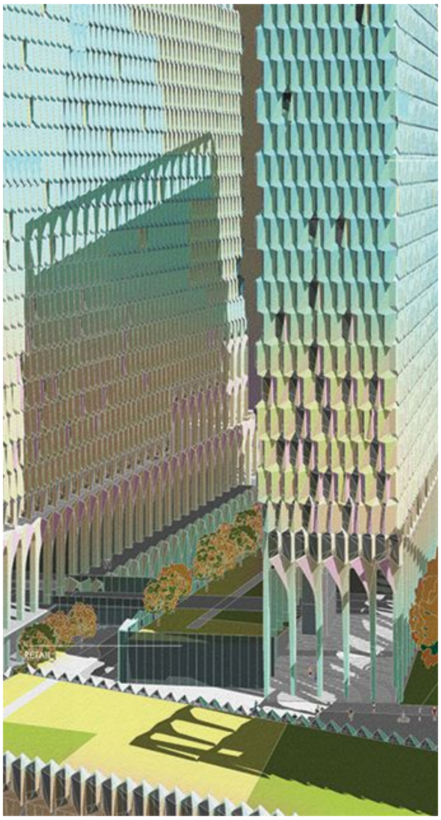
Detroit
Levi Wall, DLR Group

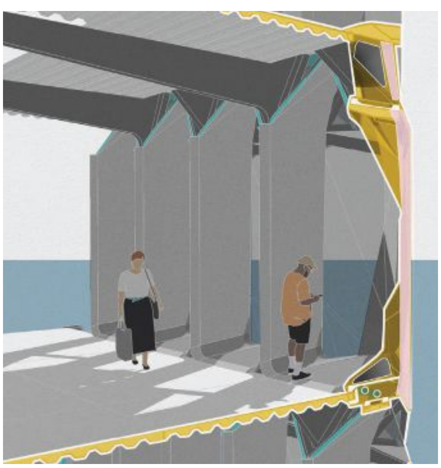
AISC Member Fabricator Partner:
Matt Cole,
Business Development Director,
Drake-Williams Steel

Since its heyday as the center of U.S. automobile manufacturing, the city of Detroit has been characterized by decline, both in mythology and in actuality. Like many American cities, and especially those in the Rust Belt, it bears the scars of economic contraction in its urban fabric in obsolete and abandoned buildıngs and infrastructure in disrepair. And also like so many American cities, the Motor City has experienced the hollowing out of urban renewal and the injection of freeways and overpasses into its urban core.

Detroit is a stand-in for many American cities, where formerly booming industries recede or where the vibrant density of the turn of the century gave way to car-dependent sprawl. Now, American manufacturing of automobiles has ebbed and flowed, and car assembly plants are located throughout the U.S. and Mexico, creating economic opportunities for this area. At the same time, major urban centers have seen a resurgence of investment and densification, creating a high demand for housing, amenities, and services. Unfortunately, the quality of the buildings meeting this demand is often sub-par, the result of labor shortages and apathy toward the craft of building. In addition, larger-scale developments often continue the tradition of International Style modernism, which tends to ignore the human scale.

This project proposes using a mass-customizable, steel-framed component manufactured in repurposed automobile factories as the main enclosure and structure for high-rise development in the center





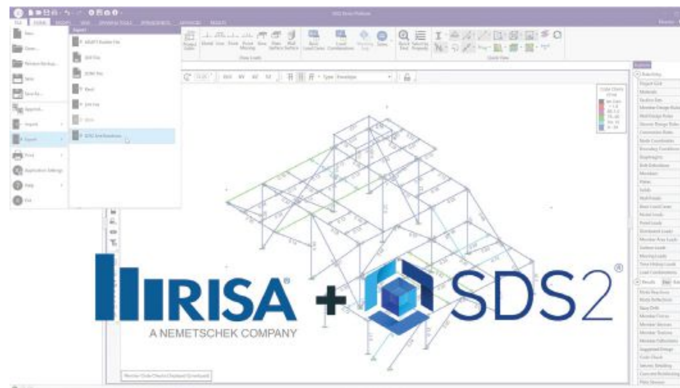
of the continent. This addresses local economic conditions through using local manufacturing infrastructure and labor, addresses the problem of quality through established high-quality manufacturing processes, and addresses the problem of scale through a readily human-scaled system (the automobile). Additionally, this innovative system would greatly minimize on-site construction time, as components would be set into place with fully integrated finishes and systems. In this way, the project doesn't conceptualize a new approach to steel and other materials but rather a readaptation of existing methods toward a radically new way of building. The project tests this approach through the conceptual design of a mixed-use development on Detroit's waterfront. ■

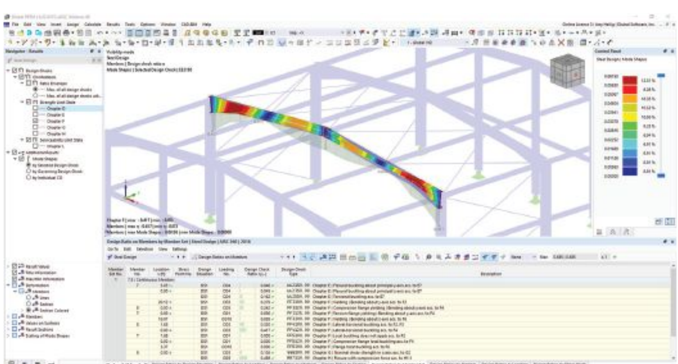
new products

This month's New Products section focuses on software and features a new connection between prominent design and fabrication software packages, a next-generation 3D program that combines finite element analysis and design, and the latest version of a design suite.

RISA-3D Version 20.0.2

The latest release of RISA-3D (Version 20.0.2) now allows users to integrate models between RISA-3D and SDS2. This new approach allows users to directly import a RISA-3D model, including end reactions, into SDS2, creating a more streamlined path for the design, fabrication, and detailing of steel connections. To learn more, visit **www.risa.com**.



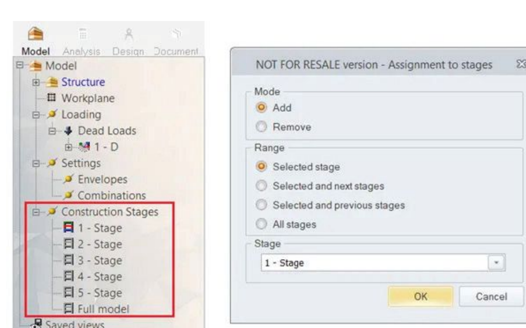


Dlubal Software RFEM 6

The recently released RFEM 6, along with the Steel Design add-on, is a new generation 3D finite element analysis (FEA) program that combines steel analysis and design into a single workflow. Design properties such as effective lengths can easily be assigned with the detection of nodes along the member length. The assigned intermediate restraints are then graphically displayed on the member for clarity. Use Member Representatives to quickly apply the same effective length conditions to multiple members at once. Curved or non-straight members are also considered for the full analysis and design workflow, including graphical output of the anticipated failure mode shape for lateral-torsional buckling. The RFEM steel design results include detailed output such as all factors, formulas, and references directly from the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360-16, **aisc.org/specifications**) used in the calculation. These detailed results can be efficiently and easily followed for transparency while eliminating guesswork for engineers. To learn more, visit **www.dlubal.com**.

Graitec Advance Design 2023

Part of the Graitec Advance suite, Advance Design 2023 was enhanced to improve several user-focused functionalities. For example, users can now define and analyze construction stages easily and efficiently. Stages can be defined in many ways, also considering changes in sections, materials, or supports between stages. And to save the most precious resource—time—the new version introduces several changes that result in a significant reduction of the time required for calculations, including improvement of the calculation solver and software architecture, changes to how results for combinations are calculated, and optimization of verification procedures for steel elements. In addition, the new version includes new possibilities for defining nonlinear relationships for supports, fast and easy checking of FEM results using Results Tables, and several other enhancements. To learn more, visit **www.graitec.com**.



BRIDGES

University of Wyoming Study Finds Steel Bridge Greener, More Economical than Concrete Counterpart

A team of researchers compared two functionally equivalent rural bridges to evaluate sustainability and life-cycle cost, and the steel bridge outperformed its concrete counterpart across the board.

Over the bridges' life cycles, the steel bridge will result in 26.3% fewer embodied CO2e emissions, consume 8.7% less energy, and lead to 17.8% more recycled material (assuming the concrete is recycled at all) at the end of its service life—plus, the steel bridge's life-cycle cost is 23% lower than that of the concrete bridge.

"These findings are frankly not at all surprising," said National Steel Bridge Alliance (NSBA) senior director of market development Jeff Carlson, PE. "This direct comparison of two functionally equivalent bridges confirms what we've known for years: that steel is the most sustainable and economical structural material out there—both when a bridge is built and for the duration of its service life."

Michael Barker, PE, of the University of Wyoming's Civil and Architectural Engineering and Construction Management program led a team that evaluated two real bridges in Whitman County, Wash. Both bridges met the two-lane rural crossing requirements and were built by the same crew. The study considered only the superstructures of these bridges to allow a direct comparison.

The Seltice-Warner bridge is a roughly 36-ft-long prefabricated, modular steel bridge with seven rolled beams and a corrugated gravel deck. The Thornton Depot bridge, meanwhile, is a 34-ft-long prefabricated, precast, pre-stressed concrete girder bridge with eight beams and a concrete deck. The Whitman County, Wash. bridge crew built them within the last three years.

Researchers evaluated both bridges throughout their construction, maintenance, and demolition phases according to four sustainability criteria:

- Embodied carbon and equipment emissions (measured in kg of CO2e)
- Embodied and equipment energy consumption (measured in MJ)
- Waste management and recyclability (measured by percent weight recycled)
- Life-cycle cost (measured in present values)

Although "the decision on which bridge type to select is clear," as the report says, researchers also developed a series of procedures to help society or a bridge's owner consider sustainability for more expensive projects.

"The historical decision criteria for choosing which bridge should be built is based on first costs for installing the bridge," the report noted. "Responsible owners may also consider life-cycle costs over the bridge service life. Neither of these consider sustainability benefits of one bridge over another."

"Sustainable design is predicated on the idea that society is willing to pay extra for reducing harmful effects on the environment. The owner or society determines an acceptable additional cost they are willing to pay for reducing emissions, reducing energy consumption, or reducing material sent to the landfill."

The full study is available at **www.shortspansteelbridges.org**, as is a Short Span Steel Bridge Alliance (SSSBA) video (**www.youtube.com/watch?v=LHjzGQFGAJQ**) in which Michael Barker reviews the research methods and findings. The American Iron and Steel Institute (AISI) and SSSBA provided oversight for this independent research.

Correction

In the June SteelWise article "Are You Properly Specifying Materials?" the "New Things" sidebar suggested that "jumbo" hollow structural sections (HSS) with 1-in.-thick walls are not currently produced in the U.S. But in actuality, AISC member producer Atlas Tube makes jumbo HSS (with walls up to 1 in. thick) in its Blytheville, Ark., mill in the following sizes: squares up to 22 in., rounds up to 28 in., and rectangles up to 34 in. by 10 in.

People & Companies

The **Steel Erectors Association of America (SEAA)** has announced the winners of its 2022 **Projects of the Year**. And multiple winners are AISC member and/or certified erectors. Class I Structural (up to $500,000) was awarded to **Steel Fab Enterprises, LLC**, for an Amtrak train station and walkway bridge in Middletown, Pa. Receiving an Honorable Mention in this category was **Hodges Erectors, Inc.**, for a 57-story condominium called Missoni Baia in Miami. Class III Structural ($1 million to $2.5 million) was awarded to **Williams Steel Erection Co., Inc.**, for building a multi-purpose 10,000-seat arena on the campus of James Madison University in Harrisonburg, Va., Atlantic Union Bank Center Arena. Receiving an Honorable Mention in this category was **Flawless Steel Welding** for an apartment community in Denver known as the Uptown Pearl. **Deem Structural Services** was recognized in Class IV Structural (over $2.5 million) for its work on the United States Airforce Academy Cadet Chapel in Colorado Springs, Colo.

Integrated design firm **SmithGroup** has opened an office in Houston, its 17th location worldwide. This new office strengthens the company's network of talent and expertise in Texas and expands upon SmithGroup's successful relationships with colleges and universities across the state. The office will be led by **Jay Rambo**, who also serves as director of the firm's Dallas location.

Engineering firm **Walter P Moore** opened its 24th domestic office in Miami, expanding its presence in South Florida. **Randy Beard**, a senior principal and managing director for the firm's Diagnostics Group, will lead a team of experts focusing on forensic investigations for building enclosure and structural deterioration, as well as failures, condition assessments, repair, and restoration design for the built environment.

AWARDS

AISC's IDEAS² Awards Program Accepting Entries until September 30

AISC's flagship competition for buildings is now accepting entries for the 2023 IDEAS² Awards.

The Innovative Design in Engineering and Architecture with Structural Steel (IDEAS²) Awards recognize outstanding projects that illustrate the exciting possibilities of structural steel.

The winners will get a prime-time spotlight at NASCC: The Steel Conference in Charlotte, N.C., next April, and the May 2023 issue of *Modern Steel Construction* magazine will feature them. In addition to substantial press support and publicity through AISC's own print and online media, winning teams have the unique opportunity to present their projects to the AEC community during special webinars or live events throughout the year. If possible, AISC will conduct an on-site award presentation at some point in 2023.

Entries are due by September 30, 2022, and AISC will announce the winners in early 2023. Visit **aisc.org/ideas2** for more information, eligibility requirements, and to enter.

You can read all about this year's winners in the May 2022 issue, available in the Archives section at **www.modernsteel.com**.

ENGINEERING JOURNAL

Third Quarter 2022 *Engineering Journal* Now Available

The third quarter 2022 issue of *Engineering Journal* is now available, along with past issues, at **aisc.org/ej**. Here are summaries of this issue's articles.

Experimental Investigation into the Capacity of Concentrically Loaded Steel Connections with Pretensioned High-Strength Bolts and Longitudinal Fillet Welds in Combination
Christopher D. Waite, Ligang Shen, Mohamed Soliman, and Bruce W. Russell

This paper presents the results of an experimental study investigating the behavior of steel connections that combine pretensioned high-strength bolts and longitudinal fillet welds on a common faying surface. A total of 75 double-shear tension splices were tested under direct tension loading to quantify the effect of connection variables on load-deformation behavior. These variables include the bolt pattern (2×2 and 2×3); bolt size (¾ in. and 1 in.); bolt grade (ASTM F3125 Grade A325, A490, and F1852); bolt pretensioning method (turn-of-nut and tension control bolts); faying surface class (Class A and B); and weld/bolt strength ratio. The investigation shows that the capacity of the combination connection with pretensioned high-strength bolts and longitudinal fillet welds can be computed by adding the capacities of the individual connecting elements while considering strain compatibility.

Wind Design of Composite Plate Shear Walls/Concrete Filled (SpeedCore) Systems
Soheil Shafaei, Amit H. Varma, Jungil Seo, Devin Huber, and Ron Klemencic

Composite steel plate shear walls/concrete filled (C-PSW/CF), also known as the SpeedCore system, are a composite solution for the design of mid- to high-rise buildings. A C-PSW/CF system consists of steel plates (web and flange plates) and an infill concrete core. The composite interaction between steel plates and concrete core is developed by either tie bars or tie bars and shear studs. Generally, in low- to mid-rise buildings (less than 15 stories), planar (uncoupled) C-PSW/CFs are adequate for resisting lateral loading and deformations. Coupled C-PSW/CFs become more prevalent in mid- to high-rise buildings when increased lateral stiffness is desirable. This paper presents the wind (nonseismic) design requirements and procedures for planar uncoupled and coupled C-PSW/CF systems. It includes a design example of a 15-story building located in Chicago using both uncoupled and coupled systems.

The Chevron Effect: Reserve Strength of Existing Chevron Frames
Rafael Sabelli and Eric Bolin

Recently an analysis model has been developed to address the large shear forces (the so-called "chevron effect") that can develop in the connection regions of chevron-braced frames. These shear forces (and the corresponding moments) are the result of the application of the brace forces at the beam flange, eccentric to the beam centerline. Prior to the presentation of these methods, such forces were not generally considered in design without apparent incident. Sabelli and Saxey presented an alternative model that determines substantially higher resistance in these connections. Both models resolve the shear and moment within the connection region such that forces outside that region are consistent with those determined using a centerline model. Greater resistance can be determined if the flexural strength of braces and the beam outside the connection region are used to resist a portion of the chevron moment.

Obliquely Loaded Welded Attachments Fatigue Categorization in Steel Bridges
Cem Korkmaz and Robert J. Connor

This paper summarizes finite element analysis studies based on local stress and structural hot-spot stress approaches that were conducted to investigate and classify welded attachments placed at angles other than 0° (transverse) or 90° (longitudinal) for a variety of stiffener geometries and thicknesses. This study includes a new classification for incorporating the findings into the AASHTO *LRFD Bridge Design Specifications*, AREMA *Manual for Railway Engineering*, and the AISC *Steel Construction Manual*.

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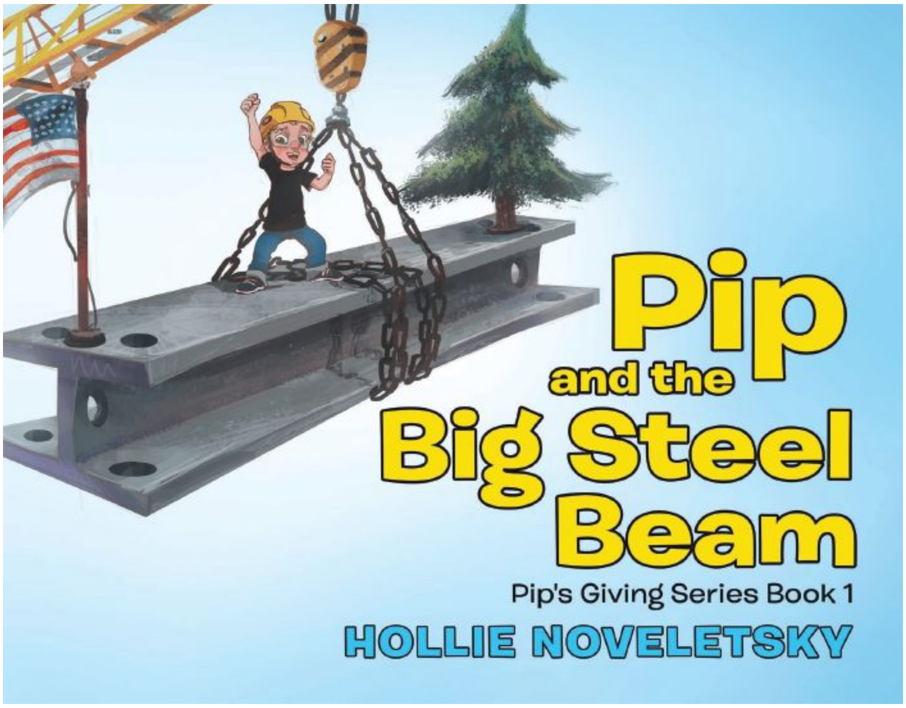
Steel Storytime

AISC BOARD MEMBER Hollie Noveletsky is the CEO of AISC member fabricator Novel Iron Works in Greenland, N.H., which her father started.

Before that, she was a nurse practitioner who spent much of her career specializing in home care for people with dementia (and still puts on her nurse's cap in her current role when the need arises).

And now she's an author.

Her first book, *Pip and the Big Steel Beam*, which was released this past spring, tells the story of her grandson, Pip (whose real name is JR; Pip is short for his nickname, Pipsqueak), who spends the day with his dad in a steel fabrication shop. Here, she provides some background on her decision to write a book and her plans for continuing the series.



What was your impetus for the book?

I've always loved to write. In nursing, my goal was to write nursing theory. And I have published a few nursing articles and chapters. But since coming into the steel industry full-time, I really haven't written anything. I was toying with writing again but wasn't sure who my target audience was. Then, one day, I thought about how much my grandson loves to come to work. He loves being in the office and the shop, and the story just came out. It's his story pretty much through and through, from donut Fridays to the characters in the story who are real employees. It was easy since none of it is made up. I picked my target audience first—three- to six-year-olds—then I knew to keep it to ten pages, so that was my structure.

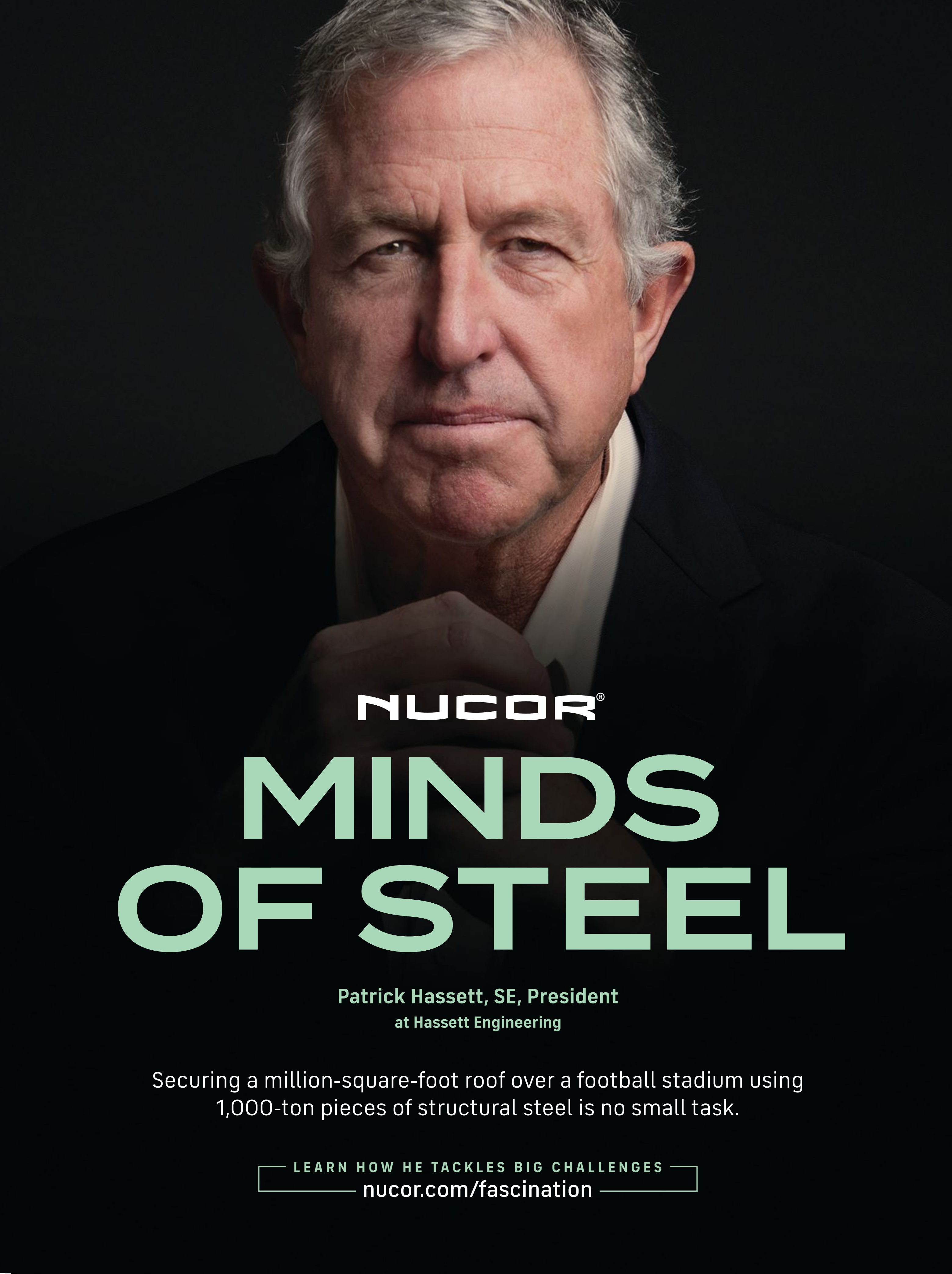
What's the publishing process like?

I used a publishing company out of Canada called Tellwell. They have been great to work with. I sent their illustrator lots of pictures of my shop and job sites, and he created the illustrations based on the pictures. The illustrations were so good that Pip recognized himself right away. He enjoys the book and has shared it with his classmates at daycare.

Neat! Are more books in the works?

There are more books. *Pip and the Big Steel Beam* is the first book in the Pip's Giving series. Each book is written about Pip and a special person in his life, and a portion of the proceeds from each book will be given to a charity that is important to that person. The first book is about Pip and his dad, and donations will go to AISC's Educational Foundation, specifically towards welding scholarships. Book two, *Pip and the Big Wrecking Ball*, is about Pip's maternal grandfather, who owns a demolition company. It's already through the editing process and is waiting for illustration. (Unfortunately, the illustrator for the first book left, but I've found another one for the subsequent books.) Book 3, *Pip and Ogi* (Ogi is what Pip calls him), is about my fiancé, Dennis, who is part Native American, and in the book, Pip spends a day learning about what makes Ogi Native American. It's already available. And the fourth book is about Pip and his wild and crazy paternal grandfather. That one is being illustrated now, and I'm hoping to have it out on the market by the end of the summer. *Pip and the Big Wrecking Ball* will hopefully be out this fall. ■

*You can read/hear more about Hollie in the August 2020 Field Notes column "Lifetime Advocate" and the associated podcast, both available at **www.modernsteel.com**. And you can find her books via online outlets like Amazon, Barnes and Noble, and Walmart.*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