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ON THE COVER: Austin FC is raising the roof at its new home, Q2 Stadium, p. 30. (Photo: Austin FC)

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editor's note

My favorite website (besides **modernsteel.com**, of course) is **quora.com**. Back in 2009, the former CTO of Facebook, Adam D'Angelo, started the site as a place where people could ask questions and anyone could answer them. Questions range from the philosophical ("What is the meaning of life?") to the mundane ("What's a good recipe for chicken Marsala?").

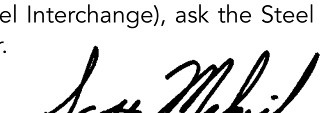
In essence, Quora is a generic version of our Steel Interchange—which started way back in March of 1992! Originally, Steel Interchange was just like Quora. People sent us questions, which we published. Readers would send answers in, and then we'd review them and publish those several months later (back then, we were limited by the speed of mail and the time lag for publishing a magazine). As time went on, AISC's technical staff became more and more invested in answering questions, and ultimately the column evolved into a monthly compendium of the most frequent and interesting questions sent to AISC's Steel Solutions Center (SSC). (You can see every question and answer from every Steel Interchange in the magazine archives at **www.modernsteel.com**.)

When I speak with my peers at other trade and technical associations (both in the construction community and the greater world at large), they're often fascinated by the SSC. They're almost always surprised that we offer it as a free service that anyone can email (**solutions@aisc.org**) or call (866.ask.aisc) about anything related to the design and construction of fabricated structural steel, and usually get an answer within a day or two.

While AISC has four dedicated staff who work directly within the SSC, the operation is actually much bigger. In addition to all of AISC's staff and library resources, there's a cadre of consultants who frequently provide answers, and it's not unusual for the SSC staff to call on AISC's hundreds of committee volunteers for answers or to seek answers from other groups, such as the American Galvanizers Association or the American Welding Society.

It's also not unusual for the SSC to field as many as 200 inquiries a month, and these inquiries often form the basis for AISC's ongoing activities. If we see a lot of inquiries on a specific subject, we recognize that more information might be needed, which might spur the creation of a session at NASCC: The Steel Conference, an article in *Modern Steel*, a proposal for a full research project, or even a new AISC Design Guide (you can access the entire library of Design Guides at **aisc.org/dg**).

So if you're wondering whether Wonder Woman could beat Thor, ask Quora. But if you're interested in getting information on out-of-date specifications and properties and dimensions of structural steel shapes that are not currently being produced (and by the way, that was the first question ever answered in Steel Interchange), ask the Steel Solutions Center.



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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**.

steel interchange

All mentioned AISC codes, standards, or manuals, unless noted otherwise, refer to the current version and are available at ***aisc.org/specifications****, AISC Design Guides are available at* ***aisc.org/dg****, and* Engineering Journal *articles are available at* ***aisc.org/ej****.*

AB Column Shape Designation

I recently came across an existing drawing set for a building in Chicago built circa 1927. The column schedule had a unique column designation that I haven't come across previously. Here are some of the designations shown in the column schedule:

AB12-170
AB12-138
AB10-53

Do you know what type of shape these designations refer to and where I can find information about the geometric properties?

AB designations refer to the American Bridge Company, which fabricated shapes called "Constant Dimension Columns" designed by the American Bridge Company (see Figure 1). These columns are not rolled columns but rather were created by combining plate and angles. Milo Ketchum's *Structural Engineers' Handbook*, which you can access for free via Google Books (**google.com/books**), provides a list of section sizes, including the three shape designations you provided as an example, in Table 162. The properties provided include the size of the web plate and four angles used to create the constant dimension columns, the weight, the strong and weak axis section modulus, and the radius of gyration. Another source of information on the shapes is available from the University of Illinois Library at **tinyurl.com/ambricohandbk**.

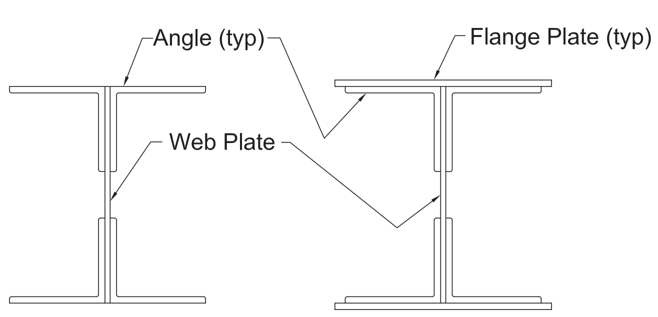


Fig. 1.

Carlo Lini, PE

End-Plate Moment Connection Stiffeners

I have a question regarding end-plate stiffeners in bolted extended end-plate moment connections as covered in AISC Design Guide 4: *Extended End-Plate Moment Connections—Seismic and Wind Applications*. In the calculation procedures covered in the design guide, I do not see where the addition of stiffener plates would reduce the end-plate thickness. I also would like to know what percentage of the beam flange force goes into the stiffener as I could not find guidance on this either.

The stiffener plates were considered in selecting the yield line patterns used to derive the equations for Y_p in Tables 3.1 through 3.3.

The stiffeners are designed according to Equations 3.15 and 3.16. The load distribution at the plate edges will change with the load level. Generally, the actual stresses will likely be highly nonlinear at lower loads and become more uniform with stress redistribution due to yielding at higher loads. The design guidance for these connections is intended to provide adequate ductility to allow for this stress redistribution without buckling or rupture.

Although not required for end-plate connections designed according to Design Guide 4, I have developed a method to calculate the force along each edge of a rectangular yield line pattern. An article on it, "A Yield Line Component Method for Bolted Flange Connections," appears in the second quarter 2011 issue of *Engineering Journal*.

Bo Dowswell, PE, PhD

Table 10-10a—Controlling Limit State (Part 1)

I am having trouble manually calculating the value in Table 10-10a in the 14th Edition AISC *Steel Construction Manual* for three ¾-in.-diameter Group A bearing bolts in standard holes with a $^5\!/_{16}$-in.-thick A36 Plate. Table 10-10a provides an available strength equal to 43.4 kips (LRFD). Do you know what the controlling limit state is?

The 43.4-kip value is shown for $^5\!/_{16}$-in. to $^7\!/_{16}$-in. plate. This would indicate that the plate does not govern. This leaves the bolts and the welds. The welds are sized to the strength of the plate, and therefore the welds cannot govern. This leaves the bolts. We are now certain that bolt shear is the controlling limit state.

Carlo Lini (**lini@aisc.org**) is AISC's director of technical assistance with AISC's Steel Solutions Center. **Bo Dowswell**, principal with ARC International, LLC, and **Larry Muir** are both consultants to AISC.

STEEL SOLUTIONS CENTER

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

The opinions expressed in Steel Interchange do not necessarily represent an official position of the American Institute of Steel Construction and have not been reviewed. It is recognized that the design of structures is within the scope and expertise of a competent licensed structural engineer, architect or other licensed professional for the application of principles to a particular structure.

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

Table 10-9 provides information on "Design Values for Conventional Single-Plate Shear Connections." Here, we can see that the design eccentricity, e, is $a/2$. The discussion to Table 10-10 states: "…the tabular values are based on a = 3 in…" So our design eccentricity is 1.5.

Interpolating in Table 7-6, we get C = 2.42. From Table 7-1, the bolt value is 17.9 kips. (17.9)(2.42)= 43.3 kips, which is the value in the table, as you note. Therefore, the controlling limit state is the shear strength of the bolt.

Larry Muir, PE

Table 10-10a—Controlling Limit State (Part 2)

A follow-up to your response to my previous question: When I look at Table 7-6 and interpolate, I get a value of 2.47. Can you show me how you got a value of 2.42?

For the purposes of design (and interpolation), 2.42 and 2.47 are essentially the same value. There would be nothing wrong (in my opinion) with using your value of 2.47 instead of my value of 2.42.

Technically speaking, you have not interpolated; you have extrapolated. When the eccentricity is zero (e = 0), all bolts will effectively resist the shear. So C = 3 because C is the number of bolts that are effective in resisting the shear, considering that some of the bolt strength is used to resist the moment.

Extrapolation:
$e_x = 2$, $C = 2.23$
$e_x = 3$, $C = 1.75$

$e_x = 1.5$, $C = 2.47$

Interpolation:
$e_x = 0$, $C = 3$
$e_x = 2$, $C = 2.23$

$e_x = 1.5$, $C = 2.42$

Table 7-6
Coefficients C for Eccentrically Loaded Bolt Groups
Angle = 0°

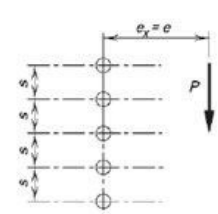
Available strength of a bolt group, ϕR_n or R_n/Ω, is determined with

$$R_n = C \times r_n$$

or

LRFD	ASD
$C_{min} = \frac{P_u}{\phi r_n}$	$C_{min} = \frac{\Omega P_a}{r_n}$

where
P = required force, P_u or P_a, kips
r_n = nominal strength per bolt, kips
e = eccentricity of P with respect to centroid of bolt group, in. (not tabulated, may be determined by geometry)
e_x = horizontal component of e, in.
s = bolt spacing, in.
C = coefficient tabulated below



s, in.	e_x, in.	Number of Bolts in One Vertical Row, *n*										
		2	3	4	5	6	7	8	9	10	11	12
	2	1.18	2.23	3.32	4.39	5.45	6.48	7.51	8.52	9.53	10.5	11.5
	3	0.88	1.75	2.81	3.90	4.98	6.06	7.12	8.17	9.21	10.2	11.3

Note that the 15th Edition AISC *Steel Construction Manual* has added 'C' values in Table 7-6 for eccentricity, e_x, equal to 1 in., which would allow users to interpolate between 1 in. and 2 in. for cases where the eccentricity is equal to 1½ in.

Larry Muir, PE

steel quiz

This month's Steel Quiz looks at the 2016 AISC *Code of Standard Practice for Steel Buildings and Bridges* (ANSI/AISC 303, **aisc.org/specifications**) from a fabricator's perspective.

You can find the answers in both the *Code* and in the 2020 NASCC: The Virtual Steel Conference session "Your Code of Standard Practice: A Fabricator's Perspective," presented by Scott Armbrust of LeJeune Steel Company, at **aisc.org/education-archives** (search for "Armbrust").

All of this month's questions and answers were developed by Maysaloon Abugrain, an AISC intern and a recent graduate student from Oregon State University. (Thanks, Maysaloon!)

1 **True or False:** The fabricator shall be permitted to perform corrective procedures when the mill material does not satisfy ASTM A6/A6M tolerances for camber, profile, flatness, and sweep.

2 **True or False:** Materials with special requirements do not require shape, grade, and heat number.

3 In Section 6.2.2, "Shop Fabrication and Delivery," surfaces specified as "finished" in the contract documents shall have a roughness height value measured according to ASME B46.1 that is equal or less than which of the following:
a. 400 μin. **b.** 500 μin. **c.** 600 μin. **d.** 700 μin.

4 For straight structural members other than _______ members, the variation in straightness shall be equal to or less than that specified for structural shapes in the applicable ASTM standards except when a smaller variation is specified in the contract documents.
a. compression
b. flexural
c. tension
d. both compression and flexural

5 **True or False:** In Section 8, "Quality Control," only the fabricator is required to maintain a quality control program to ensure that work is performed in accordance with the requirements, the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360), and the contract documents.

TURN TO PAGE 14 FOR THE ANSWERS

1 **True.** Section 5.1.2, "Mill Materials," indicates that when mill material does not satisfy ASTM A6/A6M, the fabricator is permitted to perform corrective procedures, including the use of controlled heating and/or mechanical straightening, subject to the limitations in the AISC *Specification*. This is discussed near the 30-minute mark in the presentation.

2 **False.** Section 6.1.1(c), "Shop Fabrication and Delivery," indicates that for material ordered in accordance with an ASTM supplement or other special material requirements in the contract documents, identification capability shall include shape designation, material grade, and heat number. The corresponding material test reports shall be furnished by the fabricator if requested to do so by the owner's designated representative for design, either in the contract documents or in separate written instructions given to the fabricator prior to ordering mill materials. This is discussed near the 33-minute mark in the presentation.

3 **b.** Equal to or less than 500 µin. This is discussed near the 34-minute mark in the presentation.

4 **a.** Section 6.4.2, "Shop Fabrication and Delivery," states that for straight compression members, the variation in straightness shall be equal to or less than 1/1000 of the axial length between points that are to be laterally supported. This is discussed near the 36-minute mark in the presentation.

5 **False.** Both the fabricator and the erector are required to maintain a quality control program. In addition, according to Section 8.1.1, the fabricator shall have the option to use AISC's Quality Certification Program to establish and administer the quality control program, whereas Section 8.1.2 states that the erector shall have the option to use the AISC Erector Certification Program to establish and administer the quality control program. This is discussed near the 46- minute mark in the presentation.

STEEL SOLUTIONS CENTER

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

steelwise

BEAM-COLUMN DESIGN: A PRIMER

BY RICHARD M. DRAKE, SE, ERIK ESPINOZA, SE, AND MOHAMMED BALA

Tips on designing beam-columns in accordance with the AISC *Specification.*

Richard M. Drake (**rick.drake@fluor.com**) is a senior fellow in structural engineering, **Erik Espinoza** (**erik.espinoza@fluor.com**) is a director in structural engineering, and **Mohammed Bala** (**mohammed.bala@fluor.com**) is a design structural engineer, all with Fluor Enterprises, Inc.

See Rick and Erik's recent SteelWise articles on compression, tension, and flexural members in the Archives section at **www.modernsteel.com**).

BEAM-COLUMNS ARE SUBJECT TO SIMULTANEOUS flexure and axial compression.

In this article, we'll discuss key design steps in designing these steel members in accordance with the provisions of the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360-16, **aisc.org/specifications**). Note that only W-shape columns are considered; members that are subject to simultaneous flexure and axial tension are not, although much of the material is readily applicable to other rolled shapes.

Beam-columns—again, structural members with both flexural loads and axial compression loads—commonly occur in many steel structures and can take the form of beams and columns rigidly connected to resist gravity and lateral loads as well as top chords of roof trusses supporting vertical roof loads between panel points in addition to the axial loads from truss action. Some industrial structures offer challenging examples of beam-column design, including crane columns (see Chapter 16 of AISC Design Guide 7: *Industrial Building Design*, **aisc.org/dg**) and pipe rack columns (see "Design of Structural Steel Pipe Racks" in the Fourth Quarter 2010 issue of *Engineering Journal*, **aisc.org/ej**).

The Perfect Storm

Similar to the film *The Perfect Storm*, beam-column design is the confluence of three separate design "storms": compression member design, flexural member design, and the interaction of axial compression and flexural loads. Unlike the movie, these three design storms are harnessed by the *Specification* to work together to help the engineer design safe and economical structures.

Storm 1: Compression member design. All of the principles involved in compression member design are applicable for beam-column design, including effective length, flexural buckling, torsional buckling, flexural-torsional buckling, flange buckling, web local buckling, and stiffness reduction. See Figure 1 for a graphical summary of fundamental compression member behavior, which was discussed in a companion article, "Compression Member Design: A Primer," in the June 2021 issue, available at **www.modernsteel.com**.

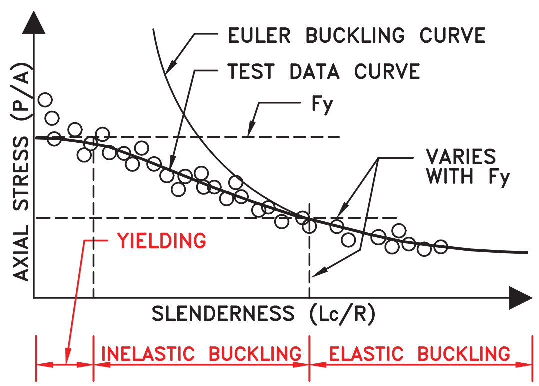


Fig. 1. Compression member behavior.

Storm 2: Flexural member design. All of the principles involved in flexural member design are applicable for beam-column design, including flexural yielding, lateral-torsional buckling, flange local buckling, web local buckling, shear, and deflection. See Figure 2 for a graphical summary of fundamental flexural member behavior, discussed in another companion article, "Flexural Member Design: A Primer," in the September 2021 issue.

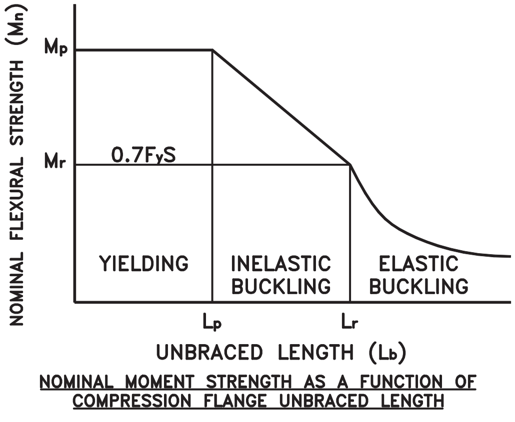
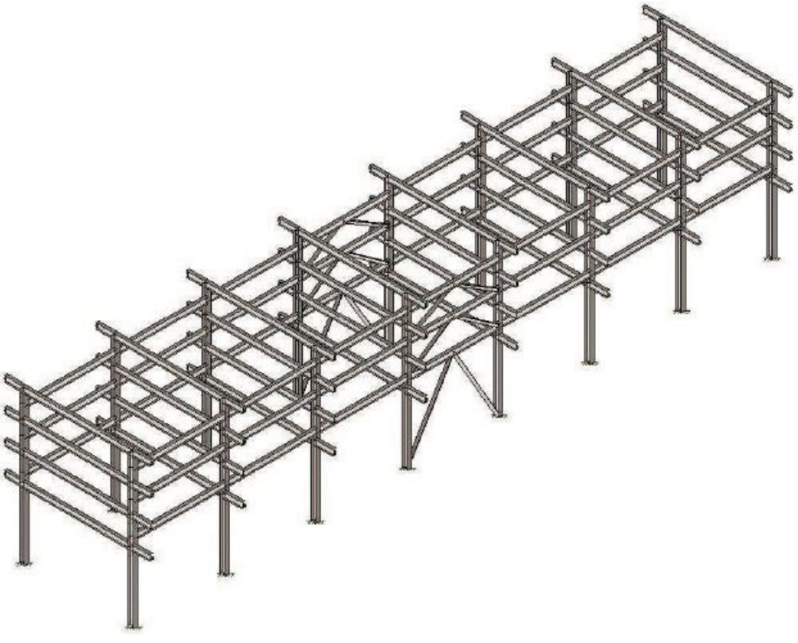
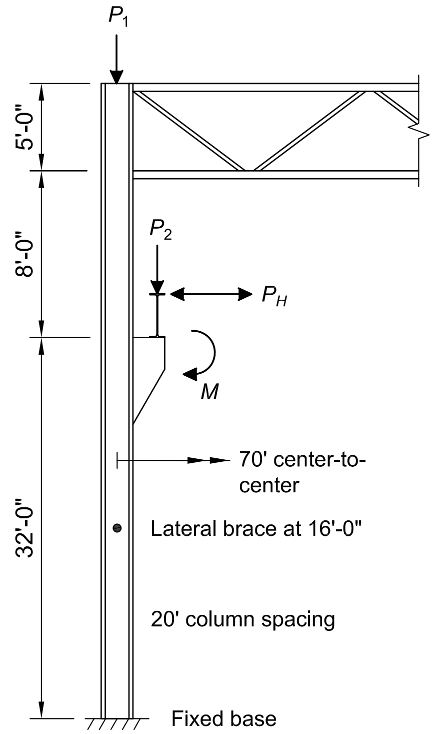


Fig. 2. Flexural member behavior.

below: Industrial structures such as pipe racks can be challenging when it comes to beam-column design.





A bracketed crane column example.

Storm 3: Interaction of axial compression and flexural loads. Additional principles related to the interaction of axial compression and flexural forces are necessary to understand and appreciate beam-column design, including member displacement (δ), frame displacement (Δ), second-order effects, and frame stability.

Member displacements are the displacements relative to a straight line between the member ends. Frame displacements are the displacements due to the lateral sidesway of the frame that a beam-column is a member of. The interaction of the member and frame displacements with the beam-column axial load (*P*) creates secondary moments that must be accounted for in beam-column design. Collectively, these P-δ and P-Δ secondary moments are called P-delta effects or second-order effects. See Figure 3.

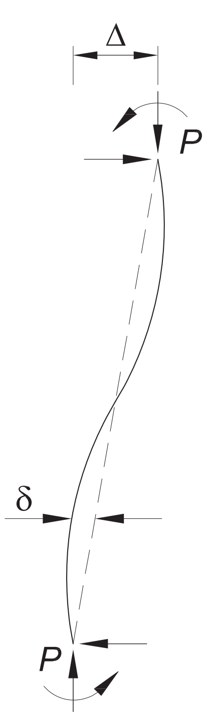


Fig. 3. Member and frame displacements. (This is Figure C-C2.1 from the AISC *Specification*.)

Second-Order Effects

The single most complicating factor in the analysis and design of a beam-column is the interaction between the instabilities associated with beam flexure and axial flexural buckling.

First-order analysis. Applied loads cause shears (*V*), bending moments (*M*), member displacements, and frame displacements. Note the following:

- Common elastic methods of structural analysis assume that all displacements and deformations are small.
- The results of the analyses are referred to as first-order effects, including first-order forces, first-order moments, and first-order displacements.
- This is the type of analysis performed in both determinate and indeterminate analysis courses.

To account for the interaction effect of the displacements on the forces and moments, an additional analysis must be performed: a second-order analysis.

Second-order analysis. The applied *axial* load multiplied by the resulting *bending* displacements causes additional bending moments. These amplified bending moments must be accounted for in beam-column design. Keep in mind that:

- The second-order analysis results in changes in moments as the direct result of structural displacements.
- The second-order analysis is nonlinear—i.e., changes in member moments are not proportional to changes in structural displacements.

In frames braced against sidesway (braced frames), the member ends do not translate with respect to each other, and P-δ moments are dominant. Begin with an initially undeflected and unloaded simply supported column, not free to sidesway. Apply a lateral load, resulting in a bending moment (M_x) and a member deflection. See Figure 4.

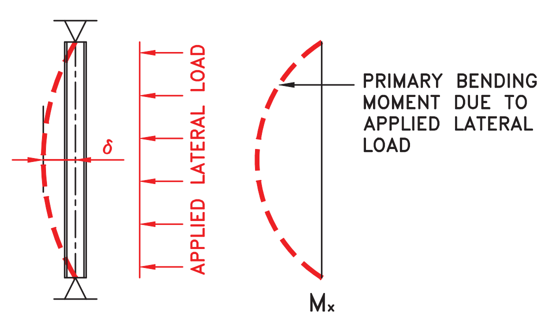


Fig. 4. Primary moment on braced frame.

Add a vertical load, resulting in additional bending moment and additional member deflection (*y*). See Figure 5. A secondary moment is created that is equal to the axial load times the flexural displacement.

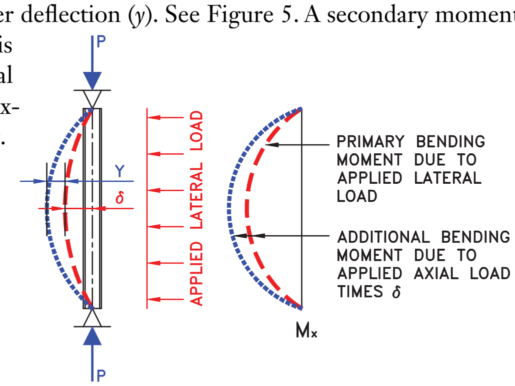


Fig. 5. Secondary moment on braced fame.

$M_{secondary} = P(\delta + y)$

This secondary moment causes additional deflection (y) and additional moment, which causes additional member deflection and moment, etc., until the solution converges. The maximum bending moment, including secondary effects, can be defined as:

$M_x = M_{lateral} + P(\delta + y)$

Note that for braced frames, the maximum moment and maximum deflection occur at approximately the same beam-column location.

In frames not braced against sidesway (unbraced frames), the member ends translate with respect to each other, and P-Δ moments are dominant. Begin with an initially undeflected and unloaded cantilever column, free to sidesway. Apply a lateral load, resulting in a bending moment and a frame deflection. See Figure 6.

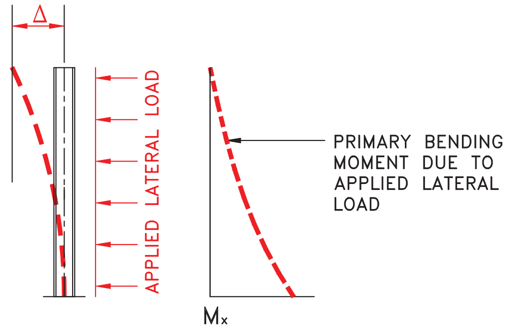


Fig. 6. Primary moment on unbraced frame.

Add a vertical load, resulting in additional bending moment and additional member deflection. See Figure 7. A secondary moment is created that is equal to the axial load times the flexural displacement.

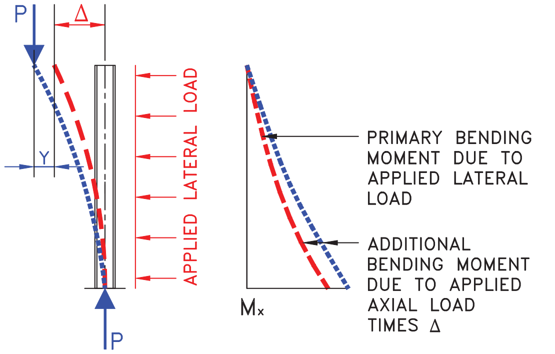


Fig. 7. Secondary moment on unbraced frame.

$M_{secondary} = P(\Delta + y)$

This secondary moment causes additional deflection and additional moment, which causes additional frame deflection and moment, etc., until the solution converges. The maximum bending moment, including secondary effects, can be defined as:

$M_x = M_{lateral} + P(\Delta + y)$

Note that the maximum moment and maximum deflection for unbraced frames occur at different beam-column locations. This is different than what we saw for braced frames.

Second-order analysis methods. *Specification* Section C1 requires that analysis of second-order effects be considered in the evaluation of frames, including beam-columns.

Commercial finite-element analysis (FEA) software is capable of performing the exact calculations to yield the required strength of beam-columns, including second-order effects. In most commercial software, there is a checkbox to request second-order effects be considered.

Specification Appendix 8 provides an alternate method to calculate approximate second-order effects, increasing first-order analysis results by amplification factors.

For braced frames, the exact second-order moments are replaced with approximate moments:

$M_x = M_{lateral} + P(\delta + y)$
$M_x = B_1 M_{lateral}$

For unbraced frames, the exact second-order moments are replaced with approximate moments:

$M_x = M_{lateral} + P(\Delta + y)$
$M_x = B_2 M_{lateral}$

Required Strengths

The *Specification* prescribes three methods of analysis to determine required strengths (M) and (P) that account for second-order effects. A more detailed comparison can be found in *Specification* Chapter C Commentary.

Direct analysis method. *Specification* Chapter C describes requirements for the direct analysis method to determine second-order required strength (P_u or P_a), including:

- Perform analysis with *reduced* flexural rigidity ($0.8\tau_b EI$).
- Perform a second-order analysis.
- Determine compression available strength ($\phi_c P_n$ or P_n/Ω_c) with an effective length factor (K) equal to 1.0.

Effective length method. *Specification* Appendix 7 describes requirements for the effective length method to determine second-order required strength, including:

- Perform analysis with *unreduced* flexural rigidity (EI).
- Perform a second-order analysis.
- Determine compression available strength with an effective length factor (K) determined in accordance with *Specification* Chapter C.

First-order analysis method. *Specification* Appendix 7 describes this method, a modification of the direct analysis method assuming target drift ratios and a high amplification factor (B_2).

- Perform analysis with unreduced flexural rigidity.
- No need to perform a second-order analysis.
- Determine compression available strength with an effective length factor (K) equal to 1.0.

Available Strengths

Determine compression available strength in accordance with *Specification* Chapter E, except as modified for the direct analysis method and first-order analysis method. The AISC *Steel*

Construction Manual Design Aids (**aisc.org/manual**), discussed in the "Compression Member Design: A Primer" article, can be used.

Determine flexural available strength in accordance with *Specification* Chapter F. The *Manual* Design Aids discussed in the "Flexural Member Design: A Primer" article can be used.

Interaction Formula

For an individual structural steel member, the strength acceptance criteria can be summarized in a general form as:

$$R_r \le R_c$$

Where:

R_r = the required strength
R_c = the available strength

This can be written in the following form:

$$\frac{R_r}{R_c} \le 1.0$$

If more than one type of resistance is involved, it is logical to extend the concept to this interaction equation:

$$\left(\frac{R_r}{R_c}\right)_1 + \left(\frac{R_r}{R_c}\right)_2 + \left(\frac{R_r}{R_c}\right)_3 \le 1.0$$

The combined resistances of axial and bending about both the x-axis and y-axis can be expressed as the interaction equation:

$$\frac{P_r}{P_c} + \frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \le 1.0$$

Where:

P_r, M_{rx}, M_{ry} = the required strengths determined by one of the three analysis methods as previously described
P_c, M_{cx}, M_{cy} = the available strengths determined as previously described

This is the starting point to understand the *Specification* interaction equations.

Specification Section H1.1 addresses W-shape members subject to combined flexural and axial compression forces. The above interaction relationship is modified as follows:

For beam-columns that are more column than beam—i.e., when $P_r/P_c \ge 0.2$:

$$\frac{P_r}{P_c} + \frac{8}{9}\left(\frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}}\right) \le 1.0$$

For beam-columns that are more beam than column—i.e., when $P_r/P_c < 0.2$:

$$\frac{P_r}{2P_c} + \frac{M_{rx}}{M_{cx}} + \frac{M_{ry}}{M_{cy}} \le 1.0$$

Beam-Column Basics

The basic concepts presented here should help you achieve more economical beam-column designs, which is inseparable from frame stability concepts. In addition to the resources listed in this article, you can also find more detailed beam-column design information in the *Specification* Commentary Chapter C (Frame Stability), *Structural Stability of Steel—Concepts And Applications For Structural Engineers* by Ted Galambos and Andrea Surovek, and *Guide to Stability Design Criteria for Metal Structures* by Ron Ziemian. ■

Want to know when the construction industry has fully recovered after a recession? Keep an eye on these three key milestones in the general economy.

GETTING BACK ON TRACK

BY JOE DARDIS

	2019				2020				2021	
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	Q1	Q2
Seasonally Adjusted GDP (billions)	21001.6	21289.3	21505.0	21694.5	21481.4	19477.4	21138.6	21477.6	22038.2	22722.6

Source: Bureau of Economic Analysis

WHAT DID THE CONSTRUCTION INDUSTRY learn from the Great Recession of 2008?

One key lesson is that construction typically lags overall economic recovery by around three fiscal quarters (or nine months). This is because historically, nonresidential construction activity will not begin expanding until three critical economic hurdles are cleared.

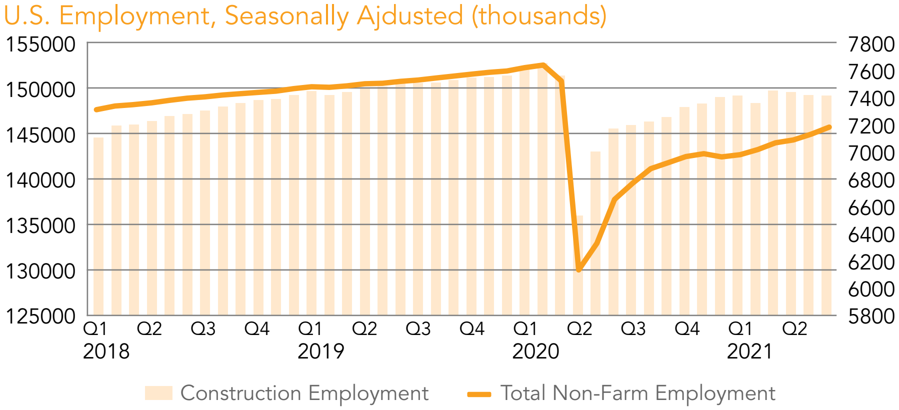
The first of these is that the dollar value of real GDP must return to pre-recession levels. Prior to the onset of in the first quarter of 2020, COVID and its related economic downturn, U.S. GDP was roughly $21.5 trillion and declined from there, starting in the second quarter of 2020, but had risen back to an estimated $22.7 trillion in the second quarter of 2021 (see the above table).

The second hurdle is for GDP to grow at an annual rate of greater than 3%. There's good news on this front, too, as GDP has grown 6.3% and 6.5% in the first and second quarters of 2021, respectively.

Thirdly, total U.S. employment numbers must reach pre-recession levels. Just before COVID hit, U.S. non-agricultural employment was roughly 153 million and bottomed out at around 130 million in April 2020. While employment numbers have risen dramatically since then (as indicated in the below chart), we are still about 7 million jobs short of the pre-COVID total.

While two out of three isn't bad, we aren't quite "back" yet. Nonresidential construction put-in-place dollars have declined 3% to 5% each quarter from the onset of the pandemic through the first quarter of 2021. But things are looking up, as this figure only decreased by 0.2% in the second quarter. With this crucial number beginning to level out and with U.S. GDP currently looking healthy, it would appear that the construction economy is slowly (and hopefully surely) back on the right track. ■

U.S. Employment, Seasonally Ajdusted (thousands)



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

ALTERNATE REALITIES

INTERVIEW BY
GEOFF WEISENBERGER

Engineering professor Hannah Blum is working to make the most of her and her students' experiences in the real and virtual worlds.

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**.

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

HANNAH BLUM KNEW EARLY ON that she wanted to become an engineer. She just wasn't quite sure what type.

But she found her calling—civil engineering—as an undergraduate and is now an assistant professor and the Alain H. Peyrot Fellow in Structural Engineering at the University of Wisconsin-Madison. She has also *embraced* her current role as the Vice-Chair of the Structural Stability Research Council's (SSRC) Stability of Steel Systems Task Group.

Read on to learn about her travels and studies in Australia, her experiences with remote teaching, her work with virtual and mixed reality, and her stability research—and see if you can catch her pun.

When did you first become interested in buildings?

I decided to become an engineer because I was interested in science and applying science to produce creative solutions. Also, engineering is known as a typically stable career. I originally wanted to be an environmental engineer because I think that's very important, but I found that I didn't like chemistry and preferred the mechanics area of physics. So I switched my major to civil engineering.

Sounds like you chose the right type of engineering for your interests. On that note, how did you become involved with stability research?

After I switched my major to civil engineering, I decided it would be a good use of the opportunities available to me to get involved in undergrad research. The first team I joined wasn't a good fit. So I tried again and, based on a suggestion for my classmate, joined another research group. They were a great group, and I was lucky to have the opportunity to participate in three research projects during my undergraduate years. The first was laboratory-based and included experiments on cold-formed steel-framed walls with a PhD student. The second project was fieldwork-based and was on field measurements of a historic wooden covered bridge with a research associate. The third was computational-based, and I studied bracing requirements in cold-formed steel-framed walls. This project was my first exposure to stability research, and I really enjoyed it.

What's your role with the SSRC?

I previously served as the vice-chair of the thin-walled structures task group for a few years, and I recently changed to the vice-chair of the stability of steel systems task group.

What research are you currently involved in?

I currently have a mix of research topics, including steel joists, stainless steel angle compression members, advanced high-strength cold-formed steel, mixed reality in structural steel fabrication, machine learning in structural engineering, and the use of virtual reality in structural engineering education.

What's the current hot topic when it comes to stability research?

Well, I suppose the current hot topic would be the stability of members and systems under elevated temperatures.

How long have you been at the University of Wisconsin? And can you tell me what you like most about Madison?

I've been at UW-Madison for three years. There are some beautiful local and state parks in the area. I also really like the dedicated bike paths, which make it easy and safe to get around town.

Can you talk a little bit about your experience as the faculty advisor for the Wisconsin student steel bridge team?

The bridge team is exceptional. They are responsible, organized, creative, and hard-working students who consistently perform well enough at regionals to qualify for the national competition. I was really looking forward to Regionals being at UW-Madison for the 2020 competition, but for obvious reasons that didn't happen.

Can you talk about your work with artificial intelligence and virtual reality and how it's gotten students more engaged?

My team has made several virtual-reality and mixed-reality teaching aides. We've developed a virtual reality building plan matching game to help students understand how to read building plans through an interactive environment. We also partnered with AISC to create a virtual-reality tour of a steel building to allow students to go on a virtual field trip at their convenience. My team also developed a mixed-reality steel connection teaching module to help students identify failure paths in steel bolted connections. I received two educational Innovation grants from my university to develop these teaching aides and to purchase equipment to furnish a mobile virtual-reality and mixed-reality teaching lab. I was hoping to start using these teaching modules in my class at the end of the spring 2020 semester, but that didn't happen, again due to factors out of our control. I now plan to have these in class for this coming semester.

Do you have any advice for engineering students or engineers that are just starting out?

I'd say it's okay not to have your career path fully planned out. I recommend trying out new opportunities as they become available and don't feel bad moving on if something isn't the right fit at the right time.

So obviously, nearly everybody had to transition to online life last year, whether for school or work. Can you talk about what that was like in terms of your classes? Were there any interesting challenges that you weren't anticipating?

The first transition was a little bit difficult, not having the right equipment that you would need and using a different format. For example, you can't write on the board. Luckily, I was able to get the equipment I needed, such as a webcam, and I use my touch screen tablet to write on like I would on the board. I've run into a few challenges involving cats. There were a few incidents where my cat thought my touchscreen stylus was a toy and shut down the notes program I was broadcasting to the students. I have two cats, and sometimes when I'd ask the students a question, the cats would answer.

You mentioned your undergraduate work, and I understand you got your PhD in Sydney, Australia. What made you decide to go abroad for that degree? And can you tell me a little bit about the experience of living in Australia?

I had the opportunity to study abroad in Sydney during my master's degree, and after that I decided I wanted to do my PhD studies there. I had a great time living in Australia—friendly and laid-back people and culture, beautiful landscapes, and lots of unique plants and animals in Sydney. It was truly a melting pot of people from all different backgrounds.

Was there any type of local food found there that you fell in love with and can't really find in other places?

I really enjoyed something called beetroot, which I believe is pickled beets, that they would put on burgers, sandwiches, and salads. It just adds a pop of flavor, and it's amazing. I haven't had great success finding it here. I did find someone at the Madison farmers' market that pickles beets, and sometimes I'm able to get a can of those.

While we're on the subject of Australian cuisine, did you eat Vegemite when you were there?

I've had it. I did not enjoy it. It tasted like salt paste.

That's not a ringing endorsement. One more question about Australia: Uluru is one of the country's most, if not *the* most, recognizable geographic features. Did you get to visit it?

I did get a chance to go. I found it was stunningly beautiful the way the light reflects off the rock at sunrise and sunset, causing the whole area to glow. This copper color is gorgeous. And even though you're in the middle of the desert, there's actually a lot of life there. You can hear a lot of small animals and insects around, and it has its own unique types of plants. ■

This article is excerpted from my conversation with Hannah. To hear more about her, including her experience playing the French horn and soccer—and perhaps another pun or two—check out the August Field Notes podcast at ***modernsteel.com/podcasts****.*

business issues

THE UNEXPECTED MENTOR

BY ALEX MORALES

Mentorship, whether it is declared up front or occurs on the fly, can be a crucial component to more rewarding careers and projects.

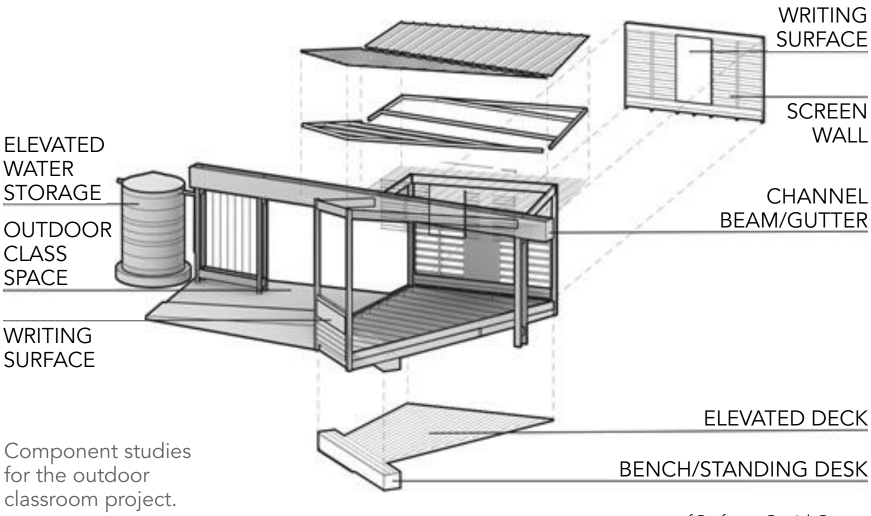
Alex Morales (**morales@aisc.org**) is AISC's Houston senior structural steel specialist. He also leads AISC's Forge Prize and National Architecture Engagement Program and serves on AIA Houston's Board of Directors.

MENTORSHIP IS PERHAPS one of the most powerful ways to lift the next generation of leaders into the built environment.

For some, it may mean the difference between having a seat at the table or being left out, even forgotten.

But mentorship isn't always appreciated or even acknowledged. Certainly, some of us do have an air of independence, even a cumbersome stubbornness. This is especially true in terms of controlling our creative process as designers, but it is likely that we have been propped up many times by leaning on folks who bring the valuable expertise we lack. It has been my personal practice to both be a mentor and to collect a tribe of mentors, for myself and others, in the belief that this surely contributes to the success of our roles in and the overall environment of the construction world.

So when one of my colleagues reached out about helping a group of future architects that were designing and donating an outdoor classroom for a middle school, I immediately thought of one individual. With a babyface and appearing one mile tall, Joshua Hanson (Josh for short) does not "stay in his lane." He is the young and ambitious CEO of MSD Building Corp., an AISC member fabricator in Pasadena, Texas, that works on a variety of small- and large-scale projects, including the 21st Century Classroom Building at Texas A&M University, my alma mater (see "Well-Rounded Education" in the September 2020 issue, available in the Archives section at **www.modernsteel.com**, to learn about this project).



Component studies for the outdoor classroom project.

courtesy of Professor Patrick Peters

Hanson's expertise in steel fabrication was precisely what these young designers could use as intellectual capital. From reducing project costs to eliminating material waste, notions that coincide with the fundamentals of architecture, Hanson became the unexpected mentor. And from there, the group embarked on a tour of the steel supply chain.

"So this is the process of how steel ends up at your job site," he explained when they visited his shop. "And here we see how this piece is actually made, as you can see from the joints."

The sparks that began to fly were not a result of steel meeting fabrication equipment but rather sparks of enthusiasm from these future architects, eager to learn more about the role of steel technologies in the design and fabrication process.

As I stood there holding my camera to capture some of these moments, I felt empowered. Empowerment came not because I alone was the curator of the moments captured with my ever-present smartphone appendage, but rather because I realized I was slowly beginning to answer one of my own questions: Do we do enough when it comes to mentoring?

Architecture has made significant strides in accomplishing a diverse workforce—not just diversity in race and gender but also in age, perspective, and culture. In front of me stood a representation of a remarkable feat that was years in the making: a human prism of hues, variation, and knowledge. This small sample of design students from the University of Houston's College of Architecture and Design, arguably the most diverse institution of higher learning in (also arguably) the most diverse city in the country, represented architecture's evolving quilt of Asian, Anglo, Black, and Latinx architects in the making. This is the diversity that will certainly strengthen the future of how we design and build.

In fact, one marker of diversity that must also be equally championed is the diversity of thought. Enter the big cloak of mentorship. It is perhaps the best tool for the job, sharpened and refined through literally thousands of hours of individual, separate experiences happening in different contexts. We call this wisdom. Wisdom is simply wisdom if we keep it bottled up and locked away, selfishly, never to become anything else. But when we turn and twist wisdom and share it, it crystallizes into the powerful party that is mentorship.

Josh Hanson (at right) shows University of Houston architecture students the fabrication process for structural steel members.

Patrick Peters, a professor of architecture at the University of Houston, is the man orchestrating deliberate interactions across disciplines through his design-build studio. Formally, Peters is an admirable professor churning out the future of architecture, many students at a time. Informally, he has a cupid-esque quality, matching his students with mentors to help them gather support from industries that have a peripheral impact on architecture, like steel fabrication.

Josh the steel fabricator was now Josh the mentor, who happened to be a steel fabricator. Attending pin-up reviews and studio crit was just one page of an effective plan to ensure that his professional knowledge as a fabricator transferred into the design process to find the efficiency, elegance, and robustness that every project deserves.

Hanson had used the mentorship playbook again, and suddenly we found ourselves out of class and at another structural steel facility, Triple-S Steel, an AISC member service center located near downtown Houston. The group learned the role and efficiencies that a service center provides to the structural steel supply chain, and even witnessed a robotic plasma cutter in action, a "living" example of how steel technologies can be leveraged in architecture and a case study of sorts in eliminating waste and reducing fabrication costs. The information that the

courtesy of Patrick Peters

left: Josh Hanson, right, participates in a pin-up review during design development of the outdoor classroom project.

below: University of Houston professor Patrick Peters, RA (center), and his students gather in front of AISC member service center Triple-S Steel in Houston for a tour to understand the steel supply chain.

group learned here generally lives in the domain of a fabricator's expertise but can be shared to improve the design process.

After several moments of mentorship over many months, and through the massaging of collected information into the design process, the students arrived at the apex, having gone from concept to construction documents. Not only is their project ready to bring purpose as a real-life educational space, but the journey to make it happen will continue to echo in their memories once they enter the workforce. Theirs is just one of many examples of how mentoring, while a generous act of selflessness and a sharing of wisdom, is also somewhat of a responsibility. We can all do more on this front, and it will be empowering for everyone. ■

Scoring Goals

BY BRENT HUNGERFORD, PE

An integrated delivery approach for the steel package for Austin FC's Q2 Stadium ensured an on-time project completion for a much-anticipated opening.

Austin FC


Austin FC

Q2 Stadium's steel-supported roof is 198,000 sq. ft, the second-largest for a Major League Soccer venue.

WHEN 11 SOCCER PLAYERS on a pitch perform flawlessly, they work in harmony to (hopefully) score at least one goal.

By the same token, when building a state-of-the-art soccer stadium, all members of the building team must work in concert to achieve *many* goals.

Construction of Austin's Q2 Stadium commenced in September 2019. The goal was to finish the new home of Austin FC, the city's Major League Soccer (MLS) team, in time for its inaugural season home opener on June 19, 2021—one of the most aggressive design and construction schedules ever for an MLS stadium in the U.S. Fortunately for the building team and the stadium's owner, accurate scheduling and a pattern of consistently meeting construction deadlines allowed the stadium to host a soft opening for an exhibition match between the U.S. Women's National Team and Nigeria on June 16, three days before the home team's opening match.

Cool Canopy

The new stadium can host up to 20,500 fans for a match and features the second-largest roof for an MLS stadium, at 198,000 sq. ft. The steel-framed roof canopy enclosure features a combination of customized curved metal panel systems on the bullnose, soffit, and edges, and single-ply roofing on the top side at the north and south end to provide protection for the stage area when the venue is used for concerts. At the high roof, a curved Epic Metals deck system was used with no roofing to act as a rain screen.

The steel roof is a cable-supported structure—a first for an MLS stadium—held aloft by four 100-ft-tall columns. The cable system is positioned at the north and south ends of the stadium to reduce structural tonnage and achieve the floating corners. Additionally, the orientation of the stadium is designed to pull in breezes from open corners, which helps keep the lower bowl cooler for the fans and players.

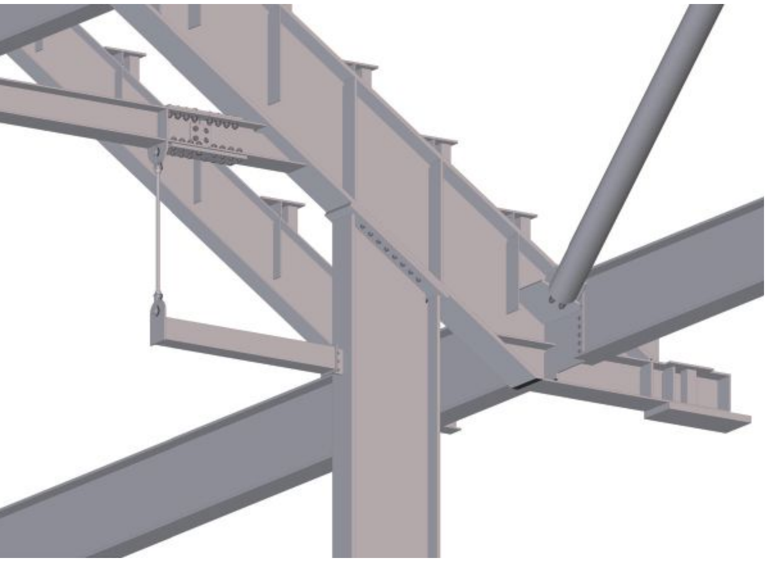
The canopy is constructed from wide-flange shapes and hollow structural sections (HSS), and the long-span roof truss is built from W14 web, vertical, and chord members. Typical columns supporting the outer perimeter of the roof are W30s, and HSS were used at the north and south ends with the cable elements and corner trusses where the steel is most visible from exterior vantage points. HSS were also used to prop up long roof cantilevers and provide additional diaphragm bracing. A rigging grid, made from W14 beams hung from HSS8×8 hangers to the underside of the roof canopy and supported from the south roof canopy, is designed for a maximum total load of 75 tons and is accessible via a catwalk from the south scoreboard area.

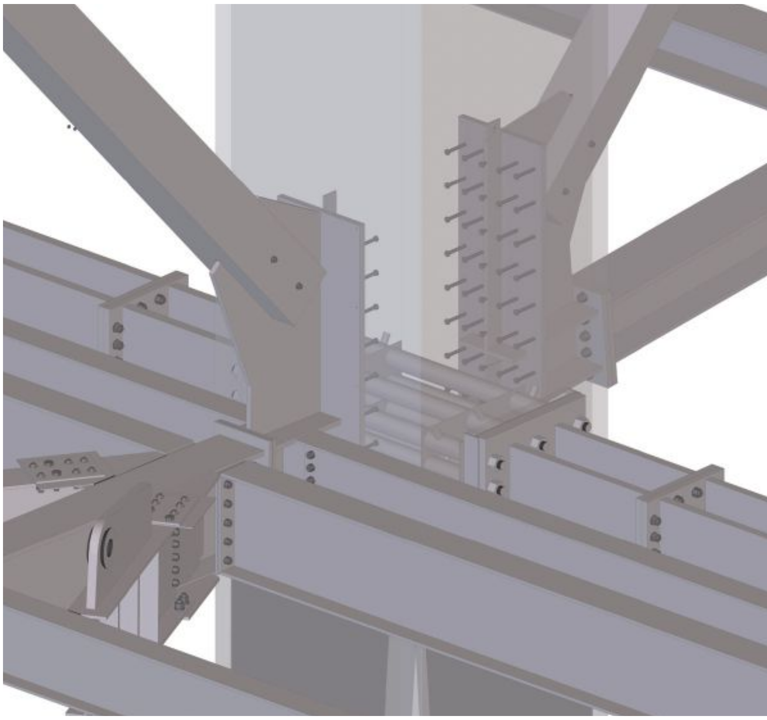
Brent Hungerford (bhungerford@walterpmoore.com) is a principal in the Construction Engineering Group at Walter P Moore.

The venue's west, east, and south building structures—which house premium content stands, boxes, suites, additional seating, the scoreboard, and a catwalk—were constructed primarily from wide-flange shapes. These structures follow more typical stadium and building construction but are all tied to the roof canopy by the perimeter W30 columns. The north building structure is a reinforced concrete building, a portion of which is directly below the steel roof canopy and connects to the canopy via concrete columns. The stadium is framed with approximately 4,500 tons of structural steel, with roughly 2,700 tons dedicated to the roof canopy.

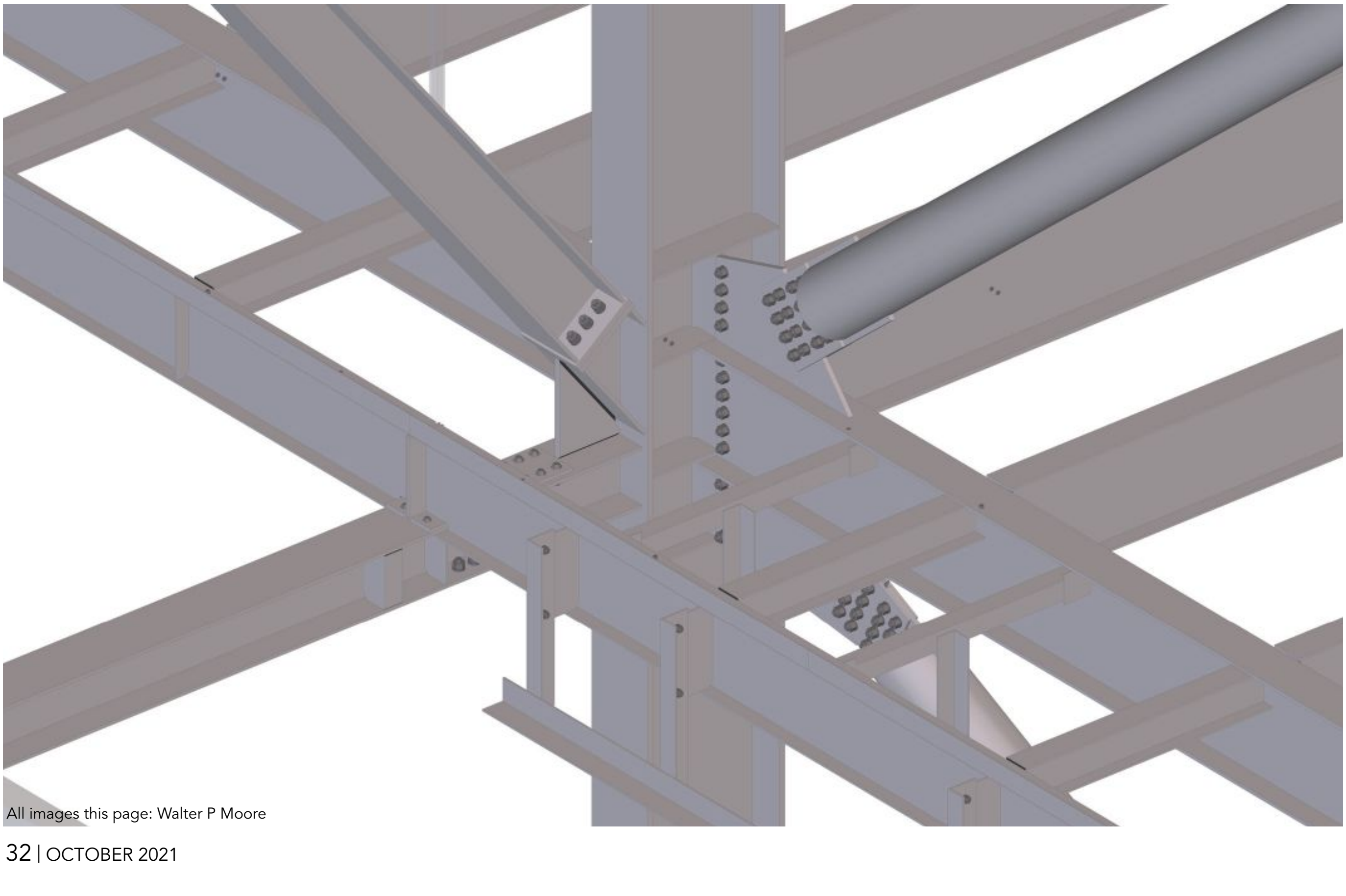
The entire structure was delivered using the multi-discipline service approach instituted by global engineering firm Walter P Moore (WPM).

"We were hired for structural engineering, enclosures consulting, and performing a whole-building life-cycle assessment," said Jeff Nixon, principal at Walter P Moore (WPM). "More importantly, we added the scope of construction engineering, which was needed to meet the schedule set by the owner."





3D models of structural steel framing for seating (above), connecting to one of the stadium's concrete columns supporting the roof structure (right), and bracing (below).



All images this page: Walter P Moore

LOD Approach

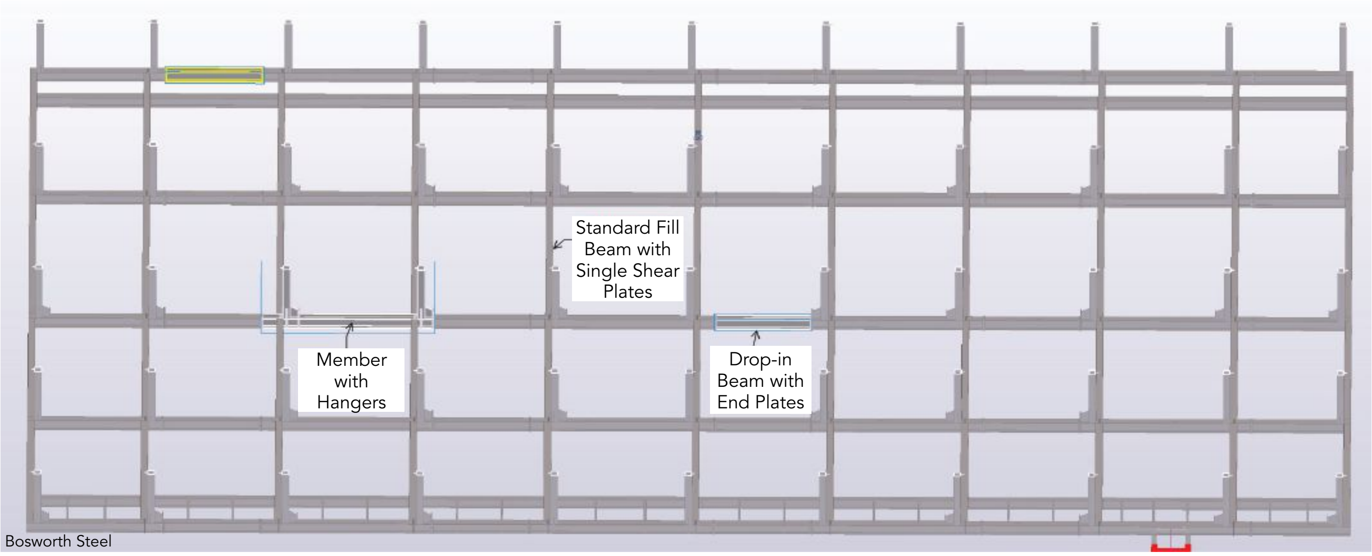
Given the demanding schedule—approximately 22 months—WPM's construction engineering team was hired early in the design phase to provide connection engineering and develop an LOD (level of development) 400 steel fabrication model using Tekla software alongside the design team in a parallel process. (An LOD 400 model is detailed enough to provide fabrication-ready geometry, whereas an LOD 100 model would be considered conceptual.) In July 2019, a steel procurement package, including a reference Tekla model, was provided to the contractor and then sent to subcontractors to begin the basis of their bids. Then, by 50% of the construction documentation, a portion of the building's LOD 400 steel model was completed in September 2019, Irwin Steel was selected as the steel fabricator, and the first LOD 400 steel models were sent to Irwin so the mill order and fabrication process could begin immediately. Concurrently, WPM worked with the project's general contractor, Austin Commercial, to develop a phased delivery of the LOD 400 steel model to keep construction on Q2 Stadium progressing.

Bosworth Steel

above: Topping out the roof canopy's steel framing.

below: The long-span canopy trusses are built from W14 web, vertical, and chord members.

Austin Commercial

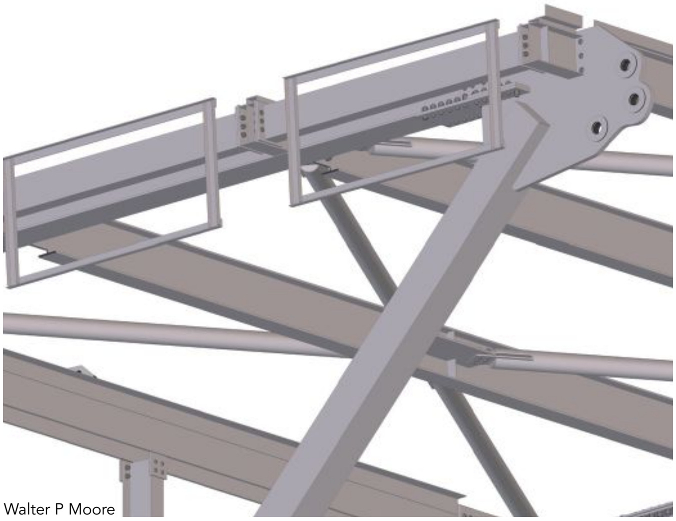


Bosworth Steel

Austin FC

left: The stadium seats 20,500 in all.

above and below: The steel roof is a cable-supported structure, a first for an MLS stadium. The cable system is positioned at the north and south ends of the stadium to reduce structural tonnage and achieve the floating corners.



Walter P Moore

The integrated delivery process spearheaded by WPM centered around the LOD 400 steel model and allowed for steel detailing to be completed while overlapping structural and connection design. This resulted in an overall schedule savings of approximately three months.

"WPM created the most technology-driven workflow we have come across in the structural engineering industry," noted Christopher Pfeiff, senior vice president of commercial construction at DBM Vircon, the steel detailer for Q2 Stadium. "The experience and platforms they bring to the table allowed us to collaborate through 3D concepts in an iterative fashion. Connections can be reviewed simultaneously for structural integrity, constructability, and relative cost without the RFI response lag time that plagues traditional delivery."

According to Pfeiff, DBM Vircon provided feedback to ensure that its feedback could be applied to all required locations in the LOD 400 steel model. This allowed for constructability issues to be corrected during design when cost-effective solutions were still feasible prior to steel procurement.

Building Team Collaboration

The LOD 400 steel model required precise coordination among all members of the building team to ensure the integrated delivery process resulted in very few changes prior to and during construction.

"We promoted both the steel connection design and LOD 400 steel modeling, identifying, and discussing this overlapped process with the general contractor as essential to the schedule for the stadium," explained Mark Waggoner, principal and senior project manager at WPM. "We developed and drove the steel design and delivery schedule through LOD 400 steel model completion."

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As a result, many issues related to the structural steel were resolved by the design team resulting in fewer revisions during the approval process.

"At the time of steel procurement, nearly all questions relating to steel locations and connection details had been addressed, and the entire project was modeled with fully detailed connections for all main structural members," Pfeiff noted.

Additionally, the steel members were designed and gross geometry accurately defined in a LOD 300 (precise geometry level) steel model, which allowed for the procurement of an advanced steel mill order. Through the LOD 400 process, the entire building team became very familiar with the model and all connection details, resulting in a quick turnaround for shop drawings issued for fabrication.

When Irwin was awarded the fabrication contract on Q2 Stadium, the company was able to quickly place its first steel order without waiting for the traditional detailing process to transpire. Because DBM Vircon was both the LOD 400 steel modeler as a sub-consultant to WPM, as well as the shop drawing detailer for Irwin, full continuity with the project's schedule was achieved.

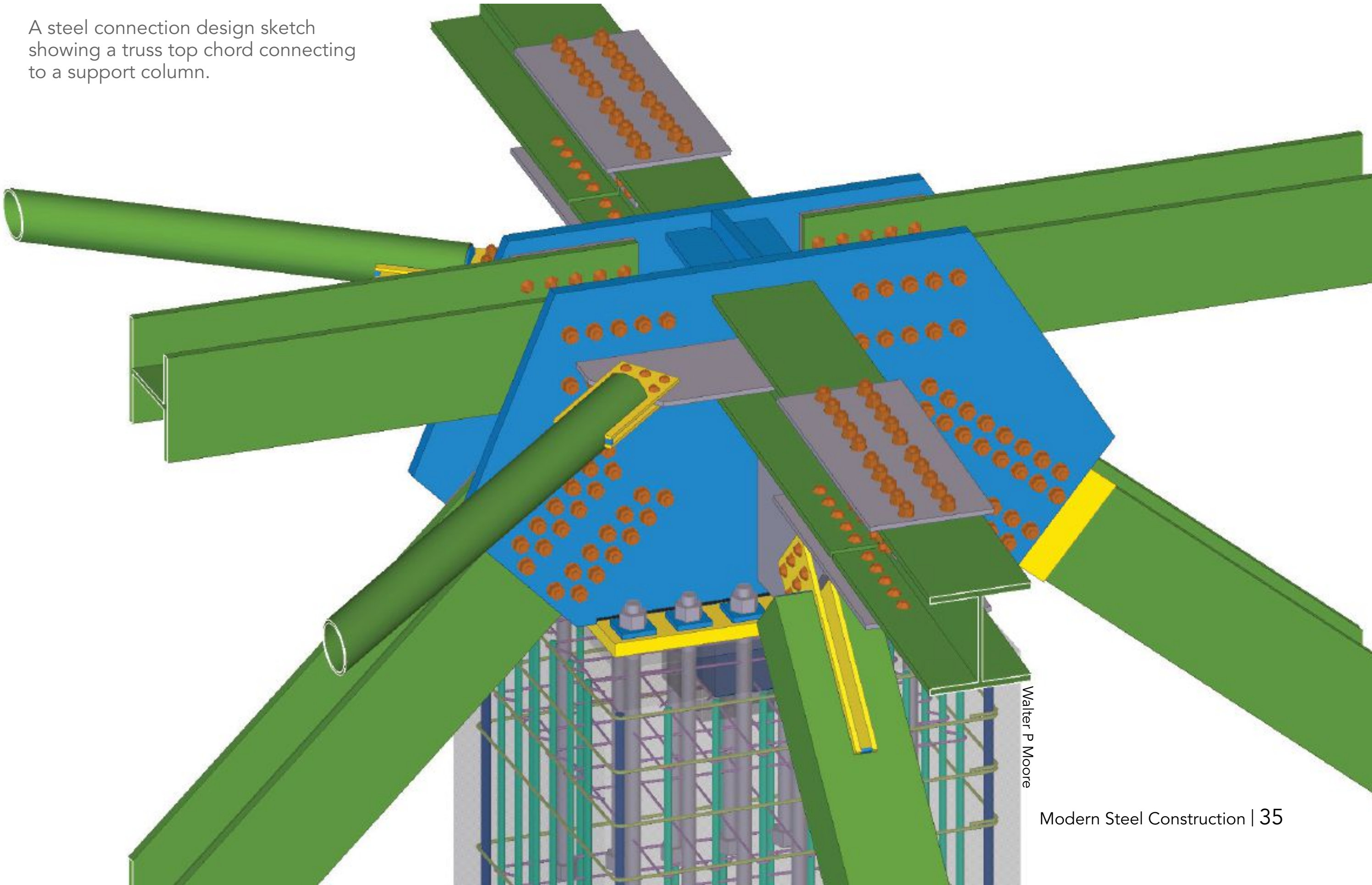
"Our project manager worked with the DBM Vircon and the design team to help maintain the submittal schedule, which allowed us to fabricate and, eventually, erect the structure on time," said Bryan Irwin, Irwin's vice president. "WPM was helpful in regard to working through any design gaps and areas that aided in speeding up steel erection."

According to Pfeiff, the design team was also proactive in coordinating with the precast concrete elements interacting with the steel members.

"This benefited the project overall as all necessary connections to support precast had been coordinated and finalized prior to the models being handed over to the fabricator, which further expedited shop drawing creation and approval," he said.

Austin FC

The stadium is framed with approximately 4,500 tons of structural steel, with roughly 2,700 tons of this total dedicated to the roof canopy.



A steel connection design sketch showing a truss top chord connecting to a support column.

Walter P Moore


Austin FC

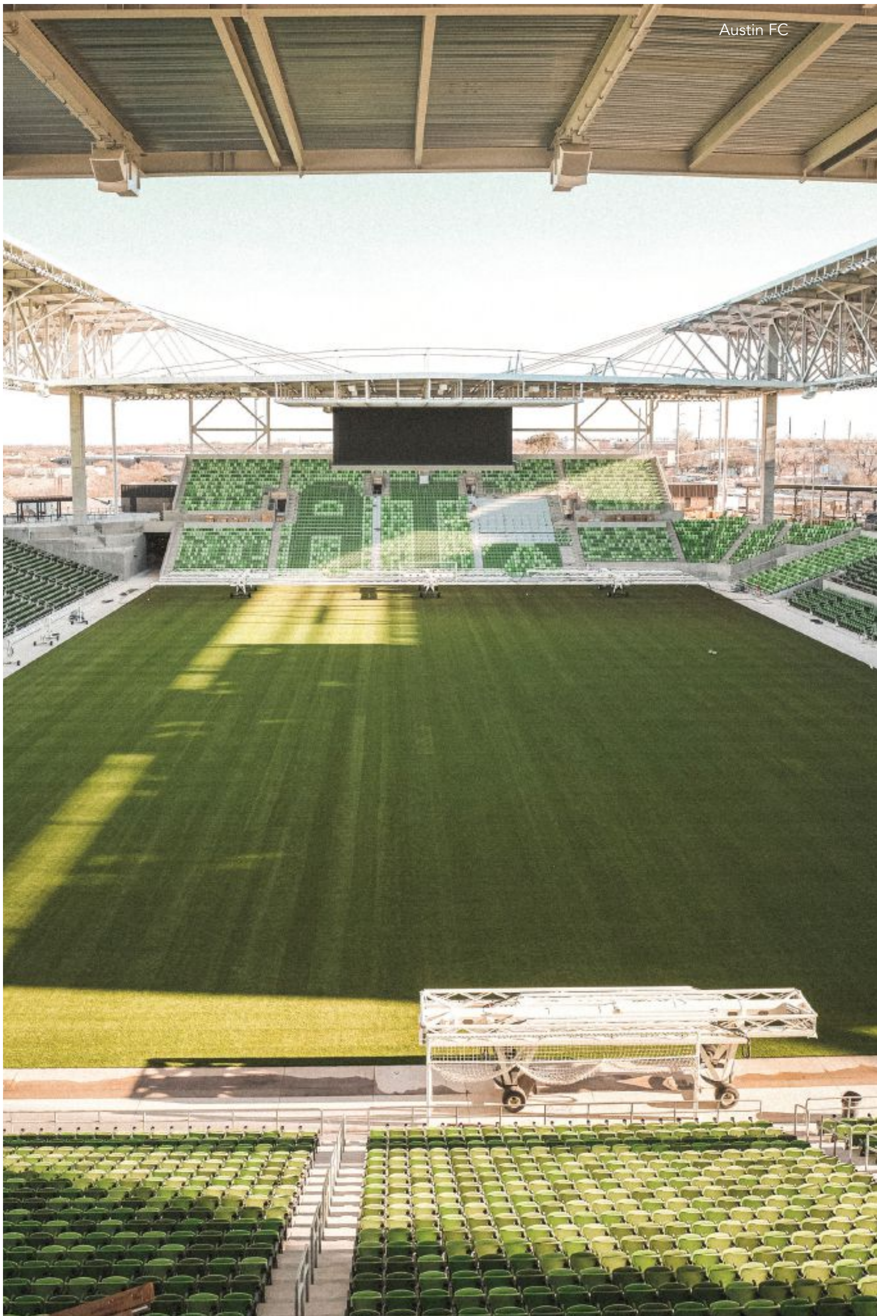
above and right: The cable-supported roof is held aloft by four 100-ft-tall columns.


Austin Commercial

above: Installing a soffit on the underside of a portion of the roof canopy.

below: Team branding on a seating row.

Austin FC


Austin FC

Formal RFIs

Despite the overall size and accelerated schedule for the Q2 project, the formal RFIs from Austin Commercial were significantly reduced. Because of the integrated delivery approach incorporated prior to detail model release and fabrication, a large majority of RFIs normally received in the construction administration phase were answered during the design phase prior to formal construction.

However, project erector Bosworth Steel wanted to erect the stage rigging grid framing on the south end of the stadium roof by using the crane from above, which necessitated leaving the deck open on the hanging leaf frames and using fabricated members that could be erected in this manner.

To address this, Bosworth worked with WPM to get the fabricated members and connections needed and on the leaf frame installation sequence necessary to install the rigging grid.

"The design concept was to erect the leaf frames in large full-width sections," said Carl Williams, director of preconstruction and engineering with Bosworth. "Due to site logistics, weight, reach and crane capacity, it became necessary to erect panels in less than full size. WPM worked with us to develop a method of assembly that would work with the equipment and reaches that we could accommodate."

Ultimately, the LOD 400 steel model, in concert with the integrated delivery approach, helped drastically reduce RFIs because accurate information was available to the building team during the entire scope of the project. Score one for the building team. ■

Owner
Precourt Sports Ventures, LLC, Austin

General Contractor
Austin Commercial, Dallas

Architect
Gensler, San Francisco

Structural Engineer
Walter P Moore, Austin

Steel Team

Fabricator
Irwin Steel (AISC Certified Fabricator), Justin, Texas

Erector
Bosworth Steel Erectors (AISC Associate, AISC Certified Erector), Dallas

Detailer
DBM Vircon (AISC Detailer), Tempe, Ariz.

Office Upgrade

BY JEFFREY SMILOW, PE, AND PATRICK CHAN, PE

WHAT WILL THE FUTURE of the commercial office buildings look like in the post-COVID world?

While there are lots of theories being expressed, one thing is for sure: The old rules are changing. The new office will need to be exciting and collaborative to attract employees to leave their "work from home" environment.

The supertall tower at 66 Hudson Boulevard, known as "The Spiral," is certainly making its case to bring people back to the office—and it was ahead of the game. Part of the Hudson Yards Zoning District on the west side of Manhattan, the building, which contains 66 floors of commercial office space, was planned prior to COVID and was designed with unique spiraling terraces working their way up the exterior of the building, providing every floor with exciting outdoor spaces. These terraces spiral up the building from the lower setback at level 7 all the way up to the roof, giving the building its nickname. Adjacent to each terrace is an interior open office environment area for staff to gather, collaborate, and enjoy the views, and the various tenants are customizing them for their individual needs to create their own "office of the future." The site for the 2.85 million-sq.-ft tower, 1,050-ft-tall tower occupies a full city block and is located one block from the Jacob Javits Convention Center.

Structural System Overview

The tower's foundation consists of concrete footings supported on Manhattan schist bedrock with a minimum bearing capacity of 40 tons per sq. ft and further enhanced by local codes via rock socketing. The core, which is composed of elevator pits surrounded by shear walls, is supported on a combination of strip footings and/or localized mat foundations. The main gravity load-resisting system consists of a structural steel frame composed of steel beams working compositely with the concrete slab on metal deck. The vertical loads from the 66 floors are carried by perimeter steel columns ranging from A992 (50 ksi) to A913 grade 65, the latter of which structural engineer WSP specified thanks to its high strength per ton.

Because of the building's high vertical loads, built-up columns composed of grade 65 steel were also used where necessary in addition to standard rolled column shapes, thereby reducing member sizes. Gravity trusses are located at the seventh-floor mechanical level, accommodating the transfer of the entire perimeter column system from the tower into the podium locations and thus avoiding interior columns within the large podium floor plates. A reinforced concrete core surrounding the centralized elevator banks, egress stairs, and MEP rooms functions as the spine of the building's

Tishman Speyer

A new high-rise in Manhattan's Hudson Yards development is at the forefront of elevating the office environment in a post-COVID world.

primary lateral system, and coupling beams link the various banks of core walls to enhance the lateral and torsional stiffness of the tower.

The concrete core and a steel outrigger system function as the key components of the lateral system. The outriggers stiffen the tower by engaging the perimeter columns and linking them to the core, thereby reducing stresses in the core walls resulting from wind and seismic demands. The construction methodology selected by general contractor Turner Construction and steel fabricator Banker Steel was "steel first," meaning that temporary erection steel was embedded within the concrete core. This enabled steel erection to proceed first, totally unimpeded by the concrete core forming process. The embedded steel columns in this system serve a double purpose. Prior to the concrete core placement, they function as erection steel; however, they ultimately function compositely with the concrete core walls and the vertical rebar reinforcement, thereby reducing the amount of rebar required to resist tension forces within the shear walls. There are three primary outrigger zones: the upper mechanical levels at level 66, the mid-level mechanical floors from levels 37 to 39, and the tower transfer level at floor 6.

The outrigger system is composed primarily of jumbo steel and built-up shapes due to the large forces being transmitted into the concrete core from the overall wind overturning moments. Axial loads in the chord members of the outrigger trusses have forces as high as 11,000 kips. A detailed construction sequence analysis was performed, and it was determined that due to the stiff core interacting with the perimeter steel columns through the outrigger trusses, large amounts of perimeter column axial forces are dragged into the concrete core from the perimeter columns. The transfer of perimeter axial gravity forces

Jeffrey Smilow (**jeffery.smilow@wsp.com**), executive vice president and managing director of building structures with WSP in New York, functioned as principal-in-charge for 66 Hudson, and **Patrick Chan** (**patrick.chan@wsp.com**), a senior vice president with WSP, was the project director.

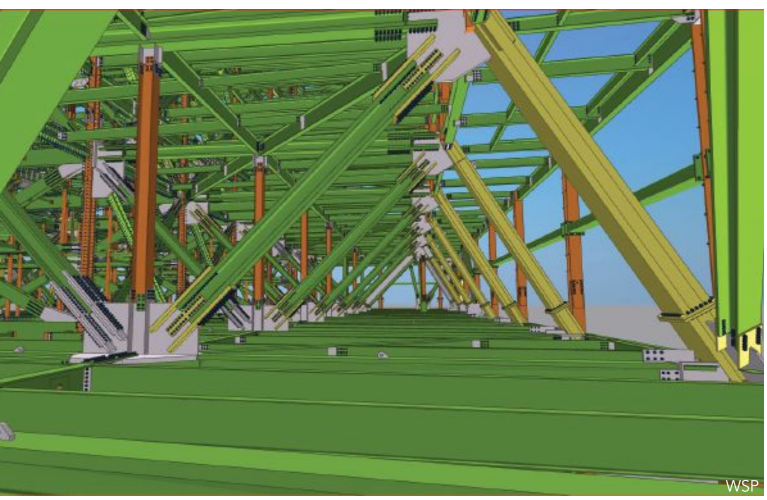
imposes a significant demand upon the outrigger system, which in turn contributes significantly to the high magnitude of forces in the outriggers.

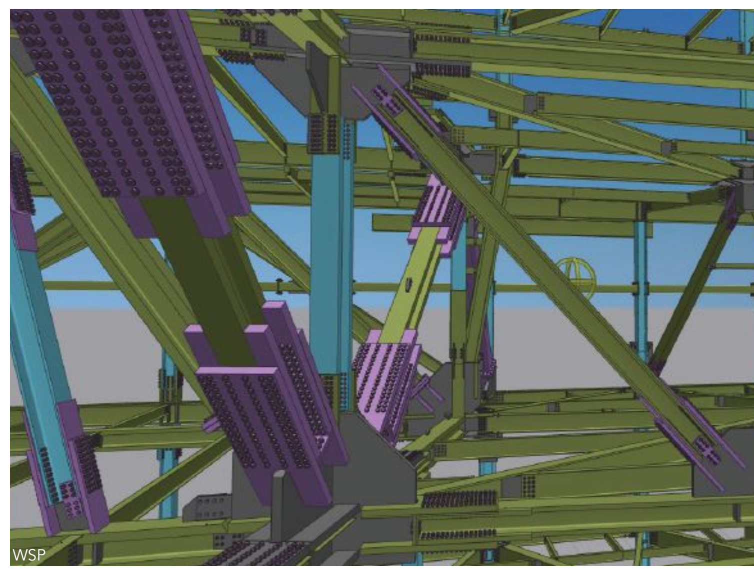
Moving In(ward)

The signature element of this building, the spiraling terrace design, resulted in unique floor plates at each level, which was addressed by shifting the exterior columns and façade inward by 5 ft in the building sections containing the terraces. The architectural concept of shifting columns inward at each terrace was required to take place without any column being visible from the exterior. Furthermore, each terrace area was framed to allow for a local double-height space adjacent to the spiraling terrace, with an option for an interconnecting stair between two adjacent levels. These options, for those tenants who wished to incorporate them, were achieved with a "knock-out" removable framed area directly inboard of the terrace, wherein the framing is designed to be removed after the completion of the building's construction. In order to achieve this design intent, a repeating multi-story system of two-story sloping columns, 10° each, was adopted, allowing the perimeter columns to be at ideal locations while continuing the load path required for the superstructure loads to travel efficiently to the building's foundation.

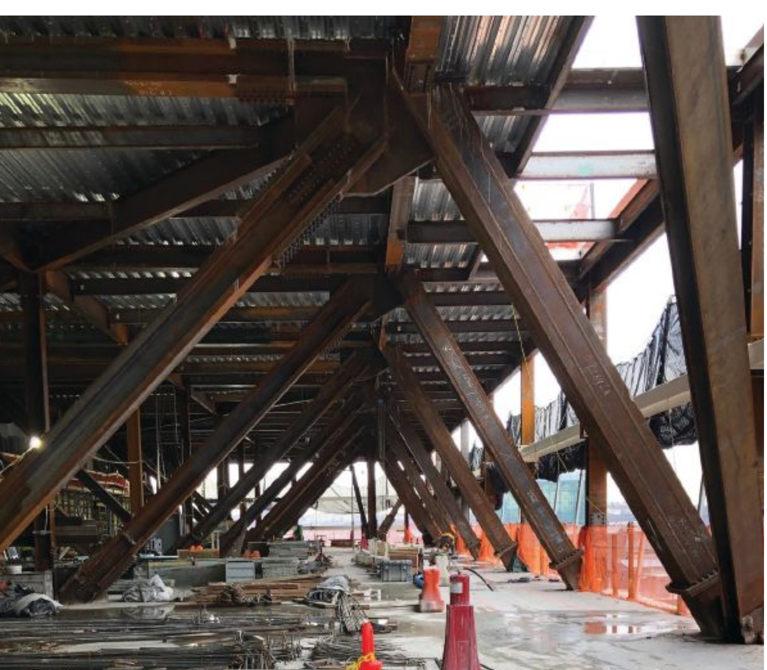
Because of the "moving" terraces, the 5-ft column offset, and the various sloping columns, no two floors in the building were identical. As such, the column stabilization forces required a proper load path that balanced the compression and tension at the top and bottom of the sloping columns. In many cases, the load path was split, with some of the stabilization forces being balanced by the reverse slope of the neighboring column. In other cases, the stabilization forces were directed to the shear wall within the core where sloping column forces could be resisted and balanced properly.

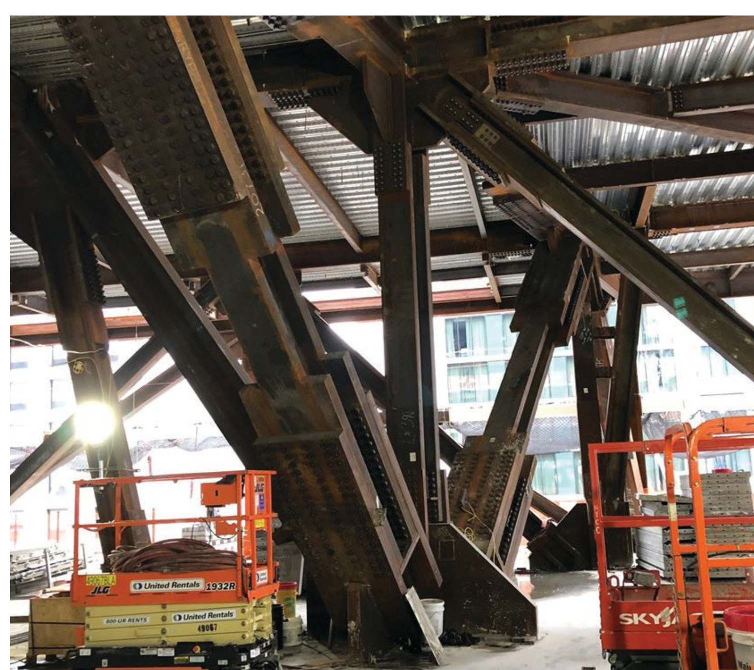
Depending on the location of the terraces, a variety of methods were used to direct the diaphragm stabilization forces to the shear walls within the core or to the neighboring sloping column or partially to both. At some levels, the direct path to the core was

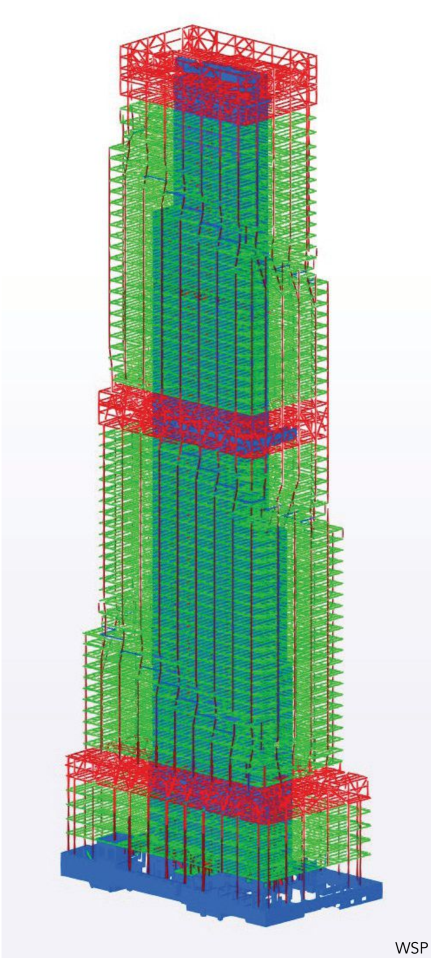




Tekla model and real-life views of the 6th floor main trusses (above/below) and pick-up truss (right).






WSP

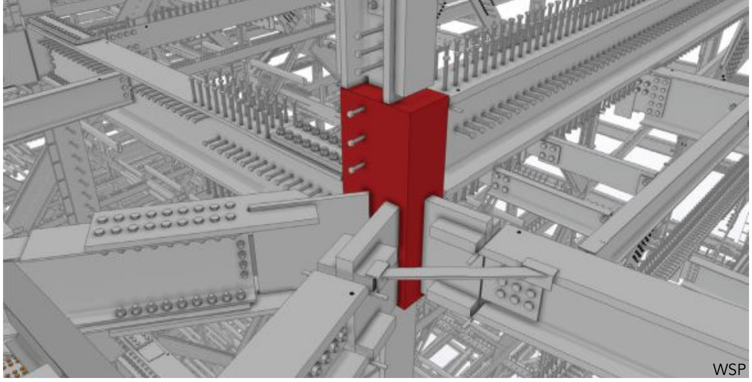

Tishman Speyer


Jeff Smilow

Turner

achieved by an upgrade of the steel beams (and their respective connections), which connect the perimeter columns directly to the core. The upgrade was required due to the large horizontal axial forces as a result of stabilizing the sloping columns. Where the terraces were closer to the building's corners, the sloping columns and stabilization forces required a system of horizontal floor trusses to transfer the loads to the core and/or to the neighboring sloping column. Another important consideration for the sloping columns involved the horizontal movements of the diaphragm and their effect on the building envelope. These movements, due to both gravity and lateral loads, were analyzed carefully for multiple load combinations and factored into the design of the curtain-wall system.

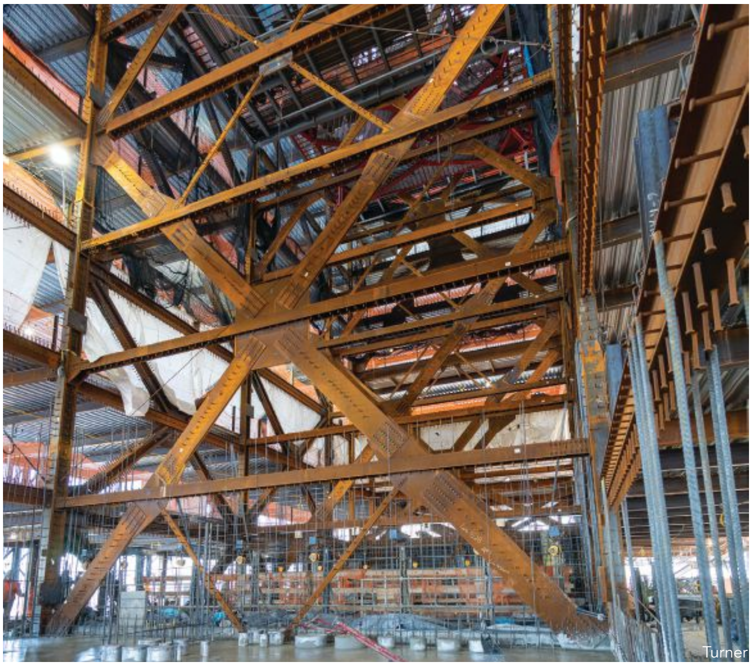
Within the interior of the building, the spans from the perimeter columns to the core vary throughout the height of the building, with 65-ft spans in the podium reducing to 50-ft spans directly above the podium. At the upper levels, the spiraling terraces further reduce the spans to 40 ft and 35 ft. As a consequence of the varying span conditions, the floor framing also varies in size. At the podium levels up to floor 6, the typical floor beams are W24s spanning approximately 60 ft to 65 ft from the core to the perimeter columns. From the 8th floor through the 32nd floor, typical beam spans vary from 45 ft to 50 ft, and sizes vary from W21×44 to W21×62. Continuing upward around the spiral, the spans reduce in 5-ft increments, ultimately to 35 ft at the top of the building, with an average filler beam size of W18×35.



WSP

above and below: Forged steel nodes in the Tekla model and at Banker's fabrication facility.

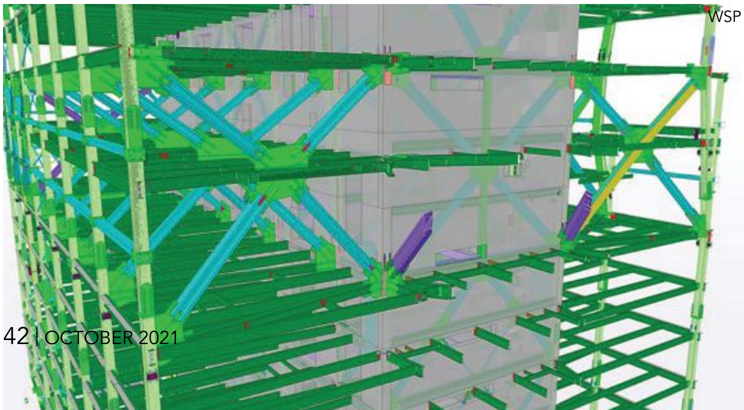
Banker



Turner

above: Temporary erection bracing at the core prior to placing shear wall concrete.

below: Outrigger trusses at the 36th floor.



WSP

Notable Nodes

The large forces and complex geometry of the building necessitated many complicated nodes, often with kinked structural members at outriggers and vertical and horizontal trusses. These nodes had to be designed to account for the large horizontal stabilization forces between the core walls and lateral system at each level. These forces act in multiple directions and pass through the relatively light vertical erection columns located within the concrete core, which required significant reinforcement of the steel nodes forming the joints at the floor level. The challenge was how to transfer the large forces into the core in an economical manner. Some of the horizontal forces emanating from the lateral system outrigger system exceeded 11,000 kips.

WSP and Banker strove to reduce fabrication costs and field welding of these nodes and considered steel forgings, castings, laminated plates, and other options. Due to the multi-directional trusses and their members coming into the nodes, a solid rectangular steel section was considered most appropriate. (Using a series of stacked plates to create the rectangular nodes was also considered but was deemed too labor-intensive and costly.) To achieve optimal strength, tolerance, consistency, and ductility of the steel, forgings were chosen over castings due to the inherent structural properties accomplished in the forging process.

Erection Stability

As previously mentioned, a steel-first erection sequence was employed, requiring an erection frame 12 stories below the steel working deck, which was required to maintain a stable structure prior to the placement of the concrete shear walls. This temporary 12-story steel braced frame was constructed mostly with a steel plate tension-only bracing system since it was required to fit within a 16-inch space behind elevators and avoid interfering with the concrete placement and the rebar within the shear walls. The 12-story steel braced frame also supported the two tower cranes situated within the core, as well as stabilized the steel frame outside the core as it was constructed, in addition to the construction hoist system, safety (cocoon) systems, and active construction loads imposed upon the working deck. In addition, it also completed the load path for the unbalanced stabilization forces from the sloping column systems adjacent to the terraces. Since this temporary steel frame would always be at the top 12 floors of construction, it was continuously exposed to the highest wind loads. The structural demands were significant upon the temporary bracing system in addition to the practical demands of expediting the erection to maintain the schedule, especially during the COVID emergency.

As wind loading on exposed steel frames is not sufficiently addressed by any code or standard, WSP commissioned wind consultant RWDI to perform a wind tunnel test upon the partially constructed steel frame in order to determine accurate wind loading scenarios for the under-construction temporary steel frame. The test determined that the actual wind loading was significantly lower than what was predicted by current standards. As a result, no additional stabilization steel was required.


Banker


Banker

above and right: Banker Steel fabricated 33,000 tons of steel for the project.

below: A view of some of the two-story sloping columns.


Turner

66 Hudson is just one of many skyscrapers planned for the Hudson Yards neighborhood. But its spiral of green terraces gives it its own signature element. And the collaborative relationship between fabricator, connection designer, and structural engineer enabled this element—and the rest of the building—to come together quickly and come out on the other side of the COVID pandemic, creating the office space of the future. ■

Owner/Developer
Tishman Speyer Properties, New York

Construction Manager
Turner Construction Company, New York

Architects
Bjarke Ingels Group, Brooklyn, N.Y.
Adamson and Associates, New York

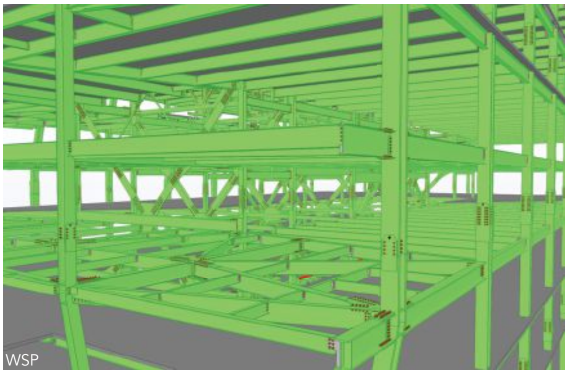
Structural Engineer
WSP, New York

Connection Design
WSP
CSD Structural Engineers, Milwaukee

Steel Team

Fabricator
Banker Steel, Lynchburg, Va.

Erector
NYC Constructors, LLC, New York


WSP

Modeling through COVID

WSP acted as the structural engineer of record for the steel-framed tower and also provided the steel Tekla modeling through its 3D modeling division, as well as connection engineering (working in conjunction with CSD Structural Engineers). The initial intent of having WSP provide the fully connected Tekla model was to expedite the shop drawing production process. Project developer Tishman Speyer signed Pfizer as the prime tenant prior to construction with a very aggressive turnover date, which would have been unachievable via a conventional shop drawing production/review/approval process. WSP was able to begin connection design and Tekla modeling early in the construction documentation phase of the project and made the Tekla model available to steel package bidders early on, thereby reducing the bidding time frame. After the contract was established with the winning fabricator, Banker Steel, connection engineering calculation submittals were not required since WSP was responsible for producing the connection design together with CSD. The final steel shop drawings were produced from the Tekla model, and final submission review was simple and quick, enabling the steel fabrication to move ahead early. In addition, the collaboration process provided Banker Steel the ability to identify and flag areas of suggested detailing modifications to meet their preferences for more efficient fabrication and assemblies.

Of course, the COVID pandemic hit in March 2020, and all nonessential construction in New York was shut down for two months—and even after starting up again, construction was slowed due to COVID breakouts and the resulting staff shortages. However, steel fabrication continued since the Tekla model had been delivered months earlier and critical path shop drawings were approved significantly in advance of the fabrication schedule, virtually eliminating the typical delays associated with multiple reviews of shop drawings, connection designs, and RFIs. WSP was also able to save time using Qnect connection software, which automates the production of beam connections and links directly into Tekla. And as an early user of Qnect, WSP was able to assist the software developer by providing feedback on ease of use and compliance with New York City's building code.

It Takes a Village

BY TIM KYES, SE, PE, AND JOHN ROACH, SE, PE

In Los Angeles, steel supports a revolutionary collection of buildings—and the fight to end homelessness.

Images, unless otherwise noted, are courtesy of CannonDesign

STRUCTURAL ENGINEERS SOLVE PROBLEMS. On projects large and small, both simple and complex, structural engineers seek out design solutions that are safe, efficient, and cost-effective, typically focusing on the "how" but not always asking the "why."

To counter this, CannonDesign embraces a "living-centered design" approach that addresses the complex interdependencies that exist between people, businesses, communities, society, and the environment in order to build a world where people continuously flourish.

Similarly, Los Angeles County (LAC) recognized that a complex problem like homelessness is intrinsically tied to the interrelated issues of poverty, addiction, and health. For this reason, the county partnered with CannonDesign to create a Restorative Care Village (RCV) on the campus of LAC+USC Medical Center near downtown Los Angeles, which will provide a broad continuum of care, including supportive housing, substance abuse treatment, and behavioral healthcare. To help advance this mission, the living-centered design concept is woven through the approach to the project's structural engineering, which recognizes that every resource saved on the cost of the steel and concrete would help the efforts in the fight to end homelessness.

A Modular Approach

The RCV is a five-building complex designed for healing that offers, at an accessible residential scale, the services more commonly found in the setting of a large institution. Within this village, four Residential Treatment Program (RTP) buildings offer therapy and supportive housing for individuals discharged from LAC+USC Medical Center emergency services, inpatient units, jails, and urgent care centers. Each 10,000-sq.-ft building individually provides administrative support, community spaces, and 16 beds in a dormitory setting across three floors.

At the beginning of the project, CannonDesign proposed using a modular construction approach to accelerate delivery and reduce construction waste—an idea that LAC enthusiastically embraced. After exploring a variety of modular options, the team decided that the dormitories and toilet rooms could most efficiently be constructed off-site by ModularDesign+, a strategic partner of CannonDesign, and delivered to the RCV.

The decision to pursue modular design and construction for the RTP buildings meant that structural steel framing would be the most appropriate choice for the primary building structure. As envisioned, the structural frame and composite floor slab at each level would provide a "shelf" onto which each self-supporting cold-formed steel module could be inserted. However, the residential nature of the complex presented several unique challenges.

above and opposite: The Restorative Care Village comprises five buildings.

below: A 3D model of the framing system. The most common beam size used is W16×26.

Maximized Bracing

A traditional approach to healthcare construction would have located the RCV programs in a single building with repeating bays, spans optimized for efficiency, and perhaps two bays of bracing in each direction. Because the RCV was designed as five separate buildings, it was imperative to optimize the structure given the inherent increase in the number of columns, foundations, and braces. In all, the project uses 550 tons of fabricated structural steel, with the most common beam size being W16×26.

Given its location in Southern California, the design of the lateral force-resisting system for each building was particularly critical. For economy, the design team initially considered special concentrically braced frames (SCBFs) located at the perimeter of each RTP building. However, the small footprint of each building provided very limited

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The interiors of the buildings are defined by bold colors and expressive textures evocative of a food market.

placement opportunities. At the same time, the small tributary area to each SCBF column resulted in significant uplift forces that complicated the foundation design. Furthermore, the requirements posed by capacity design resulted in column sizes that were disproportionately large for a series of small buildings.

To overcome these challenges, the design team investigated the use of buckling-restrained braces (BRBs) in lieu of an SCBF system by conducting a comparative analysis between the two approaches using RAM Structural System. The results of this analysis demonstrated that adopting a BRB system would eliminate 48 bracing members and eight columns across the four RTP buildings relative to the baseline design. After developing an initial design using the BRB tools available in RAM Frame, the team worked with CoreBrace to finalize the member sizes.

The reduction in the number of braced frames meant that all of the buckling-restrained brace frames (BRBFs) could be located out of sight and away from the regularly occupied areas of each building to preserve the residential aesthetic. In addition, the highly ductile (R = 8.0) nature of the BRB system significantly reduced overturning forces and base shear, thereby simplifying the mat foundation under each building. Working together with the construction manager, CannonDesign Builders, it was quickly determined that BRBFs would provide a cost and schedule advantage over SCBFs given the reduction in steel. Further leveraging the design-build approach to delivery, the structural team was able to work directly with the steel fabricator and erector to develop simple bolted connections that would help accelerate construction and thereby reduce overall cost.

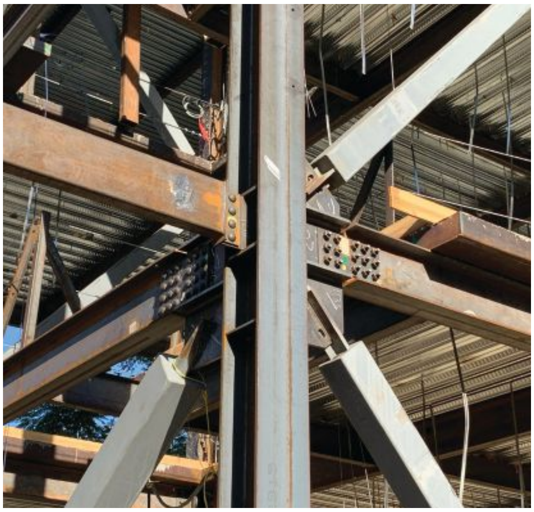
The fifth building of the RCV complex, the Recuperative Care Center (RCC), is a 36,000-sq.-ft, four-story building that provides transitional housing for individuals lacking a supportive place to live after being discharged from an inpatient hospital. As with the RTP buildings, a BRBF system serves as the lateral force-resisting system for the RCC, with a total of 80 BRBs being provided across all five buildings of the RCV.

To accommodate the installation of the modular units, which are just under 12 ft wide, the RTP and RCC buildings were laid out on a 24-ft column grid, and brace locations were coordinated with the logistical requirements for moving the modules through the buildings. While a simple array of regular 24-ft bays may not at first appear to be an obvious target for optimization,

above: A layout of the complex, which is located on the LAC+USC Medical Center campus near downtown Los Angeles.

below: One of the modular housing units under construction.

above and right: The buildings all incorporate buckling-restrained braces for the lateral force-resisting system.



above and below: The village collectively uses 550 tons of steel framing.

the design team nevertheless evaluated a range of alternatives with the goal of reducing story height and steel tonnage. Ultimately, it was determined that a 6¼-in. lightweight concrete composite slab atop 3-in. steel deck spanning 12 ft between beams provided the most efficient design. This approach, together with the BRBF system, kept the total structural steel weight below 11 psf for each RTP and under 8 psf for the RCC, excluding connections.

Creating Community

While structural steel is concealed from interior spaces across the RCV, it is boldly expressed throughout the landscaped courtyard that ties the buildings together. Along the front of each building, painted hollow structural section (HSS) posts rise from the ground to support a 9-ft-wide pergola that parallels the courtyard walkways. Overhead, the pergola canopy is comprised of 12-ft-long panels constructed from closely spaced HSS members, while a similar trellis provides shade over staff terraces located on the third floor of each RTP building.

Without any special surface preparation or architecturally exposed structural steel (AESS) designation, these fabricated steel components form a simple "kit of parts" that is repeated throughout the courtyard—and without the additional cost of AESS requirements. Together, these economical design elements help unify the RCV both aesthetically and functionally by encouraging residents and staff to gather in a relaxed, natural setting.

Embracing the Challenge

According to the National Alliance to End Homelessness, more than 20% of the homeless population reported having a behavioral health condition, and more than 16% indicated having health problems related to substance abuse. By simultaneously addressing these interrelated problems through a housing-first strategy, the RCV has the potential to revolutionize how agencies and state and local governments address homelessness in America. And while this challenge may seem daunting, it offers engineers an opportunity to contribute to this important fight by leveraging all the tools and the knowledge at their disposal. In its elegant efficiency, the LAC+USC Restorative Care Village offers a compelling roadmap for the journey ahead. ■

Owner
County of Los Angeles, Alhambra, Calif.

Construction Manager
CannonDesign Builders, Irvine, Calif.

Modular Design-Builder
ModularDesign+, Euless, Texas

Architect and Structural Engineer
CannonDesign, Los Angeles

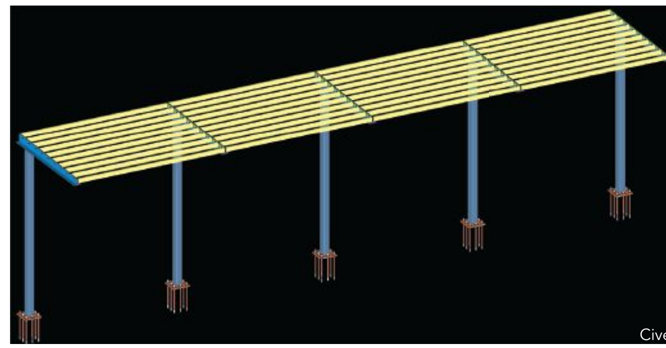
Steel Team

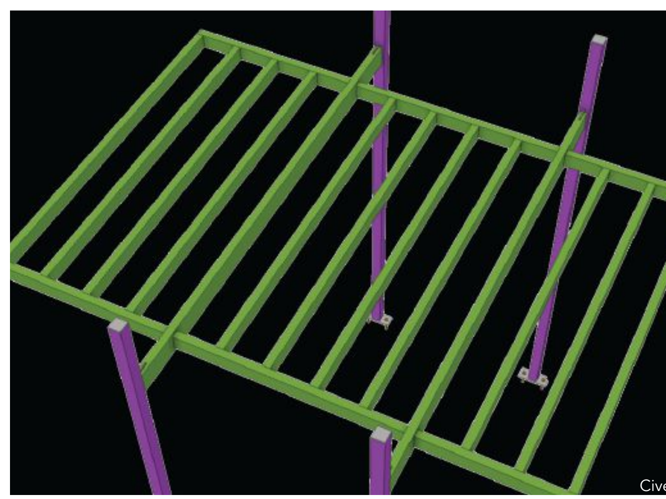
Fabricator
Cives Steel Company South-West Division AISC CERTIFIED FABRICATOR, El Mirage, Ariz.

Erector
Bragg Crane and Rigging AISC ASSOCIATE AISC CERTIFIED ERECTOR, Long Beach, Calif.

BRB Manufacturer
Corebrace, LLC, a division of SME Steel Contractors, Inc. AISC CERTIFIED FABRICATOR, West Jordan, Utah

above and below: Along the front of each building, HSS posts support a 9-ft-wide pergola that parallels the courtyard walkways.





above: A model of a galvanized 10-ft by 12-ft trellis frame to support shading in alcoves at level 3 of each RTP building.

below: A completed rendering of the project.

Simple and Continuous

BY BRIAN BYRNE, PE

Roy Couture - Photogroup, Inc.

Brian Byrne (**bbyrne@hwlochner.com**) is a senior project manager and structural engineer with Lochner.

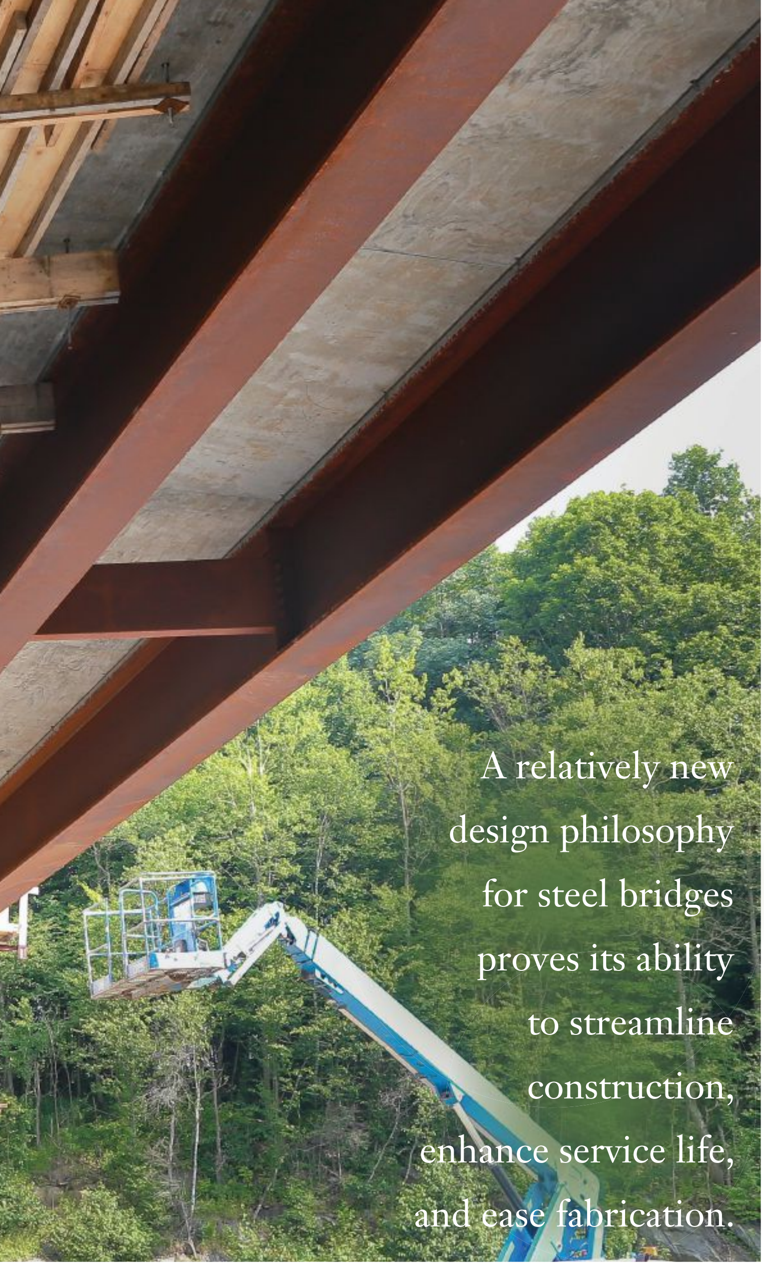
DESIGNING AND BUILDING a steel girder bridge with minimal disruption to the community and environment, while simultaneously reducing construction costs, requires a creative approach.

Simple for dead, continuous for live (SDCL) is an alternative detail and design philosophy that can help accomplish this. Though extensively researched, the use of SDCL detailing with steel girders is not yet commonplace despite numerous benefits. But it can provide a more efficient design, simplify steel fabrication, streamline construction for some accelerated bridge construction (ABC) techniques, and enhance service life.

Translating SDCL to Steel

Essentially, SDCL is the detailing of multi-span steel girder bridges to allow non-continuous girders to be set and continuity over the pier to be achieved by installing simple wedge plates between the bottom flanges and pouring a concrete pier diaphragm.

The construction of a steel girder bridge with SDCL detailing is very similar to what would be done for a typical precast concrete girder bridge. First, the girders are set between substructures with a nominal 4-in. gap between the girder ends over the pier. The deck is then cast to within approximately 5 ft of the pier's centerline, and the girders support the non-composite dead load as simple spans. This allows the girders to deflect while not locking in any negative moment stress over the pier. Either temporary or permanent end cross frames can be used to stabilize the girders during the deck placement. However, simple chains and tie-downs at the girder ends are most cost-effective and eliminate unnecessary steel cross frames which would otherwise be buried in the diaphragm.



above: Picking a prefabricated beam unit (PBU) for the Potter School Road bridge over I-84 in Willington, Conn.

left: The bridge, nearing completion, with closure pours over the pier and between PBUs.

below: Setting a PBU for the bridge's first span.

Once the deck has been poured and begins to cure, wedge plates are installed to bear against the bottom flanges and webs. These plates transfer the compressive stresses between the spans and are the first component of the moment couple needed to make the spans continuous. The wedge plates must remain in full contact with each other and the bottom flanges to maintain the superstructure's capacity. Any space between the wedge plates will interrupt the load path and can crush the concrete in the diaphragm.

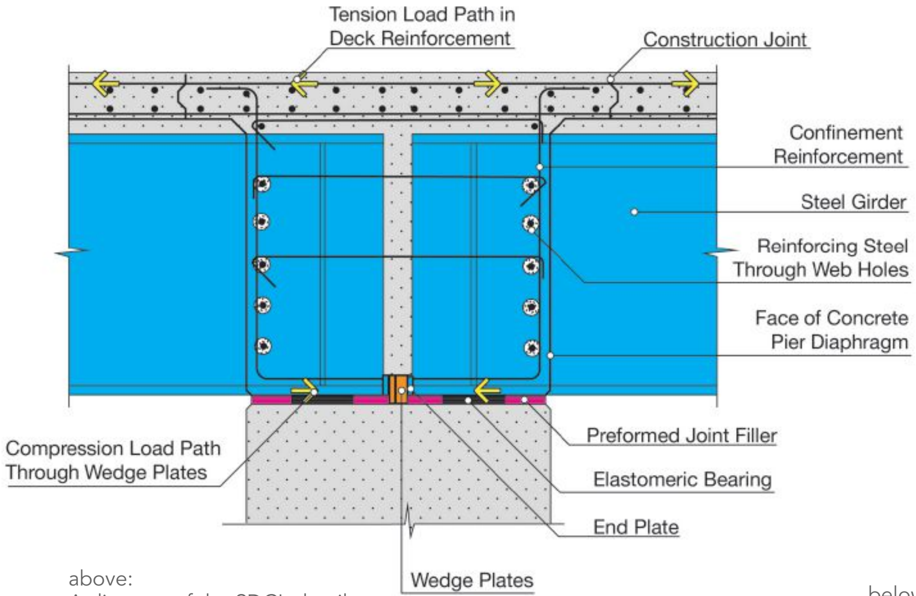
Due to construction tolerances, some variability in the distance and alignment between girder ends over the pier is to be expected. Therefore, the wedge plates must have sufficient length and taper to handle geometric variation. Plates that are slightly longer are preferable to short plates that cannot achieve a tight fit from flange to flange, and the contractor should fabricate shim plates to keep on-hand during installation and add if too much separation exists between girder ends. In addition, a field weld can be made to connect the wedge plates, though this is not necessary if the plates are set tightly against the girder ends.

With the wedge plates installed, dowels are placed through holes in the webs and are integrated with the diaphragm's transverse confinement reinforcement. Supported by over a decade of ongoing research, including that of the University of Nebraska-Lincoln (a PDF of the research report is available on the Nebraska DOT's site at **tinyurl.com/neb-sdcl-research**), they have found the pier diaphragm detail important to achieve full continuity (see Section 4.3.1 in the report). Once the concrete for the pier diaphragm and deck closure has cured, the longitudinal deck reinforcement transfers the tension stresses and is the remaining component of the moment couple.

The girders are now continuous to resist live load. This strikes a favorable balance, reducing additional positive moment demand at midspan and adding minimal negative moment demand over the pier. The detailing at the pier diaphragm completely protects the girder ends and ensures the long-term durability of the structure. When it comes to the pier, this element can be designed to facilitate future bearing replacement by simply detailing a wider pier cap and jacking stiffeners at the girders.

Successful Implementation

While not common with steel bridges, there have been some promising and successful SDCL steel examples thus far. Lochner first used SDCL for the steel-supported Route 1 Gateway, a design-build P3 (Public Private Partnership) project in New Brunswick, Canada, to add two lanes of capacity to a 35-mile section of the highway. Using



above:
A diagram of the SDCL detail.

above: A plan view of the girder ends at the centerline of the pier, with wedges and shim plates placed for a SDCL detail, for the Potter School Road bridge.

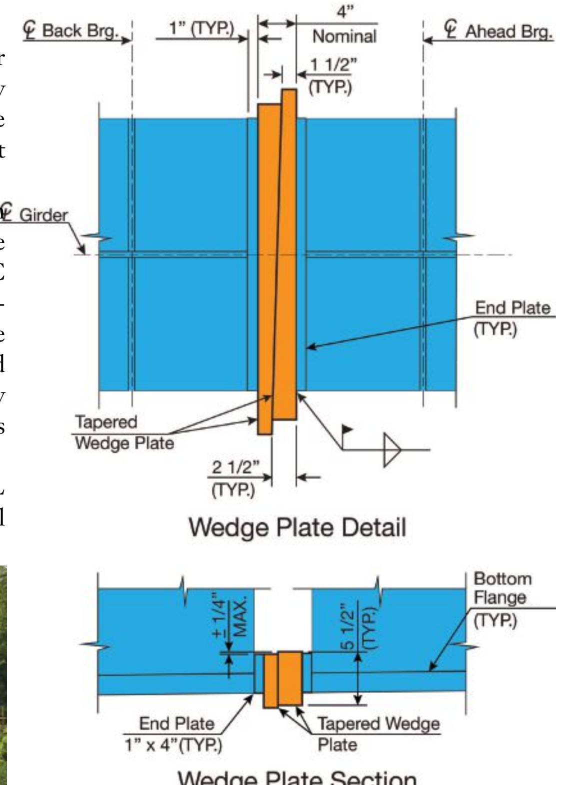
below: An aerial view of the Potter School Road bridge with all PBUs in place.

below: Setting girder sections on dunnage for field splicing, prior to span erection, for the Route 1 bridge over the Letang Impoundment in Saint George, N.B.

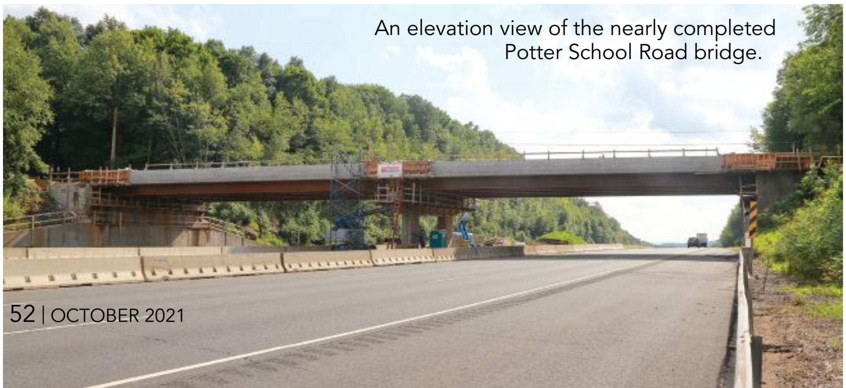
SDCL for two of the project's bridges (157-ft, 6-in. spans for one and 164-ft spans for the other) reduced their total steel weight by 10% in comparison to a conventionally continuous girder structure, which was enough incentive for the contractor to adopt the detail. Additionally, this approach simplified construction allowing the girders to be set without temporary towers or the need for a flying (air) field splice.

Lochner used SDCL again on two separate ABC projects for which the two-span superstructures needed to be installed one span at a time. The first of these, the Potter School Road Bridge in Willington, Conn. (fabricated by AISC member ARC Enterprises), was a design-build project for the Connecticut Department of Transportation that used prefabricated bridge units (PBUs) to replace a superstructure (two spans, each roughly 87 ft long) during a short-term road closure. The second project—the replacement of the Shaler Street Bridge in Pittsburgh (fabricated by AISC member Littell Steel Company)—used self-propelled modular transporters (SPMTs) to move in the two 70-ft spans.

While a link slab detail could have been used for either ABC project, SDCL allowed the girders to be made continuous and therefore economized the steel



Another view of the SDCL detail.



An elevation view of the nearly completed Potter School Road bridge.

design. Both structures are located over highways and carry existing roadways, so the improved efficiency made meeting the vertical clearance requirements much easier, especially as adjusting the highway profiles was not desirable.

Not yet under construction, Lochner's most recent steel girder design using SDCL is for the Idaho Transportation Department. Incorporating an SDCL detail has improved the design efficiency of the girders and will simplify the construction of the two-span bridge, which crosses wetlands and a creek. As designed, the new girders can be set without heavy equipment or temporary supports being placed onto the wetlands' soft soil, reducing environmental impacts.

In addition to SDCL's advantages in construction, it's important to note that there is no substantial increase in complexity when it comes to girder design. For two of Lochner's bridge designs, a simple analysis and design software package was effectively used and allowed for the definition of hinges over the pier that were switched from noncontinuous for dead loads to fully continuous for live loads. In all cases, the use of the SDCL detail reduced the negative moment over the pier, allowing the bottom flange to be thinner than that required for a continuous girder bridge. The positive moment increases with SDCL, but the bottom flange thickness is kept uniform for the length of the bridge and can often be kept under 1.5 in. Additionally, the uniformity of the design section simplifies fabrication.

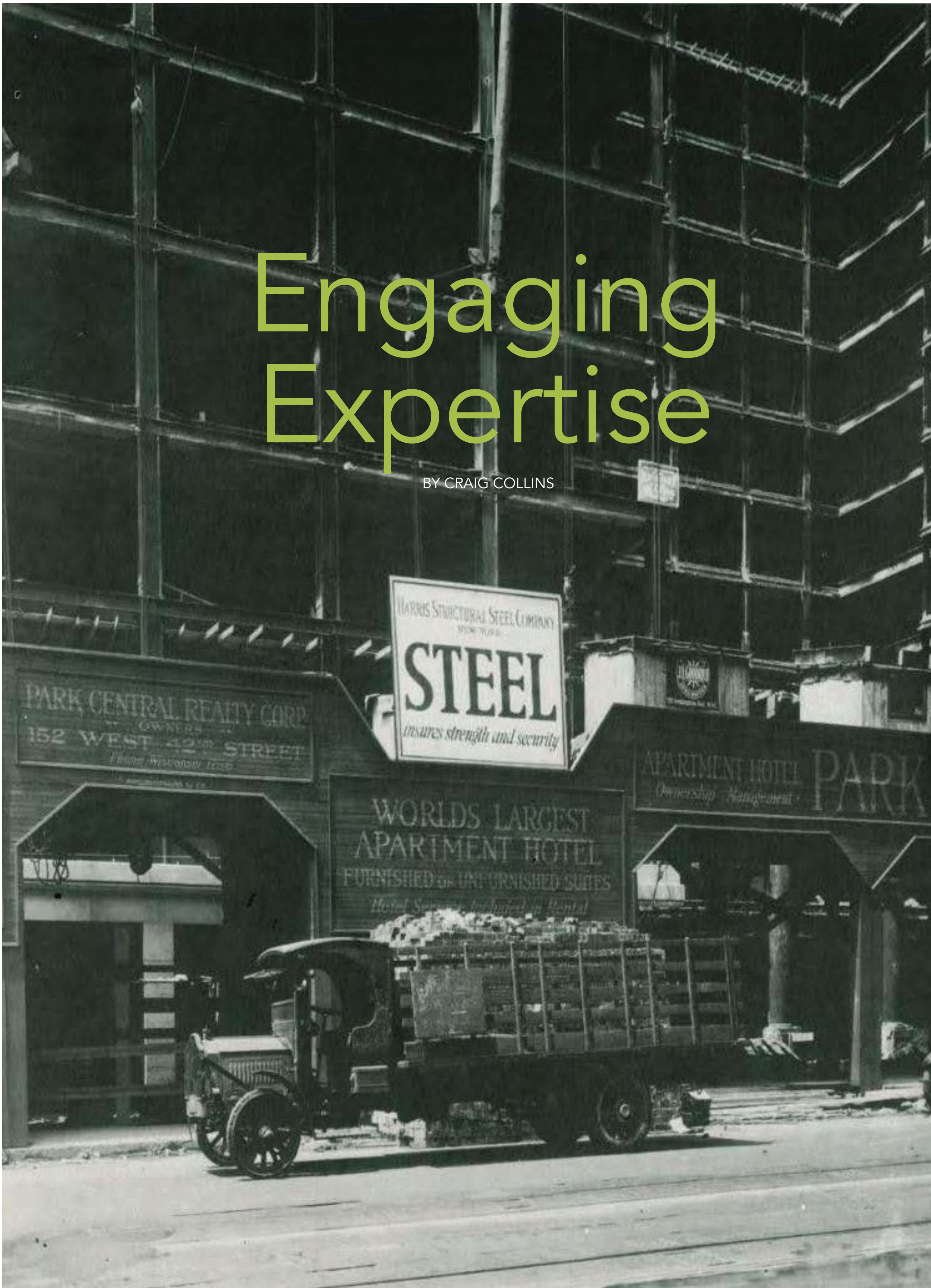
Proven and Promising

To date, Lochner has successfully incorporated SDCL detailing in the design of five two-span bridges with individual spans ranging from 70 ft to 164 ft and skews of up to 20°. The SDCL detailing reduced the quantity of steel for all bridges and simplified the steel fabrication and construction. And with the use of the SDCL detail that encases the girder ends, the superstructure's durability is maintained.

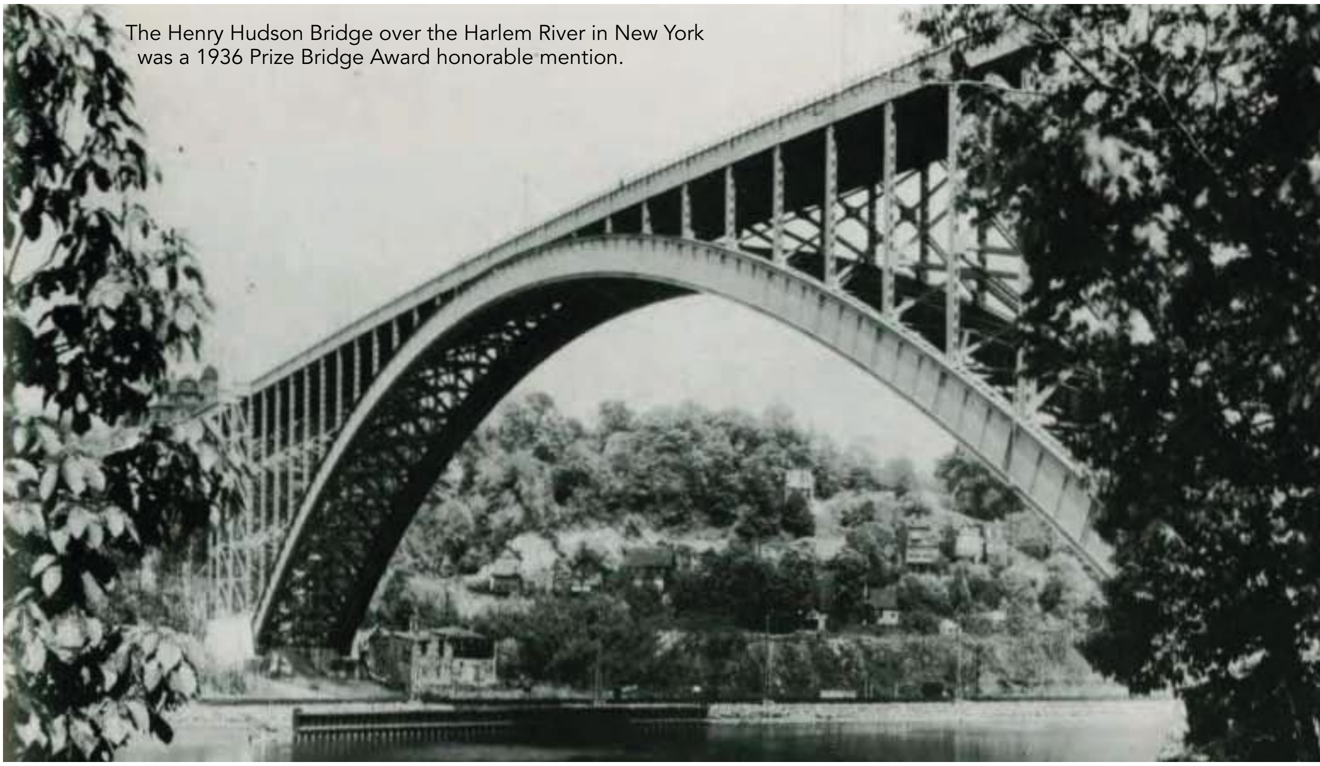
For ABC projects incorporating PBUs or heavy moves, SDCL was very effective, and the continuity of the superstructure made meeting project objectives easier. And when it comes to ABC projects for which link slabs have been proposed to make the deck continuous, SDCL detailing should be discussed as an option for improvement of the construction process. Overall, implementing the SDCL approach should be considered a viable option in situations where the design team feels that it can meet project objectives. ■

Engaging Expertise

BY CRAIG COLLINS



The second chapter of a forthcoming book on the first century of AISC focuses on the steel industry's preeminent engineering and technical experts.



The Henry Hudson Bridge over the Harlem River in New York was a 1936 Prize Bridge Award honorable mention.

AMONG AISC'S FOUNDERS, there was considerable debate about what to call themselves.

In *The First 60 Years: The American Institute of Steel Construction, Inc. 1921-1980*, author Leslie Gillette breaks down why the new organization, established in 1921, took a full year to decide on its name: some detractors argued that an organization founded for and by steel fabricators should stick with its original name, the National Steel Fabricators Association—or at least keep the word "fabricator" in some form. Others claimed the proposed name, the American Institute of Steel Construction, sounded too much like the American Iron and Steel Institute (AISI, which represents iron and steel producers).

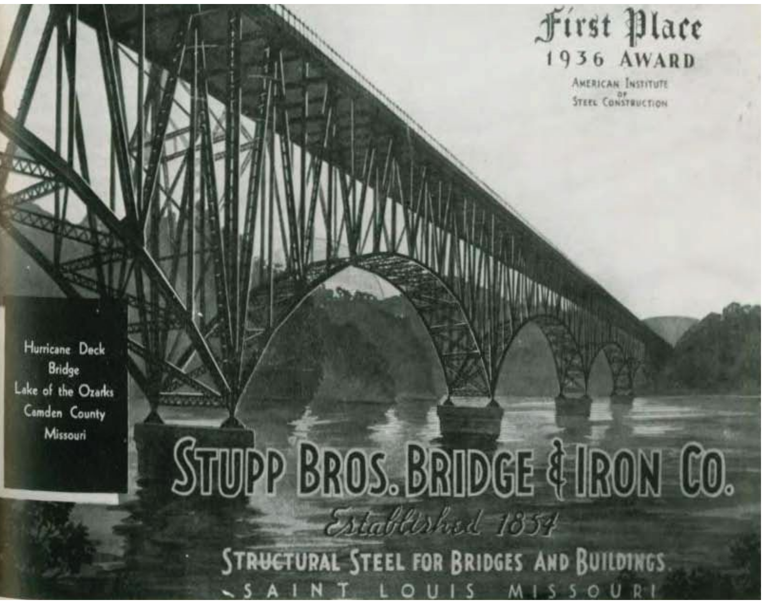
The choice to stick with the name "American Institute of Steel Construction" recognized a vision that went beyond the narrower interests of its founders; from the start, the institute was looking at the big picture: the point wasn't merely to make and sell steel shapes. The point was to give construction professionals complete confidence in steel's safety and efficiency as they designed and built the structures that enabled, supported, and celebrated American life.

The institute's first task, then, was to eliminate the confusion, waste, inefficiency—and potential danger—associated with the nationwide patchwork of design rules, load tables, and other technical data for structural steel. AISC acted swiftly, launching a tradition that has become one of its hallmarks: It assembled a committee of esteemed volunteers to solve a problem. This first specification committee, composed of experts from academia and engineering and architecture firms, set down a little more than eight pages of rules for sizing, loading, connecting, coating, and inspecting structural steel pieces.

Standard Specification for the Design, Fabrication and Erection of Structural Steel for Buildings, published in 1923, was received with universal approval by the construction community: "By AISC's second convention in November 1924," wrote Gillette, "the AISC *Specification* had been adopted by 25 prominent cities in the United

Craig Collins is a California-based freelancer who writes about science, technology, and government.

CELEBRATING 100 YEARS 1921–2021



above: The Hurricane Deck Bridge was a 1936 Prize Bridge Award winner.

below: The U.S. Pavilion at EXPO '67 in Montreal.

Chicago's Tacoma Building, which was completed in 1888, used cast iron columns and steel beams.

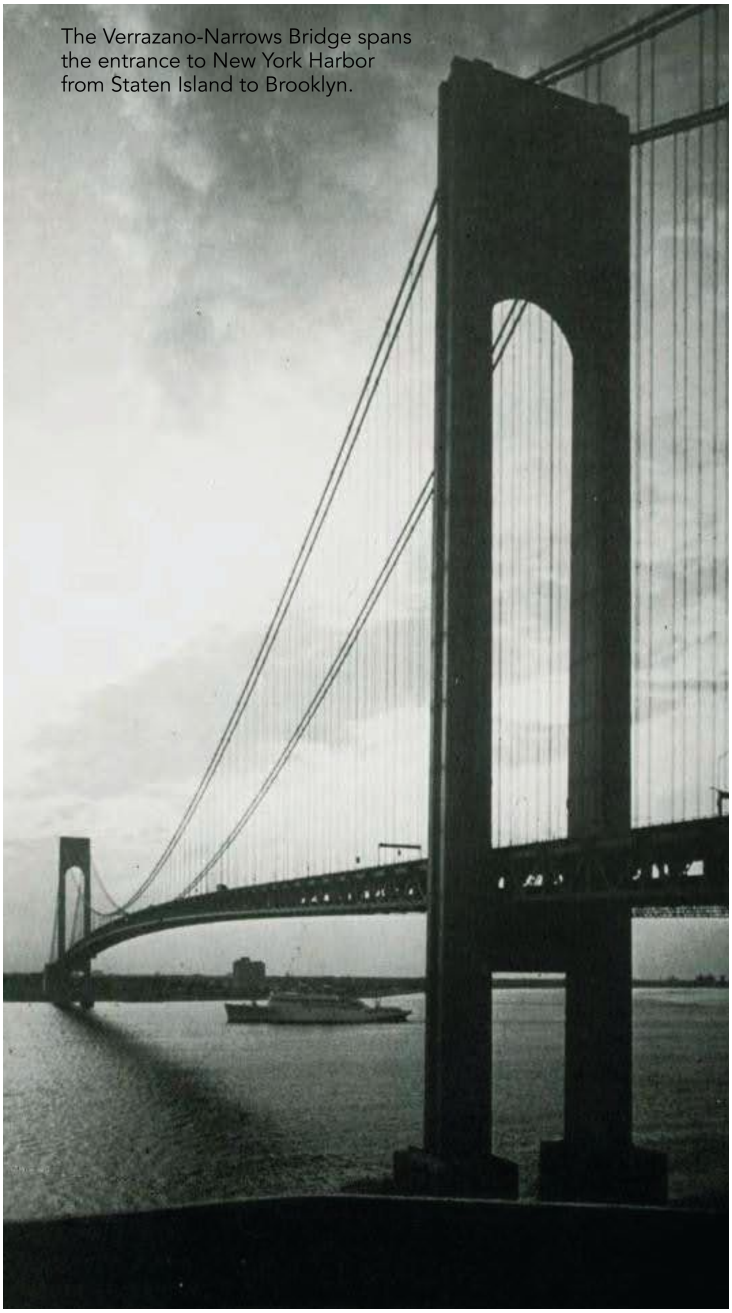
States." A year later, AISC made the men who'd served on this committee its first honorary members.

Following World War I, another important issue for the steel industry was the nation's chaotic introduction to international business. The expansion of the national economy was dominated by powerful and wealthy trusts, and some of the earliest reforms undertaken by President Woodrow Wilson were aimed at leveling the playing field and encouraging fair competition. Members of the structural steel community—architects, steel producers, and engineers—needed to understand the rules for fair and accepted practices in the fabrication industry.

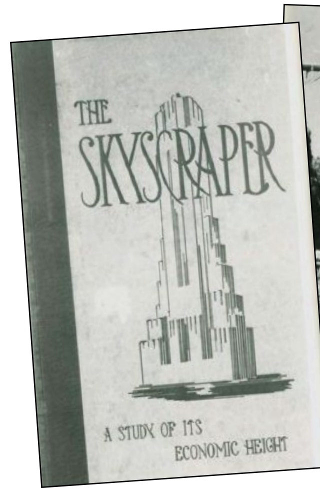
The second committee formed by AISC, the committee on code of standard practices, created and codified the first common understanding of trade custom and usage for structural steel. *Code of Standard Practice*, published in October of 1924, listed and classified the items of fabricated steel that go into structures and established rules and procedures for calculating weights, preparing and approving drawings; resolving discrepancies between drawings and specifications; inspection and delivery; erection; contracts; and other elements of the structural steel business. Like the first *Standard Specifications* (now simply known as the specification), the first *Code of Standard Practice* was a modest document, just under 20 pages of rules and guidelines; like the specification, this code was received with gratitude by everyone involved in buying and selling structural steel.

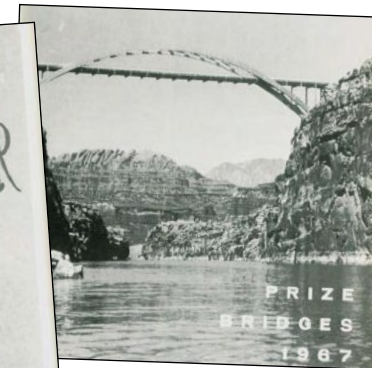
With these two sets of rules—a kind of dictionary and grammar for building with structural steel—the institute set about composing a handbook that would help professionals apply these rules. With the help of the steel mills, AISC published *Steel Construction Allowable Load Tables* in 1926, a 104-page book that included tables for every beam and column shape rolled in the United States, as well as data on connection angles, base plate, members, rivets, and bolts—all of which were based on the *Standard Specifications*.

This handbook marked the first time a designer could refer to a single publication and access all the data that had previously been available from multiple mill catalogs—but this forerunner



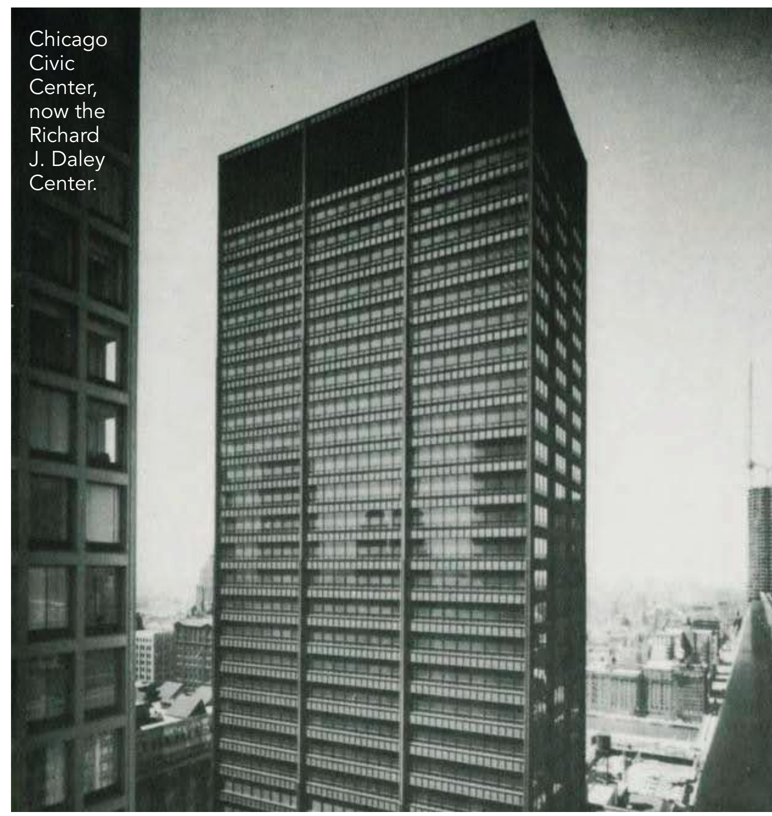
The Verrazano-Narrows Bridge spans the entrance to New York Harbor from Staten Island to Brooklyn.





above: A 1967 promotion for the Prize Bridge Awards.

left: A 1930 AISC book promoting skyscrapers.



Chicago Civic Center, now the Richard J. Daley Center.

to AISC's *Steel Construction Manual* was promptly superseded, in December of 1927, by AISC's first edition of *Steel Construction*: a comprehensive handbook that included not only the *Standard Specifications*, the *Code of Standard Practice*, and *Allowable Load Tables*, but also a host of other information, tables, and charts for finding allowable stresses in structural steel shapes. The handbook was a collaboration between AISC's engineering staff and the members of these first specification and code committees.

The *Steel Construction Manual*, now in its 15th edition, is the authoritative practical guide to analyzing and designing steel structures. It has been revised and updated many times, along with the specification and code on which it was founded—but even before the first manual was published, the specification and code were promptly taken up as navigational documents by designers, mills, the construction industry, and building code officials, all of whom were become more sure-footed in their use of structural steel. Before AISC's first decade of existence, shipments of fabricated structural steel throughout the United States had nearly tripled.

These documents, some of the first items to be produced by AISC's committees, reflect an engineering and technical expertise that Lou Gurthet, PE, a former board member and AISC's president from 1996 to 2008, calls "the heart and soul of AISC." All of the operational areas that have been added to this core competency since, and everything the institute has achieved in its 100 years of existence, are rooted in the engineering excellence that feeds its technical guidance.

"We are a technical organization first," said Charles Carter, SE, PE, PhD, AISC's current president, "and we have the responsibility to provide information that safeguards the public in steel buildings and bridges." ■

This article was excerpted from the second chapter of a forthcoming book documenting the first 100 years of AISC's existence. The book will be available at ***aisc.org/legacy*** *later this fall. Next month, we'll include an excerpt from the third chapter. And check out the September issue for an excerpt of the first chapter.*

Robotic structural steel fabrication equipment hasn't reached "end all be all" status quite yet, but those early adopters who have integrated it into their shops have generally been pleased with the results.

Nearly 360 Degrees of Separation

INTERVIEWS BY GEOFF WEISENBERGER

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

ROBOTIC EQUIPMENT IS STILL FAIRLY UNCOMMON in structural steel fabrication.

Still, with every type of technology, there are early adopters. We talked with a few AISC member fabricators that have introduced robotic equipment into their shops, discussing topics such as their initial experiences, optimal job types for robots, how their new equipment has affected shop flow and material handling, productivity gains, and what's on their robotic "wish list" for the future. (Note that we're not just equating "robots" with "automation" but rather are referring to machines incorporating, say, a six-axis robotic head for operations such as welding, coping, and fitting.) Here's what they had to say.

Answers provided by:

- Bryan Frazier, Vice President of Purchasing, Zalk Josephs Fabricators, LLC
- Steve Grandfield, President, Prospect Steel, a Division of Lexicon
- Heath Maxey, Research and Development, Banker Steel Company, LLC
- Novel Iron Works (responses are from the following: Bill Gallant, Vice President of QC and Safety; Wayne McKay, Director of Programming and Robotics; Josh Noveletsky, President; and Jennifer Paisley, Vice President of Project Management and Detailing)

What was your initial experience with integrating robotic equipment into your shop?

Frazier: When we initiated our shop overhaul in 2013, the deciding factor for us was trying to find systems that took material handling into account. We wanted to check a lot of boxes with the shop update, and part of that was bringing in a six-axis robotic coper.

We were able to recover pretty quickly from most of the issues that came to the surface. But sure, there were some kinks to work out. For example, we had to change the way we did our connection designs with shallower beams to keep the robot from basically crashing against the flange. You just need to make sure that everything from your lenses to the consumables is calibrated.

The machine is a Ficep, and there's a nice tool where the company can actually remote into the equipment in our shop. There's a library of macros or functions that the robot is capable of, and if we aren't able to locate a function, we go ahead and initiate a call with their tech support and then get that macro into our equipment.

A coper is a good way to get your feet wet with robots, so to speak. It's more of a versatile piece of equipment since coping is relevant on basically any type of job. And there are a lot of functions and opportunities to get creative.

Novel: For us, it was challenging. We knew the limits of the machine, which is a Zeman, but we didn't know the parameters well enough. Each function has dozens and dozens of parameters or adjustments that, even after two years of use, we are still fine-tuning.

Our first job may not have been ideal for a number of reasons, but we were able to use the new machine to maximize resources in the shop. Ideally, a piece will be loaded in the machine, completed, and then be ready for QC. Unfortunately, our first couple of jobs did not fit this concept. For that reason, we had to use its strengths to achieve the highest possible productivity. In some instances, we went to a fit-only mode. Other times, we only welded with the machine. Eventually, we got jobs (as well as getting through a fairly steep learning curve) that were better suited for the machine.

Grandfield: Prospect Steel was one of the first steel fabrication companies in the United States to install a complete fitting and welding robotic line solution. We have been promoting this technology since that first installation and allowing other fabrication companies to tour our facilities, as we wanted others in the industry to adopt this technology to help support its ongoing development. We originally spent a lot of time researching and looking at different options from suppliers over a number of years until Peddinghaus introduced us to the Zeman steel beam assembler out of Austria. We are into year five of that first installation in Little Rock, Ark., which is a single-line system, and we could not be happier with its performance and with our subsequent installations. We wanted to be at the forefront of robotic technology within the fabrication industry because we recognized its potential, and we also saw this as part of the solution to an aging fitting and welding workforce.

Is there a "perfect type" of job for robotic equipment?

Frazier: When it comes to the coper, we use it on almost all projects, even with vertical bracing. You'd be surprised what it can do with HSS vertical bracing that's slotted or involves a gusset plate.

Novel: The robotic assembler (a Zeman) has to scan every piece, which takes time. It takes just as long to scan a beam that has 50 parts on it as it does to scan one with three parts on it. But where the robot excels is with complicated pieces that fall within the restrictions of the machine.

The perfect job based on observations are ones where we can run 70%+ through our assembler. This number is based on what we have been able to designate for the machine when our computer room receives the drawings. The ideal job is one where the bulk of the entire job can go through the machine and then move directly to QC.

Maxey: The perfect jobs for the robots are long runs of the same item. Changes for robots are not good for productivity. There have been strides taken in the industry to make one-off pieces doable for robots, but it's still not better than loading the same part over and over.

How has adding a robot affected your show flow and material handling? Did you have to make major adjustments to accommodate it?

Frazier: Every fabricator would probably tell you that it's all about shop flow and material handling. The way our shop was initially constructed and modified over the years didn't really lend itself to good flow. We were bringing material in on one side and moving it upstream to another portion of the shop, and a lot of guys were fighting for crane time and people would get in each other's ways. It just wasn't efficient. So we invested in new Ficep equipment and were able to design a system with them, basically bringing material in from one end of our shop and having it exit and loaded on trucks on the opposite end via an automated transfer table lift and carry system as well as a roller system. Basically, we took our existing footprint and shuffled some things around and maximized our space with all of the new handling equipment. And in the middle of that, we were able to install a new blaster, two new drills, a saw, and, of course, the coper. We had to shuffle some folks

around tight quarters for a while, but we were actually doing a project in downtown Chicago and were open for business. We just had to change things up a little bit. And in 2019, we brought in two plate-processing tables.

Novel: The footprint of our robotic machine is the equivalent of three work bays. While we lost three work bays, we put the robot in a location so that material could easily be staged in front of it. We also had to add footings and redo part of our foundation to compensate for the additional weight. Our computer room felt the brunt of this. Every beam has to be vetted by the programmers to make sure that all parameters are correct for the machine. If even 1% of the beam won't work, the program will show an error.

Our primary modifications have been how we route material through the shop. Through a coordinated effort between programming and all involved shop personnel, we control the flow of material from the saw to the Zeman robot. Before we even get to that point, all material that is suitable for the robot is routed in the production software.

We are a bolted shop, so to split the work in the detailing department between the welded work of the Zeman and the bolted work of the men took a lot of forethought. We had to make sure there was enough workflow for both the Zeman and the workers. Then detail those portions of the jobs differently based on how they would go through the shop (robot versus people).

Grandfield: The first installation of the Zeman system was actually fairly seamless in our Little Rock location. We were able to integrate it in line with our existing drill, saw, and conveyor systems. The next installation of the double-robotic line in our Blytheville, Ark., facility was a similar scenario where we had the width required, and it integrated seamlessly with our equipment in that facility. We have recently added a fourth robotic line in our second shop in Little Rock, which has the capability to be a double line, and we expect to have five robotic lines in operation in the near future. In summary, we had shop bays with the width and height necessary to install this equipment, and we were able to line these up with our existing drill, saw, and conveyor systems to be able to feed material into the robotic lines. We know that space has been a potential problem for other fabrication shops with regard to these installations.

This has been a large investment, and it goes without saying we needed to ensure that we limited the downtime to maximize our return on investment. We have spent a considerable amount of time planning our production flow, specifically our parts operations, to feed the robotic lines as well as other areas of the shop. The robotic lines have really increased our overall throughput and capacity. It has driven us to further invest in other pieces of equipment, like drills, saws, and plate-processing machines, to maximize the opportunity with the robotic lines and the overall throughput and increased capacity that they help generate through the shop.

Maxey: We have changed the design of some pieces so that we can make use of the robotic coping machines. Changing the design led to faster fabrication and less work for the fabricator.

What sort of productivity gains have you achieved thanks to adding a robot?

Frazier: When we did our shop overhaul, of course we approached things from a cost-savings standpoint—you know, savings when it comes to laying parts out—and as our labor force is getting younger, some of the automated functions are nice to have for some of our greener fabricators that are perhaps just learning of what a cope looks like, or what it *should* look like. Even prior to our 2013 shop update, we had our eyes on a robotic coper, really, at every NASCC since 2006 or 2007. We didn't purchase one immediately because we wanted to see how the technology would improve over the years and see if more players would come to the table. And then we started seeing more of the automated material-handling operations. And so the menu started to grow with options in terms of automation.

Novel: We have found that on complex pieces, the robots can complete a task in 45 minutes that would take a human roughly three hours. However, this only counts for actual run time. It does not take into account programming, finding the parts, or loading the machines.

There is a noticeable decrease in handling time throughout the shop. Where time is money, there you go.

The Zeman has more potential than how we are currently using it. This has a lot to do with personnel and the types of jobs we get. We need better operators and a loader for the machine. But under the current difficult employment recruitment issues, this may be an issue for a while. The Zeman is 50% faster overall, but it is really job-specific. The in-feed and out-feed really make a difference in decreasing material handling time.

Maxey: Our savings has come from removing people from secondary tasks of coping/beveling, then moving them to assembly and fabrication. We now have the robot doing the coping/beveling where people would normally be laying out and cutting the part. This has allowed us to keep the same number of people but increase the number of parts moving through the shop.

Are you looking at any other robotic equipment? What would you add if/when you have the opportunity?

Frazier: We're curious and we're definitely paying attention to what's out there. As with the coper, we're trying to keep an eye on how different machine types improve over time and factor in what type of space we might need in the shop to install a given piece of equipment. We've talked about getting like an automated parts sorter, something that can move parts around or shake some connection material out for us.

Novel: I would add more similar equipment. Skilled labor is harder than ever to find. There will always be a need for skilled and talented people to complete the most complex and detail-oriented pieces, but society is shifting away from skilled labor and moving towards computers and automation. As time goes on, it will be much easier to find someone who can program and run programs than it will be to find someone who knows how to weld or read a tape measure. As robotics continue to evolve, we will keep a close eye on them in the future.

Maxey: I would like to add more welding robots. The strides made by the industry in the last few years have made one-off parts doable with reasonable speed using robotics. This, combined with the estimated shortage of 400,000 welders in 2024, according to the American Welding Society, is going to push even more robotics into the industry. I would consider adding more welding robots to our shop to prepare for this coming shortage. ■

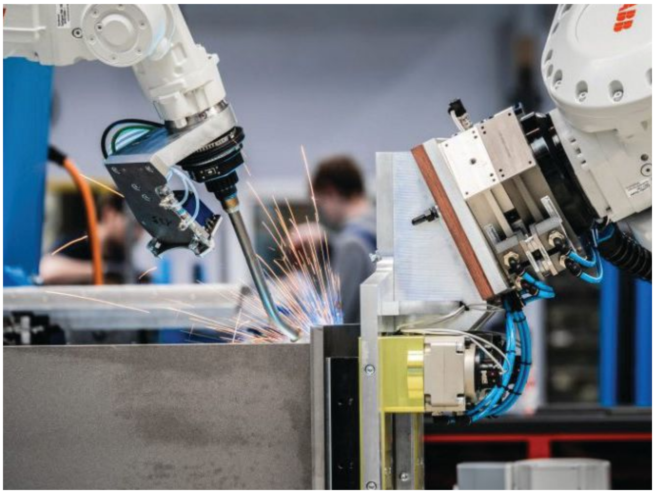
To see a list of various fabrication equipment and tools, visit www.modernsteel.com and go to Product Directory under the Resources tab.

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.

new products

This month's New Products section features three structural steel robotic assembly and cutting systems that are designed for a reduced footprint and increased output.



Zeman SBA SR Compact

The SBA (Steel Beam Assembler) Compact beam assembler is designed to offer the highest functionality in the most flexible footprint. The machine can become a part of your existing workflow with ease. In just a few months from the point of order, you can be up and running to fabricate steel faster, safer, and more reliably for your customers. Choose your in-out feed based on your shop layout and preferred work style. Available in three different lengths—12 m (39 ft, 4 in.), 16 m (52 ft, 6 in.), and 18 m (59 ft)—the machine's compact single-rail format addresses the challenge of smaller shops wanting to add robotic equipment but having trouble identifying a machine that would fit their space. This design includes a modular concept for future extension (one additional robot, in-out feed) and offers additional machine functions (pre-heating, multi-pass layers etc.), increasing efficiency and simplifying assembly and welding.

For more information, visit **www.zebau.com**.

Prodevco PCR41

The PCR41 is a new compact high-definition robotic plasma cutting system designed with structural steel and miscellaneous fabricators in mind. The PCR41 can process a wide range of structural shapes and all four faces of an HSS profile, including slots, holes, copes, and markings. The easy-to-use interface uses DSTV (NC1) files with no need for macros or other post-processing and accepts files directly from 3D detailing software packages such as Tekla and SDS2. The PCR41's advanced laser measuring system, combined with two rotary encoders, is able to determine material length and deviations resulting in optimal cutting accuracy. And its small footprint and flexible placement allow fabricators of all sizes to locate the system anywhere in the shop. In addition, the durable conveyors permit for yard in-feed and out-feed.

For more information, visit **prodevcoind.com**.

Peddinghaus PeddiAssembler

The PeddiAssembler is equipped with an intelligent laser measurement system to detect positional dimensions and tolerances of the material. The material scanning takes place as one continuous cycle. Each part is scanned on the table individually and can also be in the form of pre-welded parts. To ensure smooth and continuous production, the main profile is stabilized by integrated profile turning devices on the machine. These turning devices rotate the beam as needed for welding on all sides of the material. The whole robotics system rests on a single-rail design, which maintains a small machine footprint; the compact design only occupies the space of one fitter station. The torch-mounted laser measurement system can locate the zero reference for the entire process on a profile as well as define the measurements of tacked parts. The assembler is outfitted with Zeman's ProFit software, which runs on a Siemens control, enabling CAD file information to be transferred to machine processes with ease. The software bridges the gap and aids in helping operators determine the best process for the current material that is tacked or welded.

For more information, visit **www.peddinghaus.com**.

STUDENT STEEL BRIDGE COMPETITION

AISC, ASCE to Team up for Student Steel Bridge Competition, Starting this Fall

AISC and the American Society of Civil Engineers (ASCE) have announced a renewed partnership for the Student Steel Bridge Competition, starting with the 2021-2022 school year.

The annual Student Steel Bridge Competition, which began in 1987, challenges student teams to develop a scale-model steel bridge to fit a given hypothetical environment. Each team must determine how to design and fabricate a bridge and then plan for an efficient assembly under timed construction at the competition. Bridges are then load-tested and weighed.

The two organizations plan to run regional competitions at ASCE Student Symposia throughout North America, with the national finals to be held in May. The two groups previously worked together on the competition but separated three years ago. The new partnership runs for an initial term of five years.

"This is a natural fit," said AISC senior vice president Scott Melnick. "AISC and ASCE both have very strong educational programs for students studying civil engineering. We believe we can best serve students by working together."

"With both AISC and ASCE committed to promoting safe, sustainable, and innovative practices and technologies, we are pleased to renew this partnership and join forces in developing, educating, and motivating the next generation of design and construction professionals," said ASCE executive director Tom Smith.

"Our vision for all ASCE Student Symposia includes a portfolio of competitions and professional development opportunities that provide exceptional value to our student members," added Smith. "The Steel Bridge Competition is a popular event, and our students will be thrilled to see it added to the symposia program."

"This new agreement also provides a foundation for ASCE to build upon the successful North American competition through steel bridge competitions in other global regions," Smith continued. "More than ever, civil engineering is a global practice. What better way to advance our profession than to promote global exchange at the collegiate level?"

The official rules for this year's competition will be released on September 7. To learn more and see photos/videos from previous competitions, please visit **aisc.org/ssbc**. To learn more about ASCE Student Symposia, visit **asce.org/student_conferences**.

SPEEDCORE

Second SpeedCore Project now under Construction

200 Park, a 19-story office building that will be the tallest office tower in San Jose, Calif., when it is completed, is currently being erected. It is the first building in California to be built using the SpeedCore system and only the second SpeedCore project in the United States. The first is Rainier Square Tower in Seattle, and both were designed by structural engineer Magnusson Klemencic Associates, which developed the system. (Read more about SpeedCore at **aisc.org/speedcore**.)

Around the time construction started in the spring, the project's general contractor, Level 10 Construction, released a video depicting the conceptual structural steel sequence of the tower. The video (at **vimeo.com/522520812**) shows how 200 Park's SpeedCore system employs fabricated steel wall panels, fabricated by AISC member Schuff Steel, supported by stanchions and filled with high-strength concrete. Each panel carries up to eight floors of steel framing, allowing construction to continue independent of concrete curing times.

The project's use of SpeedCore is expected to reduce construction time by three months, resulting in an estimated completion date of May 2023. SpeedCore also helped Rainier Square Tower finish its core nine months ahead of schedule.

When it is finished, 200 Park, owned by Jay Paul Company and designed by Gensler, will comprise 937,000 sq. ft, including 26,000 sq. ft of outdoor terraces.

People & Companies

The **Steel Erectors Association of America (SEAA)** has named **Pete Gum** as its new executive director. Gum has 29 years of experience as the CEO of not-for-profit construction trade associations. He has a proven track record with helping associations increase membership and comes to SEAA from the **Associated Builders and Contractors of Western Pennsylvania**, where he served as president.

The **American Society of Civil Engineers (ASCE)** recognized the **Wisconsin Section of ASCE** as this year's **Outstanding Civil Engineer Advocate of the Year** for the team section. The Wisconsin Section recently released its 2020 *Report Card for Wisconsin's Infrastructure*, which graded 13 categories of infrastructure pertinent to Wisconsinites and provided a cumulative grade of C. The Section used this advocacy tool as a means of reaching out to elected officials to inform them of the state's infrastructure needs. The team was also active in pushing its message to the media, conducting dozens of interviews with print, digital, radio, and television outlets all over the state.

After years of development and localization of its products for the U.S. engineering community, structural steel design software company **IDEA StatiCa** has opened a U.S. office, in Mount Laurel, N.J., just outside of Philadelphia. It is led by structural engineer **Dave Eckrote**.

CONNECTIONS

AISC Offering $5,000 Prize for the Next Great Idea in Connection Performance

The Rigid SpeedConnection Challenge is looking for the next great idea in connections, and there is $5,000 on the line for the best concept!

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 do have a limitation in regards to floor framing—they allow the end of the beam to rotate. If the connections in a floor system are able to provide rigidity against rotation, deflections of the floor can be greatly reduced, paving the way for a lighter and stiffer floor system. What if you can innovate with a new floor framing connection concept that can increase the rigidity of a floor system yet is still easy and economical?

The keywords are FAST and EASY—to design, fabricate, and erect safely. We welcome all participants with a spark of inspiration and "back of a napkin" idea that we can help develop into a revolutionary concept.

To register for the challenge, visit **herox.com/SpeedConnectionRigid** and click the "SOLVE THIS CHALLENGE" button. The deadline for entry is November 19, 2021.

The SpeedConnection project—part of AISC's "Need for Speed" initiative aimed at increasing the speed of steel construction by 50% by 2025—aims to provide speed improvements for how buildings can be erected related to connections. This transformative effort's overarching goal is to develop a solution that "changes the world" for steel connections.

ENGINEERING JOURNAL

Fourth Quarter *Engineering Journal* Now Available

The fourth quarter 2021 issue of AISC's *Engineering Journal* is now available. (You can access this issue as well as past issues at **aisc.org/ej**.) Below is a summary of this issue, which includes articles on local web shear at brace connections, steel-concrete composite beam-columns, lateral-torsional buckling, and fire engineering.

Design for Local Web Shear at Brace Connections: An Adaptation of the Uniform Force Method

Rafael Sabelli, Brandt Saxey, Chao-Hsien Li, and William A. Thornton

Recent literature has examined local shear forces in beams in chevron braced frames. Subsequently, design methods based on optimal stress distributions to address these shears were developed. This paper extends those design methods to gusset connections at columns, using the adaptability of the uniform force method to facilitate design to reduce required member shear strength.

Tearout Interaction Strength of Steel-Concrete Composite Beam-Columns Including the Balance Point

Mark D. Denavit

The maximum bending moment capacity of steel-concrete composite column cross sections occurs with concurrently applied axial compression. This is seen in the shape of the interaction diagram, where the bending moment capacity increases with increasing axial compression before reaching the balance point. The size of this bulged region of the interaction diagram can be significant, especially for concrete-dominant sections. However, it is often neglected in design because of two stability-related concerns. First, the simple transformations that are recommended to convert cross-section strength to member strength produce illogical results near the balance point, with member strength exceeding cross-section strength. Second, research has shown that the stiffness reductions used in elastic analyses are not sufficient for highly slender concrete-dominant composite members subjected to high bending moments. This work seeks to address these issues through the development of more advanced transformations and stiffness reductions. These new recommendations will more accurately capture the strength of composite members and allow for more efficient designs.

Lateral-Torsional Buckling Research Needs and Validation of an Experimental Setup in the Elastic Range

Ryan Slein, Joshua S. Buth, Wajahat Latif, Ajit M. Kamath, Ammar A. Alshannaq, Ryan J. Sherman, David W. Scott, and Donald W. White

AISC *Specification* Chapter F I-section member flexural resistance equations are a central part of structural steel design in the United States. The provisions of Sections F4 and F5 address general singly and doubly symmetric I-section members. Analytical studies and experimental tests subsequent to the implementation of these provisions within the 2005 AISC *Specification* suggest that the corresponding inelastic lateral-torsional buckling (LTB) and tension flange yielding (TFY) resistance equations can be improved, resulting in significantly larger predicted strengths in certain cases and somewhat smaller predicted strengths in other cases. Additional large-scale experimental tests, specifically pushing into the inelastic LTB range, need to be conducted to further investigate these predictions. The broad objective of the additional tests is to achieve a target reliability index of $\beta = 2.6$ for building design at a live-to-dead load ratio of 3.0 throughout the design space involving all types of statically determinate I-section flexural members.

Research Update: Structural Fire Engineering

Judy Liu

Across the United States, researchers are making exciting discoveries and advances in structural fire engineering. Eleven of the leading scholars in the field are featured. Brief research highlights are organized by the topic areas of behavior and design of steel and composite structures for fire, fire following earthquakes, and performance-based fire engineering. For each individual, related steel and fire research is also noted.

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ICONIC CROSSING

GEORGE WASHINGTON'S CROSSING of the Delaware River between Pennsylvania and New Jersey in 1776 turned out to be an important and iconic military decision during the American Revolution. Also important and iconic is Washington's namesake steel crossing over another waterway, the Hudson River between Manhattan and Fort Lee., N.J.

Built between 1927 and 1931, the George Washington Bridge is now the world's busiest motor bridge, carrying more than 100 million vehicles per year. At 4,760 ft long (with a main span of 3,500 ft), it boasted the world's longest main bridge span until the Golden Gate Bridge, with its 4,200-ft span, opened in 1937. This photo from the AISC archives shows the George Washington Bridge during its construction, before the deck and superstructure were installed. The bridge is known for its exposed steel towers, which are punctuated by their crisscross bracing design. Masonry facades were initially planned for the towers but were ultimately never built.

By the way, the famed suspension bridge—which uses 113,000 tons of fabricated structural steel—opened to traffic one decade after AISC's founding in 1921. For an excerpt from our soon-to-be-released book celebrating AISC's first century of existence, check out "Engaging Expertise" on page 54 (and see "Steel Century" in last month's issue for another excerpt). And to learn more about AISC turning 100 this year, visit **aisc.org/legacy.**

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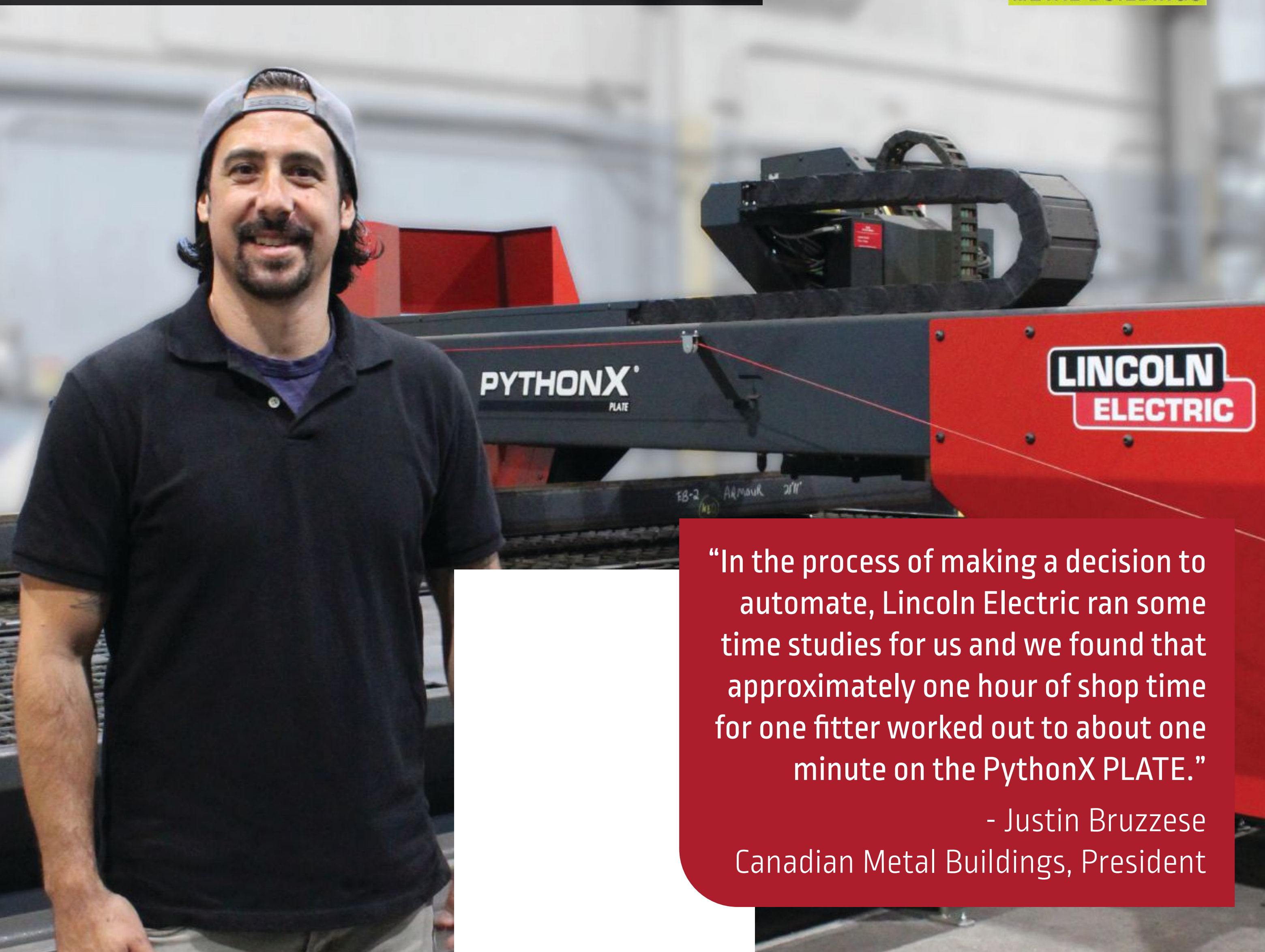

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