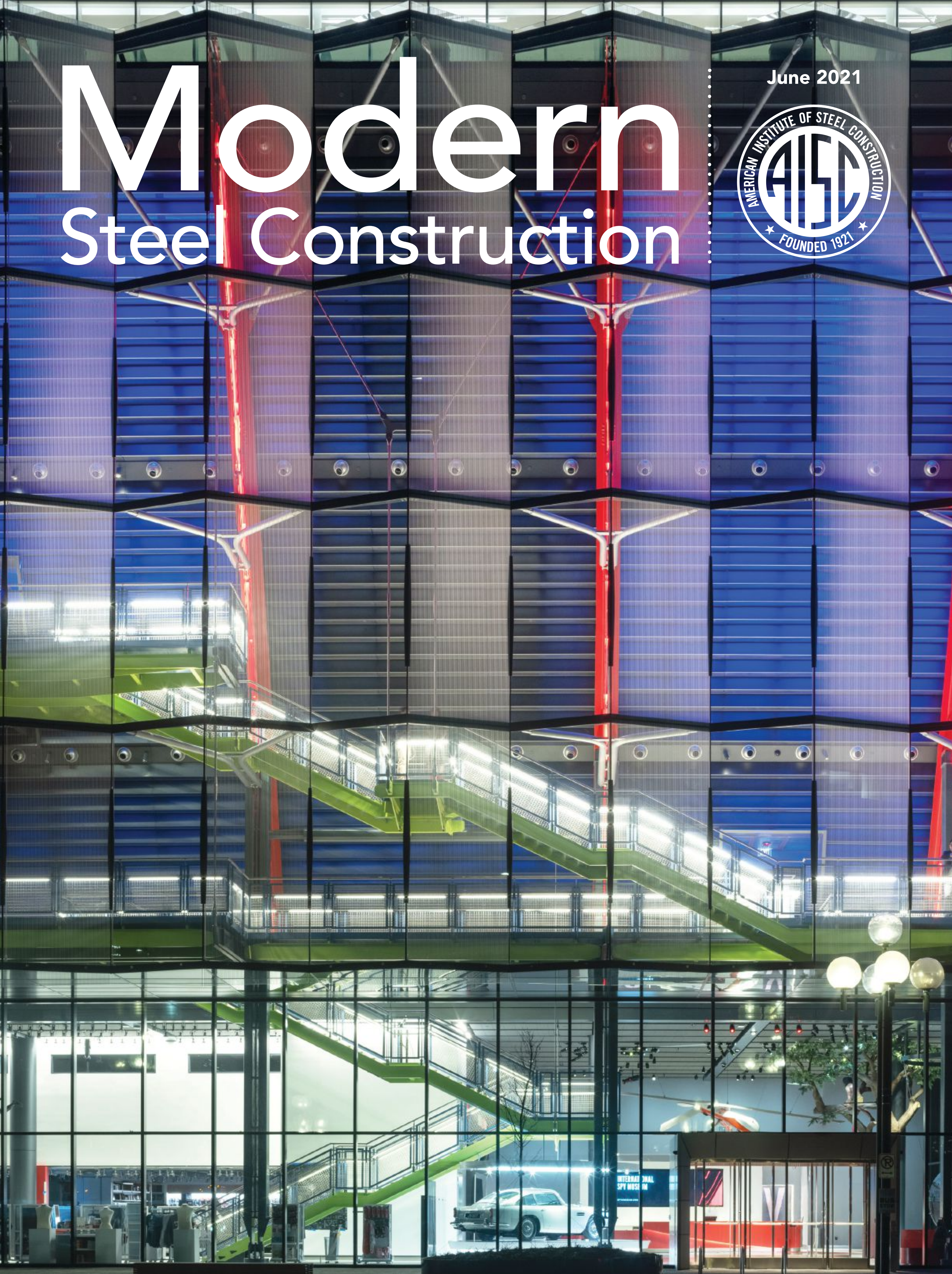
Modern Steel Construction

June 2021

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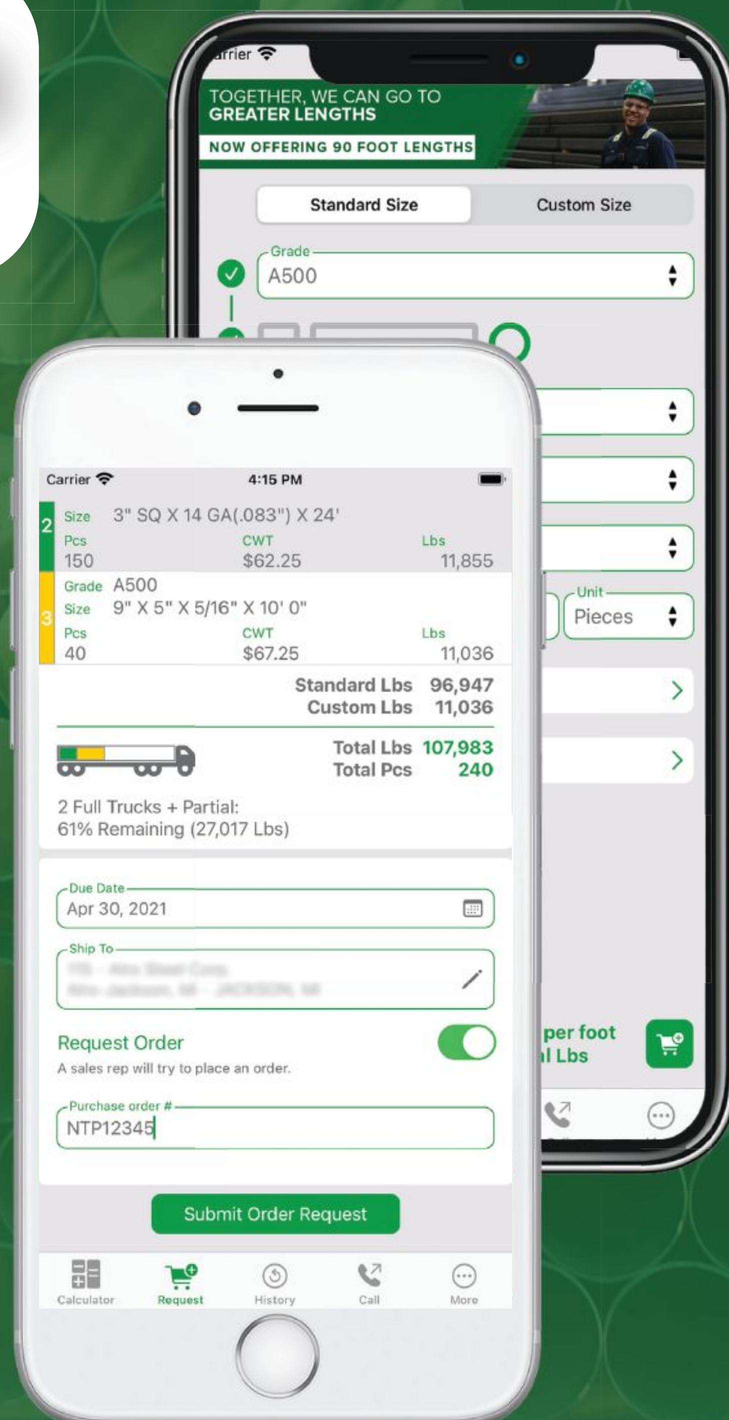
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ON THE COVER: Sneaking a peek inside the new home of the International Spy Museum, p. 26. (Photo by Nic Lehoux, Courtesy of Hickok Cole)

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editor's note

One of the few advantages of getting older is you tend to know more and more smart people.

The other day, I was complaining to Tom Scarangello, the executive chairman of Thornton Tomasetti, about some comments some of his colleagues had recently made that sounded like an unfair comparison of wood vs. steel. Tom listened politely for a few minutes before subjecting me to some well-deserved keelhauling.

In no uncertain terms, Tom reminded me that I represented steel, one of humankind's most significant inventions and should stop whining and nitpicking claims regarding other structural materials. Instead, I should be shouting from the rooftops about what the steel industry is doing to address the issues of climate change and embodied carbon and (as I put it) how freakin' amazing steel is. So here goes:

- Steel's unparalleled combination of strength and ductility make it America's leading structural material. The result is longer spans and larger column-free spaces, smaller beams and columns and less expensive foundations, and the highest-performing seismic systems. Steel's long spans and fewer columns mean more leasable space, easier retrofitting and remodeling, and more attractive interior designs. When you consider cost, flexibility, and resilience, steel's performance is simply unmatched.
- Steel is the most environmentally friendly structural material. American-made wide-flange shapes are the only structural material that can claim a recycled content greater than 93% and a 100% ability for recycling. Just as important, steel can be recycled over and over with no loss of material properties. Today, the embodied carbon attributed to steel comes almost entirely from the power grid in the form of the electricity used for steel production. Fortunately, as America turns increasingly to sustainable energy production, steel's carbon footprint will continue to shrink.
- Steel is beautiful. Every architectural aficionado owes it to themself to take a pilgrimage to the Mildred B. Cooper Memorial Chapel in Bella Vista, Ark., to see one of the world's most beautiful buildings (or check out the February 1990 issue of *Modern Steel Construction*). And of course, the Cooper Chapel isn't alone. The pages of this magazine are filled with incredibly beautiful steel structures. Exposed steel has become so commonplace that the AISC *Code of Standard Practice* now has AESS standards with five levels to help designers and fabricators select the appropriate appearance and associated level of work.
- Steel is fast. Because steel buildings can be completed faster than other structures, steel saves owners money on construction loans while generating cash flow sooner when the buildings open earlier. And you get this speed while still having the tightest tolerances of any structural material.

As the discussion wound down, Tom encouraged me to read Bill Gates' latest book, *How to Avoid a Climate Disaster: The Solutions We Have and the Breakthroughs We Need*, and think about how steel fits into the future. Fortunately, that was easy. One of Gates' key points is that the cement and steel industries contribute more than 10% of the world's greenhouse gas emissions. He correctly points out that our future depends on cutting emissions and calls for the production of cleaner iron ore that can be used as feedstock for modern, clean, electric-arc furnaces to produce steel rather than using older, dirtier integrated steel mills.

Although climate change is a global problem, fortunately, *America's* structural steel industry began realizing Gates's dream in 1987. Today, all of the more than 4 million tons of wide-flange produced in the United States comes from electric-arc furnaces. As a result, rather than depending on iron ore, more than 93% of the raw material comes from scrap and the main carbon emissions are from generating electricity, not from producing iron ore and coke.

Steel really is freakin' amazing—and I hope you all will help me remind everyone else, too!

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steel interchange

High-Temperature Applications

I am currently evaluating steel structures that will be subjected to high temperatures. What guidance and information would you recommend?

Designing steel for elevated service temperatures, especially greater than 700 °F, is highly specialized. Material properties change at elevated temperatures, including the coefficient of expansion, modulus of elasticity, yield strength, and tensile strength. Additionally, the stress-strain curve becomes more rounded, causing a further strength reduction for members controlled by stability limit states.

Other potential effects that are generally considerations only for service temperatures exceeding 750 °F are creep (including creep rupture and creep buckling), temper embrittlement, graphitization, and oxidation/corrosion/scaling. For designing at temperatures greater than 700 °F, selecting proper materials to resist these effects is an essential first step. Additives such as molybdenum and chromium have shown highly improved resistance to graphitization, temper embrittlement, and creep rupture (Meier, 2014).

Material Properties

For fire conditions, Appendix 4 of the 2016 AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360, **aisc.org/specifications**) contains information on material properties at elevated temperatures. However, these values should only be used when designing for fire conditions and other situations where large inelastic deformations are acceptable because the yield strength values are defined at 2% strain. This makes a significant difference because, at elevated temperatures, the stress-strain curve loses its well-defined yield point, and the curve becomes nonlinear at earlier stages of loading. At high temperatures, the curve for mild steel is shaped more like an aluminum stress-strain curve. Generally, 2% strain is not acceptable for design at elevated temperature service under otherwise normal conditions.

Brockenbrough and Merritt (1994) published accurate, designer-friendly equations to predict the elevated-temperature yield strength and modulus of elasticity for normal (0.2% strain) design conditions. In the newer editions of this handbook, these equations were removed, so try to locate the 2nd Edition. The equations were originally published in a journal paper by Brockenbrough (1970). Slightly more conservative values for yield strength, ultimate strength, and modulus of elasticity are tabulated in the 2010 ASME *Boiler and Pressure Vessel Code* (ASME, 2011).

Welds

The weld metal should be selected to match the base material. If the steel selected is not listed in AISC *Specification*, Section A3, you may need to design the welds according to the ASME *Boiler and Pressure Vessel Code* or another method.

Based on tensile tests of the deposited weld metal by Heuschkel (1954) for base metals listed in AISC *Specification*, Section A3, I have used the following design guidelines on past projects:

> For temperatures up to 600 °F, no strength reduction is required. For temperatures above 600 °F, the reduction factor can be calculated using linear interpolation between points (1.0, 600 °F) and (0.0, 1,300 °F). This results in a reduction factor of 0.42 at 1,000 °F. The actual curves are nonlinear, so this approach may be too conservative at temperatures above 1,000 °F.

Recent tests on transverse welded joints (Conlon, 2009) showed a reduction factor of 0.60 at 1,000 °F. Table 5.6 in Conlon's Thesis lists the reduction ratios at each temperature.

Stability

Another problem with elevated temperature design is this: The yield point on the stress-strain curve is not as well defined for elevated temperature design as it is for room-temperature design. This has a negative effect on member stability beyond the reduction due to the degraded yield strength and modulus of elasticity. Takagi and Deierlein (2007) developed design equations for the flexural buckling of columns and lateral-torsional buckling of beams at elevated temperatures, based on the AISC *Specification*, and their equations have been adopted into the provisions of *Specification*, Appendix 4.

Creep

Creep is the time-dependent permanent deformation that occurs when a material is subjected to sustained loading at temperatures in the creep range. Creep failure occurs due to excessive deformation, creep buckling in compression members, and creep rupture in tension members. Performance is dependent on stress, temperature, time, and the chemical composition of the steel. For carbon steels such as A36, A992, and A572 Grade 50, creep should be considered for temperatures exceeding 750 °F. At temperatures equal to or less than 700 °F, commonly available structural steel shapes and plates are usually the most economical materials. At temperatures greater than 700 °F, material selection is a compromise between cost and creep performance.

Bo Dowswell, principal with ARC International, LLC, is a consultant to AISC.

Two different approaches are available when designing for creep:

At sustained service temperatures greater than 700 °F, the effects of creep must be considered for most common structural steel shapes and plates. In design, this is typically done by reducing the allowable stresses. The allowable stress should be based on the time of sustained load at the sustained temperature during the useful life of the structure. In this case, creep deformation occurs, but failure is avoided until after the useful life period.

Another approach is to select materials that are resistant to creep at the service temperature. These alloy materials are usually costly compared to mild steels. These materials are typically available only for plates. Therefore, any shapes must be fabricated, built-up members, which further increases the cost.

Graphitization

When steels are subjected to elevated temperatures for prolonged periods, carbon migrates to the grain boundaries, forming graphite nodules that have an embrittling effect, known as graphitization: the breakdown of the chemical microstructure into its base elements of ferrite (iron) and graphite (carbon). This breakdown creates a localized weakened failure plane in the material, which leads to a higher potential for brittle fracture. Detrimental effects of graphitization include a considerable reduction in mechanical properties such as tensile strength, ductility, and creep resistance (Meier, 2014). The rate of graphite formation is affected by temperature, time, and chemical composition of the steel. According to Meier, "Temperatures below 800 °F may experience graphitization, but at such a marginal rate that it can be neglected over the design service life."

Meier lists some typical materials (ASTM designations) used in flue-gas ducts and their suggested maximum temperatures to reduce the risk of graphitization:

Maximum Temperature 800 °F: A36, A572, A53 Grade B, A500
Maximum Temperature 1,000 °F: A588 A or B, A242 Type I
Maximum Temperature 1,100 °F: A335 (pipe), A387 (chrome molybdenum)

Judgment will be needed to determine an appropriate material and design method for the project conditions. If the steel members will not resist sustained loads, creep is not a concern. However, the other effects should be considered. Researching the effects of temper embrittlement and oxidation/corrosion/scaling on the selected material is recommended.

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Bo Dowswell, PE

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steel quiz

This month's quiz focuses on the recently published 2020 *RCSC Specification*, which is available at **aisc.org/specifications**.

(See "Bolting Ahead" in the April 2021 issue, available in the Archives section at ***www.modernsteel.com****, for more on the new* RCSC Specification.*)*

1 **True or False:** When using the twist-off tension-control bolt method of pretensioning, the spline end is checked twice.

2 Which of the following pieces of information is a new addition to the list of things the engineer of record (EOR) may specify that may require their attention or approval when preparing the contract documents?
a. Use of alternative-design bolting components, assemblies, or installation methods, including the corresponding installation and inspection requirements that the manufacturer provides
b. Use of thermal cutting of bolt holes that are produced freehand or are intended for use in cyclically loaded joints
c. Specifying when threads must be excluded from the shear plane, if applicable
d. Use of a value of D_u other than the value provided in Section 5.4.

3 **True or False:** The expanded provisions on alternative-design bolting components now provide additional limitations for manufacturing, dimensions, and inspection of bolting components but do not allow for alternative coatings.

4 **True or False:** The storage and lubrication requirements provided apply to all bolting components and assemblies that are to be used on site.

5 Which of the following is the nominal slotting short-slotted bolt hole dimension for a $1\frac{1}{4}$ in. diameter bolt?
a. $1\frac{5}{16} \times 1\frac{5}{8}$ in.
b. $1\frac{3}{8} \times 1\frac{5}{8}$ in.
c. $1\frac{3}{8} \times 1\frac{5}{16}$ in.
d. $1\frac{1}{4} \times 1\frac{5}{8}$ in.

6 Which of the following is the correct range of turns for a snug-tight condition using turn-of-nut pretensioning for a bolt with a length five times that of the diameter, with both outer faces normal to the bolt axis?
a. $\frac{1}{2}$ turn to $\frac{5}{6}$ turn
b. $\frac{2}{3}$ turn to $\frac{5}{6}$ turn
c. $\frac{1}{3}$ turn to $\frac{2}{3}$ turn
d. $\frac{1}{2}$ turn to $\frac{2}{3}$ turn

7 **True or False:** Compressible materials are permitted in the grip of a snug-tightened thermal break joint in the primary load resisting system so long as the bolts are subject to shear and long-term loads are limited to 30% of the material's ultimate load.

8 Why is preinstallation verification testing essential?
a. It verifies the adequacy and proper use of the specified pretensioning method to be used
b. It demonstrates the suitability of the bolt tightening equipment to be used during installation
c. It determines the installation torque for the calibrated wrench method of pretensioning
d. All of the above

9 **True or False:** Torque measurement results are not always consistent for inspection.

TURN TO PAGE 14
FOR THE ANSWERS


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1 **True.** Section 7.2.3 describes that after snug tightening, an intermediate verification is required to ensure the splined end is not severed, as well as a final verification after pretensioning to ensure it is severed.

2 **c.** The Commentary to Section 1.6 was expanded to include additional considerations for the engineer when preparing the contract documents.

3 **False.** Section 2.12.3 does not prohibit alternative coatings but states that they shall meet the performance criteria specified in the alternative coating standard and shall not have a detrimental effect on the bolting components or assemblies.

4 **False.** Section 2.10.7 exempts temporary bolts from the stated requirements.

5 **b.** Table 3.1 was updated to indicate that the maximum hole size is permitted to be ⅛ in. over the bolt diameter for bolts with a diameter greater than 1 in.

6 **d.** The nut rotation tolerance was revised in Table 8.1 to +60° (⅙ turn) and -0°. Using the ½ turn stated in the table, this results in a range of a minimum of ½ turn and a maximum ⅔ turn.

7 **False.** The commentary to Section 1.1 contains a newly added discussion on the use of compressible material in the grip of a joint. The 30% ultimate load recommendation still applies, but thermal break joints are not intended for primary load-resisting systems.

8 **d.** All the tasks, including two others not shown, are listed as necessary reasons. Additional clarification on the need for preinstallation verification is now provided in the Commentary to Section 7.

9 **True.** The Commentary to Section 9 explains that torque measurements are dependent on the friction between bearing faces and threads and are influenced by the lubrication conditions of the bolting components. Instead, routine observation of installation methods is always preferred.

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steelwise

COMPRESSION MEMBER DESIGN: A PRIMER

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

Tips on compression design as it is addressed in the AISC *Spec.*

Richard M. Drake (**rick.drake@fluor.com**) is a senior fellow in structural engineering, and **Erik Espinoza** (**erik.espinoza@fluor.com**) is a director in structural engineering, both with Fluor Enterprises, Inc.

Last month's SteelWise article, also written by Drake and Espinoza, focused on tension member design. You can read it in the Archives section at **www.modernsteel.com**.

LAST MONTH'S STEELWISE was all about tension in member design.

This month, it's compression's turn.

Here, we'll highlight key steps for designing compression members according to the provisions of the 2016 AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360, **aisc.org/specifications**). Note that we'll focus solely on W-shape columns, though much of the material is readily applicable to other rolled shapes as well.

A compression member is any member that is loaded with an axial compression force. Compression members are commonly located in building columns, structural bracing, and top chords of trusses. Loads transfer to a building column from the columns above and from beams framing into it. If the center of gravity of the loads coincides with the center of gravity of the column, then the column is considered concentrically loaded, though in practice, columns are seldom concentrically loaded. Ideal concentrically loaded columns do not exist since all columns have accidental eccentricities resulting from material imperfections, end connections, initial crookedness of rolled shape, eccentric loads, and residual stresses (see Figure 1).

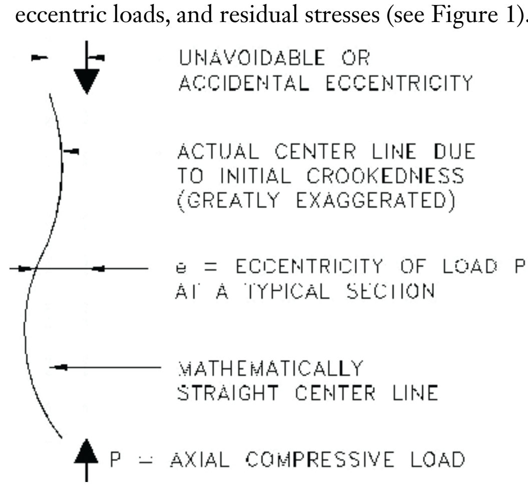


Fig. 1. Common loading eccentricities.

Application of external load (P) at eccentricity (e) introduces flexural stress. If the member is short, the lateral deflection is small, and the eccentricity will introduce negligible flexural stresses—and the column can take a lot of axial load before buckling. If the member is long, the lateral deflection is large, and the eccentricity can introduce significant flexural stresses—and the column will take much less axial load before buckling.

Elastic Column Behavior

Critical buckling. Consider an ideal concentrically loaded column, making the following assumptions:

- The column is braced against lateral translation (sidesway) but allowed to rotate at each end.
- The column is perfectly straight
- The load is applied along the column's centroidal axis.
- The column material behaves elastically.

If the axial load (P) is gradually applied, then the column will eventually buckle into the deflected shape of a simply supported beam. AISC calls this limit state flexural buckling. The axial load that forces the buckled shape is the critical buckling load (P_{cr}). The column buckles before the axial stress level reaches the material yield stress. The column is entirely elastic and is a function of its flexural stiffness (EI), as shown by Euler's critical load formula:

$$P_{cr} = \frac{\pi^2 EI}{L^2}$$

Dividing both sides of the equation by the column cross-sectional area will convert this relationship to the critical stress, as used in the *Specification*. For mathematical convenience, define the radius of gyration (r) as:

$$r = \sqrt{\frac{I}{A}}$$

$$F_{cr} = \frac{\pi^2 E}{\left(\frac{L}{r}\right)^2}$$

Yield strength (F_y) and tensile strength (F_u) have no effect on the critical stress. A36 and A992 steels have the same modulus of elasticity and will buckle at the same load for a given column size and support condition. If this elastic critical buckling stress (F_{cr}) exceeds the material yield strength, then the critical stress equation is not applicable.

Every column has an X-axis and Y-axis, each with its own I (area moment of inertia), r and L (length). Every column will flexurally buckle about the axis with the highest slenderness ratio (L/r) and therefore the lowest critical stress (see Figure 2).

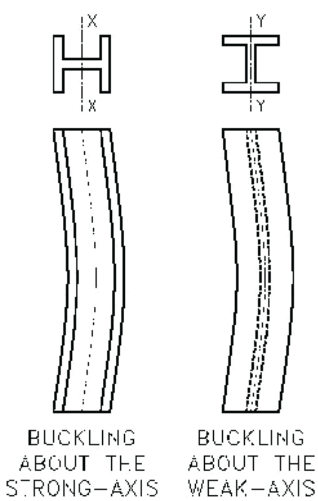


Fig. 2. Flexural buckling of columns can occur about either major axis.

Effective Length

The concept of effective length is simply a mathematical method of replacing a given column with an equivalent pinned-end column braced against side sway. In other words, the elastic flexural buckling length is equal to KL, where K is the effective length factor and L is the column length between supports.

$$F_{cr} = \frac{\pi^2 E}{\left(\frac{KL}{r}\right)^2}$$

Effective length factors can be derived by repeating the critical buckling load differential equation derivation with different boundary conditions, and they can also be determined graphically (see Figure 3).

Specification Commentary Table C-A-7.1 provides a summary of theoretical effective length factors based on upper bound derivations. It also provides recommended values that should be used in design in recognition that member end boundary conditions are rarely fully pinned or fully fixed. Note that in the *Specification*, KL is replaced with L_c.

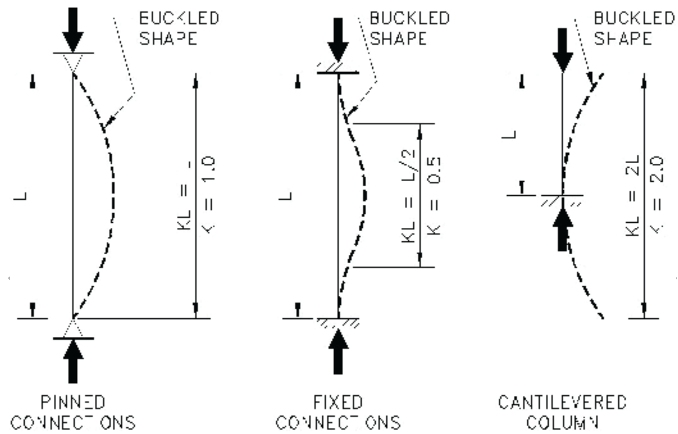


Fig. 3. Example column effective lengths.

Local Buckling

Structural steel shapes are comprised of rectangular plate elements, each with its own aspect ratio (λ). See Figure 4 for an example W-shape.

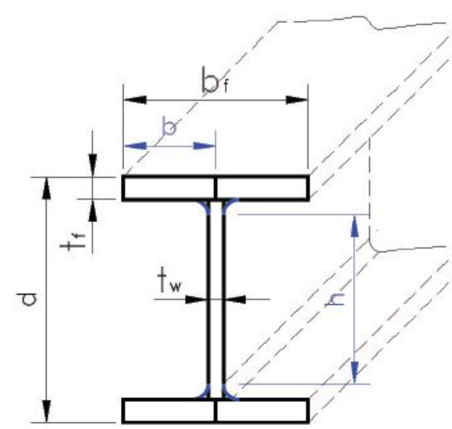


Fig. 4. W-shape plate elements.

For W-shapes:

$$\lambda_{flange} = \frac{b}{t_f} = \frac{\left(b_f/2\right)}{t_f} = \frac{b_f}{2t_f}$$

$$\lambda_{web} = \frac{h}{t_w}$$

If an individual plate element has a high aspect ratio, it may become unstable and experience local buckling before flexural buckling of the overall section can occur. The section plate elements are classified into two types based on their boundary conditions and unstiffened and stiffened elements. Unstiffened elements are supported along only one edge parallel to the normal

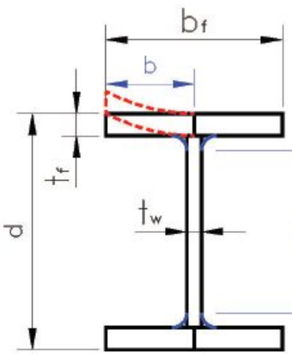


Fig. 5. Local buckling of unstiffened elements.

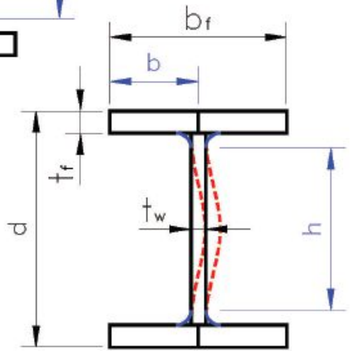


Fig. 6. Local buckling of stiffened elements.

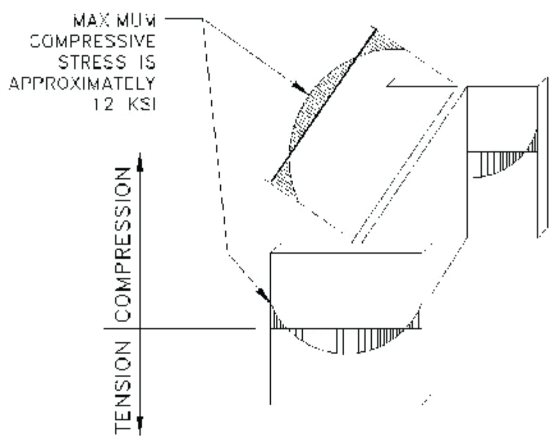


Fig. 7. Typical residual stresses in a rolled shape.

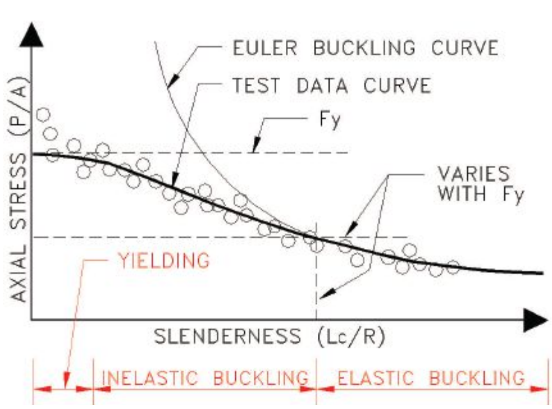


Fig. 8. Column failure modes.

compressive force and will buckle like a cantilever beam (see Figure 5). Stiffened elements, on the other hand, are supported along both edges parallel to the normal compressive force and will buckle like a fixed end beam (see Figure 6).

Specification Section B4 includes a classification system to identify the compressive members that may experience local buckling before flexural buckling. Limiting width-to-thickness ratios (λ_r) for local buckling have been developed based on elastic plate buckling theory and are listed in *Specification* Table B4.1a for members subject to axial compression.

Compression members are classified as non-slender element sections if all elements have aspect ratios less than or equal to the limiting width-to-thickness ratios.

$$\lambda \le \lambda_r$$

Compression members are classified as slender-element sections if any elements have aspect ratios that are greater than or equal to the limiting width-to-thickness ratios. Compression tests on short W-shapes (called column stubs) show that all fibers on the cross section are not stressed at the same level. Residual stresses cause early yielding, followed by inelastic behavior.

$$\lambda > \lambda_r$$

Inelastic Column Behavior

Residual stresses. Residual stresses are the stresses that remain in a member after it has been rolled into a finished shape (see Figure 7). Sources of residual stresses in structural steel include uneven cooling, which occurs after hot rolling of structural shapes. Note the following:

- The thicker flanges cool more slowly than the thinner webs
- Flange tips have greater exposure to air and cool more quickly
- Compression residual stresses exist in regions that cool the quickest
- Tension residual stresses occur in the regions that cool the slowest

Other causes of residual stress include cold bending or cambering during fabrication, punching of holes, cutting, or welding during fabrication.

When a compression load is applied to a column, the parts of the column with residual compressive stresses will reach the material yield stress before the rest of the section and go into the plastic range of behavior. The stiffness of the column will be reduced and become a function of the part of the column cross section that is still elastic. As the applied load increases, the column will buckle inelastically because part of the cross section has reached the yield stress before flexural buckling occurs.

Failure Modes of Columns

Test results indicate the following:

- Columns with smaller slenderness ratios tend to buckle inelastically before elastic buckling can be achieved (see Figure 8).
- Short columns fail by yielding. Nominal compression strengths are predicted using yield stress theory.
- Long columns fail by elastic buckling. Nominal compression strengths are predicted by considering elastic buckling theory.
- Intermediate columns fail by inelastic buckling. Nominal compression strengths are predicted using empirical formulae. Most practical (economical) columns end up in this range.

Specification Requirements

When determining the nominal strength of a compression member (P_n), it is necessary to first classify the shape for axial compression. Members in axial compression that are classified as non-slender element sections can reach flexural buckling of the entire cross section before local buckling of any elements. Members in axial compression that are classified as slender element sections will experience local buckling of one or more elements before flexural buckling of the entire cross section.

Non-Slender and Slender Element Sections. *Specification* Section E3 applies to non-slender element sections as defined in *Specification* Section B4 for members in axial compression. There are multiple useful formulas that apply to these elements:

Determine the elastic buckling stress (F_e).

$$F_e = \frac{\pi^2 E}{\left(\frac{L_c}{r}\right)^2}$$

Determine the critical stress (F_{cr}) using the appropriate equation, depending on the column slenderness ratio $\left(\frac{L_c}{r}\right)$.

For short and intermediate columns:

When

$$\frac{L_c}{r} \le 4.71\sqrt{\frac{E}{F_y}}$$

$$F_{cr} = \left(0.658^{\left(\frac{F_y}{F_e}\right)}\right)F_y$$

For long columns:

When

$$\frac{L_c}{r} > 4.71\sqrt{\frac{E}{F_y}}$$

$$F_{cr} = 0.877F_e$$

Determine the nominal compression strength (P_n).

$$P_n = F_{cr}A_g$$

Specification Section E7 applies to slender element sections as defined in Section B4 for members in axial compression. The procedure is not included here for brevity.

Manual Design Aids

Column load tables. AISC has created over 200 pages of column load tables to tabulate the calculated available strength for common column shapes and sizes, reasonable effective lengths, and common material strengths. These tables are located in Part 4 of the AISC *Steel Construction Manual* (**aisc.org/manual**).

For each shape, the tables consider the most common material yield stress only, including:

- W-shapes (W14 and smaller), F_y = 50, 65, and 70 ksi
- HP-shapes, F_y = 50 ksi
- Rectangular HSS, F_y = 50 ksi
- Round HSS, F_y = 46 ksi
- WT-shapes, F_y = 50 ksi
- Double-angles, F_y = 36 ksi
- Single-angles, F_y = 36 ksi

Note that while the double and single angles are listed as 36 ksi in the 15th Edition of the *Manual*, they will be updated to 50 ksi in the 16th Edition.

You must use *Specification* formulas for other shapes and yield stresses. Tables are limited to $\frac{L_c}{r} \le 200$ because AISC prefers that you not exceed this.

Tables assume that weak-axis buckling will govern the column design and are calculated based on L_{cy} in feet. If L_c is not the same for both axes, then the table may still be used to determine the available strength by converting the X-axis effective length, L_{cx}, to an equivalent Y-axis effective length, $L_{cy(equiv)}$.

$$L_{cy(equiv)} = \frac{L_{cx}}{\left(\frac{r_x}{r_y}\right)}$$

Every column will buckle about the axis with the greater slenderness ratio, represented by the larger of L_{cy} or $L_{cy(equiv)}$. Enter the column load tables with the larger of L_{cy} or $L_{cy(equiv)}$ and select the precalculated value for available strength. Table values consider the classification of sections for local buckling and are correct for all sections of *Specification* Chapter E, including Section E3 (non-slender) and Section E7 (slender).

Super tables. AISC has created nearly 100 pages of load tables to tabulate the calculated available strength for W-shapes ranging in size from W44 to W4 with F_y = 50 ksi. These tables are located in Part 6 of the *Manual*. AISC calls *Manual* Table 6-2 its "super table" because it combines some of the best design strength features of the *Manual* beam and column design aids. Although these tables were created to facilitate the design of members in combined flexure and axial compression, they are very useful for evaluating W-shape columns that are not included in the column load tables.

Additional Considerations

Although this primer is intended to summarize the nominal compression strength requirements in the *Specification*, designers are cautioned that the choice of member cross sections and connection details may introduce eccentricity and moment when designing compression members. In those cases, the designer should consult *Specification* Chapter H for combined flexure and axial forces. ■

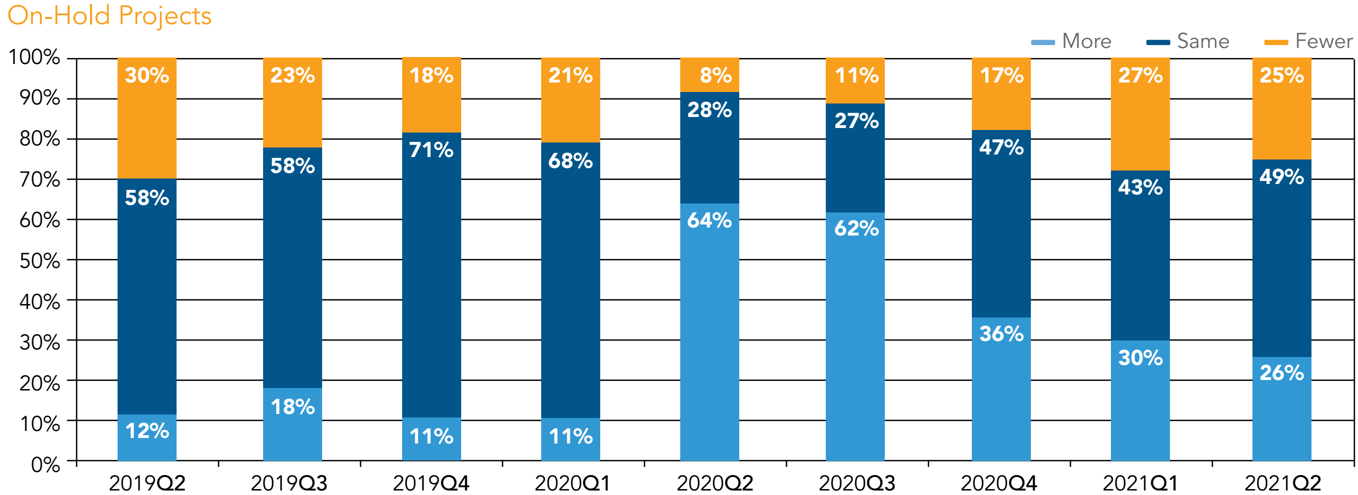
Data Driven highlights market trends, economic forecasts, or other relevant numbers that affect steel design and construction. This month's data focuses on AISC's Business Barometer.

data driven

AISC BUSINESS BAROMETER

BY JOE DARDIS

On-Hold Projects



AS A STEEL FABRICATOR, do you notice longer lead times on materials or see more of your projects put on hold from time to time? Are you finding more success with certain project types? And do you ever wonder whether other fabricators are experiencing the same thing?

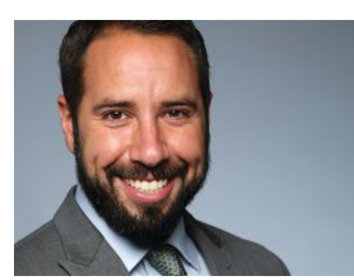
For the past 25 years, the AISC Business Barometer has been answering these questions for you. The Barometer is an anonymous, quarterly survey sent out to all AISC full member fabricators, asking for feedback on business conditions, lead times, on-hold projects, backlog, shop capacity, and future labor investment. In addition, the information collected measures current and future sentiments and variations based on region and project sector.

During times when in-person fabricator round table-type discussions can be difficult—e.g., the last year or so and counting—the Business Barometer is the next best thing. While hundreds of AISC's nearly 1,200 member shops participate in the Barometer every quarter, there are still several who don't regularly participate and whom we'd love to hear from. The more responses we get, the better we can measure the pulse of our industry and how we can adapt to the future.

If you're an AISC member fabricator, be sure to check your inbox and mail around the beginning of each quarter for the survey. You can fill it out online, mail it, or even still fax it.

You can view the most recent Business Barometer and all other market statistics at **aisc.org/industrystats**. And see above for a snapshot of the second quarter 2021 edition.

Looking at the above chart, "More Projects Being Put On Hold" has dropped continuously from 64% in Q2 2020 to 26% in Q2 2021. "Same Number of Projects Being Put On Hold" has bumped up to 49% in Q2 2021 from 43% in the previous quarter. "Fewer Projects Being Put On Hold" dropped to 25% in Q2 2021 from 27% in the previous quarter. This reporting is on a national basis only, not separated by region or segment.



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

field notes

A STABLE JOB

INTERVIEW BY
GEOFF WEISENBERGER

UMass engineering professor and structural stability expert Kara Peterman takes the long view on life.

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*.

MANY PEOPLE STRUGGLE to identify their, well, identity.

Not so with **Kara Peterman**. The assistant professor in the Department of Civil and Structural Engineering at the University of Massachusetts in Amherst has several identities (none of them secret): professor, engineer, and musician, to name a few—and also recent AISC Terry Peshia Early Career Faculty Award winner and Structural Stability Research Council (SSRC) McGuire Award for Junior Researchers winner.

"Life is long," she observed more than once in our interview, emphasizing the importance of a well-rounded life, as well as the possibility that careers can—and sometimes should—switch. And it's a lesson, in addition to structural education, that she passes along to her students. In this month's Field Notes interview podcast, she discusses how an art history class spurred her to explore the field of structural engineering, her thoughts on the present and future of stability research, and how she's stuck with the clarinet for more than two decades.

Where did you grow up?

I grew up in Hong Kong when it was still a British colony, and then after five years, my folks moved to Fairfax, Va., where I spent the rest of my childhood.

Wow, how did your parents end up in Hong Kong?

Essentially, my father was working for Apple. And my parents have a lot of history in Southeast Asia, and both spoke Chinese very well.

What got you interested in buildings in the first place?

I went into college knowing that I wanted to be an engineer, but I had no idea what type of engineer. I was all over the map, considering fields like nuclear engineering and electrical engineering. But then I took an art history class and saw a picture of a Gothic cathedral's ceiling vault, and I was just really amazed by how they managed to do that back in the 1200s and how that structure worked. And suddenly, the focus began to sharpen on what I really wanted to do, and I dedicated myself to structures after that.

I love the irony of becoming interested in engineering based on an art class! Switching gears, can you talk a little bit about your activities with the SSRC?

I got involved in stability research through my master's and my PhD work at Johns Hopkins—I did most of my studies in cold-formed steel—and my first-ever conference presentation was at NASCC, where I gave a talk at the SSRC sessions in 2010 or 2011. After I finished my PhD, I was doing post-doctoral work at Northeastern University, and I was asked to take on the role of vice-chair for the thin-walled structures task group of SSRC, then quickly went on to become chair, and I recently finished my two-year term as chair of that task group. And just recently, I was voted to be on the executive committee for SSRC. The group has been really welcoming from the very beginning when I was a 23-year-old researcher straight out of college, and it's helped me advance in my career.

What do you see as some important upcoming topics when it comes to stability research?

I think the types of problems that we apply stability solutions to will continue to broaden. I know there's a lot of exciting work in the energy industry where there's a structural stability solution to make more efficient wind turbines, for example, and I think we'll continue to see development there. I think there's quite a bit to be done in terms of improving building information modeling (BIM) when it comes to stability information. And I think advanced manufacturing techniques like 3D printing also have a role to play. For example, how do steel and other metals that are printed behave differently from traditional steel?

Let's talk a bit about your career at UMass. What made you decide to go into teaching?

There are a lot of ways a structural engineer can impact the world, and designing a building that is used and loved and an essential part of the community is a fantastic way to do that. And being able to teach people what I do and sort of give back in that sense was very important to me. The research lens is obviously very important as well. I think about how I can take the tools I learned in my studies and make the world a better place. My PhD advisor, Ben Schafer, recently told me a quote: "You're much more likely to teach a genius than to be one." I can say that I'm a capable structural engineer, but I'm much more likely to teach somebody over my career who's going to invent the society-changing thing or the start-up that turns into the big multinational company, and that's exciting.

What classes are you teaching?

Historically, I taught strength of materials, which is super-fun, and advanced steel designs. And then I recently switched over to teaching statics, which is also fun, and I developed a new course called unified structural design, which is a structural systems class. We look at arches, repetitively framed buildings, cable-supported structures, and the design of tall buildings.

Are you able to talk about some of the current research you're involved in?

Absolutely. I'm doing a lot in diaphragms right now. And I have a project where, hopefully in the next year or so, I will be doing some shake table tests of cold-formed steel. We're looking at a couple of new proposed structural systems and what we're calling a dual-skin system, which looks at cold-formed steel joists with steel deck with a fiber cement board or panel on top of that, and that's been pretty exciting. I've also spent some time doing thermal modeling work for cold-formed steel. We've been trying to make our steel buildings as sustainable as possible, and we have a couple of collaborations with some architects at UMass to try and push that forward.

Back to teaching, do you have advice for engineering students going out into the world?

I think there's a lot of pressure on young folks these days to have it all figured out as soon as possible. But there's an important bit of perspective that needs to come into play, which is that life is long, and I think that bit of advice can be useful at various points in your career. A lot of my students are 18 years old. How can you possibly have it all figured out at 18? So I've always been an advocate for trying out different types of internships and taking a wide range of classes. People can expect to work between 30 and 40 years or even more, and that's an awfully long time to do just one thing.

I understand you've been teaching at UMass for almost five years. What do you like most about Amherst?

I think what I like most is the self-sufficiency of the community and western Massachusetts in general. We have a huge amount of local stuff, like food and manufacturing, and it speaks to a larger sense of self-sufficiency than I've seen elsewhere—like all of my food for the week is farmed within 50 miles of where I live. I would also say that the quaintness of New England is not something I've ever gotten over.

So I hear you're a clarinetist.

Yes, I have been playing since I was ten, so for 23 years. When I think about my identity, I think about myself as an engineer and I think about myself as a musician, but I've been thinking about myself as a musician for way longer. I play in a wind ensemble called the Valley Winds, and I also play in a symphony orchestra, the Pioneer Valley Symphony Orchestra, and it's just something I love to do. I've always been completely addicted to playing with other people, and I've never found a reason to stop, no matter how busy life got. I've always prioritized it. ■

This article is excerpted from my conversation with Kara. To hear more, including Kara's thoughts on her students' and her own recent NASCC presentations—and her love of dim sum—visit ***modernsteel.com/podcasts****.*

economics

TOPPING OUT

BY TOM SMITH

Infrastructure's big moment has been years in the making—but maintaining it as a top priority requires a collective and ongoing effort.

Tom Smith (**tsmith@asce.org**) is the executive director of the American Society of Civil Engineers.

IS 2021 THE YEAR our nation's infrastructure will finally get the attention and resources it deserves?

At the very least, things appear to be starting off on the right foot. President Biden's eight-year, $2.25 trillion American Jobs Plan, proposed on March 31, outlined a plan for addressing a sweeping collection of infrastructure needs and priorities, including surface transportation maintenance, replacing lead drinking water pipes, transitioning to clean energy, 100% nationwide broadband access, maintenance at our nation's ports, and much more.

The president sent a strong signal that his administration considers infrastructure investment to be not only the catalyst to jumpstart our nation's economic recovery but also his top priority now that the relief bill has been passed. While the hard work has just begun, including debates on the plan's scope and pay-fors, infrastructure is front and center, and the time is now for AISC and ASCE (American Society of Civil Engineers) members to mobilize and be heard—and with a sense of urgency and passion.

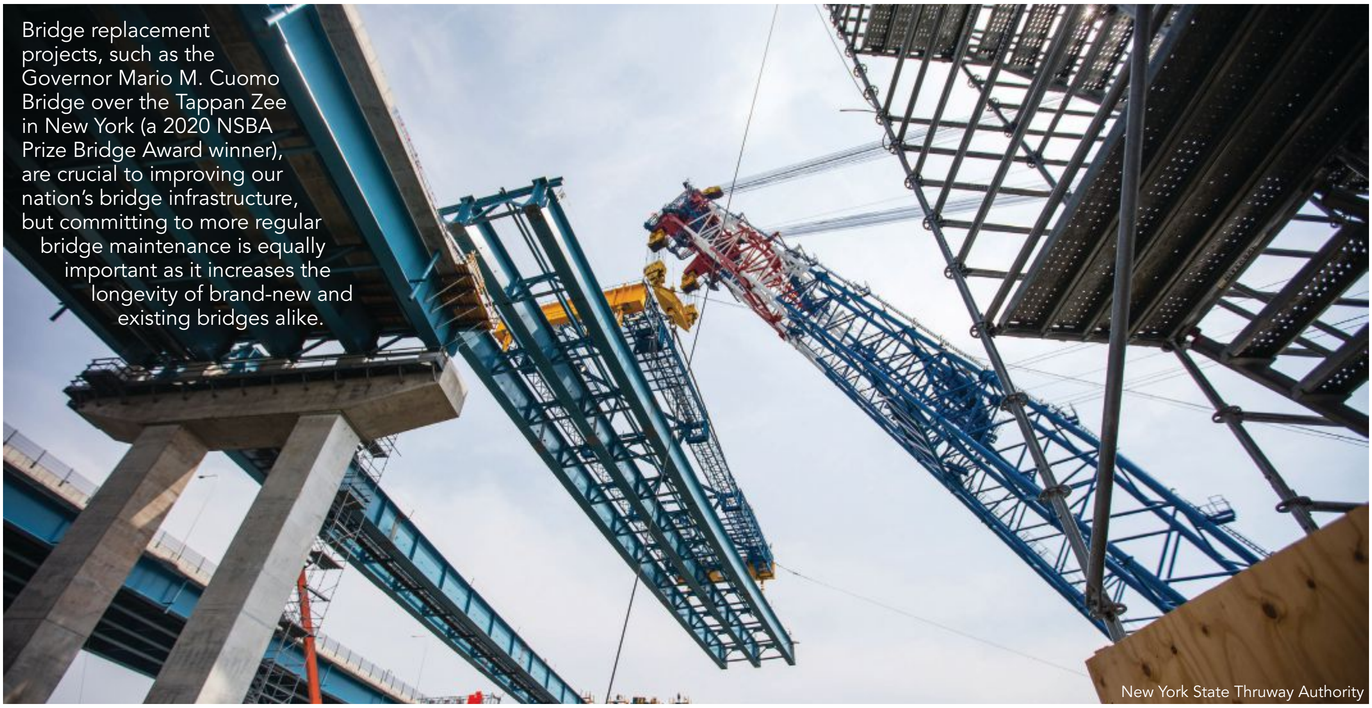
Positioning infrastructure as a top national priority has been years in the making. ASCE's quadrennial Report Card for America's Infrastructure has been underlining the issues our infrastructure systems face since 1998. The Report Card is designed to shine a light on the infrastructure beneath our feet—which is often out-of-sight, out-of-mind for most Americans—and its gradually deteriorating conditions and chronic underinvestment. Many years of news stories and raising the profile of infrastructure led to stronger voter support across the country, ushering infrastructure into the national conversation. ASCE's most recent 2021 Report Card (**infrastructurereportcard.org**) was highlighted in the American Jobs Plan, painting a picture of why such legislation is necessary, and more importantly, defining the investment and solutions required to maintain and modernize safe, resilient, and sustainable infrastructure.

How did we get here? How did our infrastructure systems reach such dire straits, and why is the price tag so high?

Infrastructure has long received bipartisan support, and members of Congress on both sides of the aisle have supported investment in the built environment over the years, yet other issues continued to take higher priority. As a result, many past administrations have been unable to move a comprehensive infrastructure bill forward, kicking the can farther down the road, while other countries moved swiftly ahead.

ASCE's 2021 report first defines and then grades infrastructure, assigning 17 categories of infrastructure a cumulative grade of C-, which is the first time since the Report Card's inception that the U.S. has received a grade outside of the D range. Nevertheless, this is not a score you'd want to take home to your parents, and there's much work to be done. Eleven of the 17 categories still scored in the D range, with transit (D-) holding the lowest grade and bridges being the only grade to decline since the 2017 report (C+ in 2017 to C in 2021).

A major reason for the low grades is the rapidly growing investment gap, leading to a maintenance backlog among key sectors. The report estimates that the U.S. is set to underinvest in its infrastructure network by $2.59 trillion over the next ten years, up from the $2.1 trillion underinvestment estimated in the 2017 report. Our surface transportation network alone is expected to receive $1.2 trillion less than what is needed to adequately maintain our systems over the next ten years.



Bridge replacement projects, such as the Governor Mario M. Cuomo Bridge over the Tappan Zee in New York (a 2020 NSBA Prize Bridge Award winner), are crucial to improving our nation's bridge infrastructure, but committing to more regular bridge maintenance is equally important as it increases the longevity of brand-new and existing bridges alike.

New York State Thruway Authority

Federal investment across most infrastructure networks has stayed stagnant or decreased steadily over time, while the country continues to react to, instead of proactively prepare for, more extreme weather events. For example, the federal gas tax, which plays a major role in supporting road and bridge maintenance as well as transit, hasn't been raised from 18.4 cents per gallon since 1993. By not addressing necessary maintenance over the years, the cost of repairs has snowballed as systems age and deteriorate beyond their useful life, resulting in a daunting maintenance bill for the country to cover.

Underinvestment puts a stranglehold on the national and global economy, as rough roads, congested ports, and interruptions to energy and water services disrupt trade and manufacturing. The report indicates that without significant investment, the U.S. will lose $10 trillion in GDP and 3 million jobs over the next 20 years.

These costs have a trickle-down effect on Americans. Poorly maintained infrastructure will cost each American household $3,300 a year on average over the next 20 years if conditions don't improve—a hidden tax we all pay, with no return on investment.

The manufacturing industry is especially vulnerable when infrastructure is not a priority. Not only do manufacturers produce the materials which build our bridges, roads, rail, and transit lines, but they also rely on an efficient transportation system to remain competitive in a global marketplace, where labor costs less virtually elsewhere else. Increasing the time and cost to make and transport goods will harm our ability to compete. In addition, when manufacturing plants suffer an electrical outage, machines are costly to stop and start, and productivity plummets as workers stand idly by.

ASCE's 2021 report mobilized policymakers and industry leaders alike, including organizations like Nucor, which joined ASCE in the Report Card release alongside Members of Congress, U.S. DOT Secretary Pete Buttigieg, and a variety of infrastructure experts. "It doesn't have to be this way," Secretary Buttigieg said, referring to the C- grade, "but it also won't change unless we make different choices, and that means a meaningful, generational investment in our country's infrastructure."

Federal, state, and local political leaders participated in the Report Card release, including Maryland Governor Larry Hogan; Senate Environment and Public Works Committee Chair Tom Carper (D-Del.); House Transportation and Infrastructure Committee Chair Peter DeFazio (D-Ore.); and Congressman John Garamendi (D-Calif.), all of whom echoed ASCE's sentiments on the need to invest more wisely. A number of these same political leaders met with President Biden the next day to work on the administration's infrastructure plan.

Decades of advocacy efforts across the industry, including members of AISC and ASCE using the ASCE Infrastructure Report Card, have developed bipartisan Senate support and led to this moment where a historic bill finally feels possible. Although the American Jobs Plan is not official legislation and there is a great deal of work to be done, the proposal signals that bold and transformative action is possible.

Maintaining and modernizing resilient and sustainable systems of road networks, bridges, rail, and water pipes, which we all rely upon every day, have long been issues that politicians on both sides of the aisle could agree upon. But these core issues for our nation's economy and the related job creation and global competitiveness have routinely been cast aside to address seemingly more urgent issues. With tools like the Report Card bringing these problems and solutions to the forefront and the collective voice of AISC and ASCE members, including engineers, fabricators, producers, contractors, developers, and suppliers, infrastructure can be a top federal priority once again. ■

Brightly colored exposed steel, visible from both the interior and exterior, is a defining characteristic of Washington, D.C.'s International Spy Museum.

I Spy

BY CHRIS GREGORY AND DANIEL COCCIARDI, SE, PE

Nic Lehoux, courtesy of Hickok Cole

THE INTERNATIONAL SPY MUSEUM has nothing to hide—at least when it comes to its framing system.

The 141,000-sq.-ft, eight-story, $162 million facility in Washington, D.C., includes three floors of museum exhibits resting on a five-story base of retail, education, and lobby spaces—and plenty of prominent architecturally exposed structural steel (AESS). Perched above the museum floors and cantilevering more than 20 ft beyond them to the north, the events space box provides architectural contrast to the inverted-pyramid museum structure below and contains offices, additional educational space, a dramatic events facility, and a green rooftop gathering space offering sweeping views of the city.

Having outgrown its original home in D.C.'s Penn Quarter, the museum wanted a new iconic location where it could continue its mission of educating the public on and showcasing the history of espionage. The overarching goal was to create a world-class museum with Smithsonian-level thermal and humidity controls in an architecturally impactful building.

Creativity and collaboration were critical to the success of this project, which was to be built above an existing operational subterranean shopping mall and garage that support a major Metro station and surrounding office building, just south of the National Mall on L'Enfant Plaza. In addition, the design and construction teams were also faced with a strict budget and a 48-month schedule. By applying for a building permit that specifically allowed the team to begin below grade, general contractor Clark Construction was able to expedite the procurement of design-assist trade partners and begin the first phase of construction well before the full building design was complete.

The final concept is a play on the business of espionage, hidden in plain sight. One of the main architectural features is a five-story glass atrium, dubbed "the Veil," that is suspended in front of an enclosed exhibit box and feature staircase. This unique structure provides a stage for the movement of people throughout the exhibit levels, contributing to the pedestrian experience along 10th Street. With its evocative form, powerful exposed structural steel sloped columns, and pleated glass veil, the museum serves as a catalyst to revitalize L'Enfant Plaza.

Unlike the secret agents it celebrates, Washington, D.C.'s International Spy Museum does its best to stand out.

Bucking the Trend

Washington is generally known as a "concrete town," where cast-in-place concrete structures are prevalent. However, as design discussions began during the early phases of the project, it became clear that structural steel was the best choice for the building structure. Steel provided the greatest flexibility needed to achieve the desired aesthetics as well as engineering, constructability, and cost benefits, and the project is framed with 1,600 tons of structural steel.

An intricate series of monumental stairs and platforms constructed of AESS members of varying shapes and profiles exist within the volume of the glass veil, all of which had expressed connections to the built-up sloping columns. Structural steel provided the strength and stiffness needed to achieve the architectural vision for this space by keeping the structural members as small and aesthetically pleasing as possible. In order to carefully evaluate vibrational performance of the stairs and platforms to ensure occupant comfort, steady-state analysis (using SAP2000) was conducted for the entire system, which accounted for the interaction between these stair/platform structures and the building's superstructure.

This unique combination of custom-built cantilevered columns, non-standard connection types (in the form of pins and large-diameter bolts for aesthetic reasons), and high-performance finishes (hot-dip galvanizing and intumescent paint) collectively made for a design unlike anything steel fabricator SteelFab had experienced before—and was a testament to structural steel's ability to strike a balance between being strong and appearing delicate.

Weight was also a major factor that could be successfully addressed by a steel framing system. The museum superstructure lives above an existing four-story below-grade concrete structure built in the 1960s, and the addition of a new building above was not anticipated in that structure's original design. In order to support the new museum superstructure loads, strengthening the existing concrete structure was necessary, so it was very important to minimize weight as much as possible. In addition, the typical floor system for the museum, consisting typically of W30 long-span composite beams and girders with lightweight concrete on metal deck, provided the open spaces required for the building's programming while also minimizing the self-weight of the structure. Vibrations were carefully analyzed during the design process and, in many cases, controlled steel member sizing.

Structural steel was a natural framing choice in helping to resolve design challenges associated with the building geometry and layout. For example, the sloping geometry of building columns at the south and west faces causes an inherent lateral drift from gravity

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Photo by Nic Lehoux, courtesy of Hickok Cole

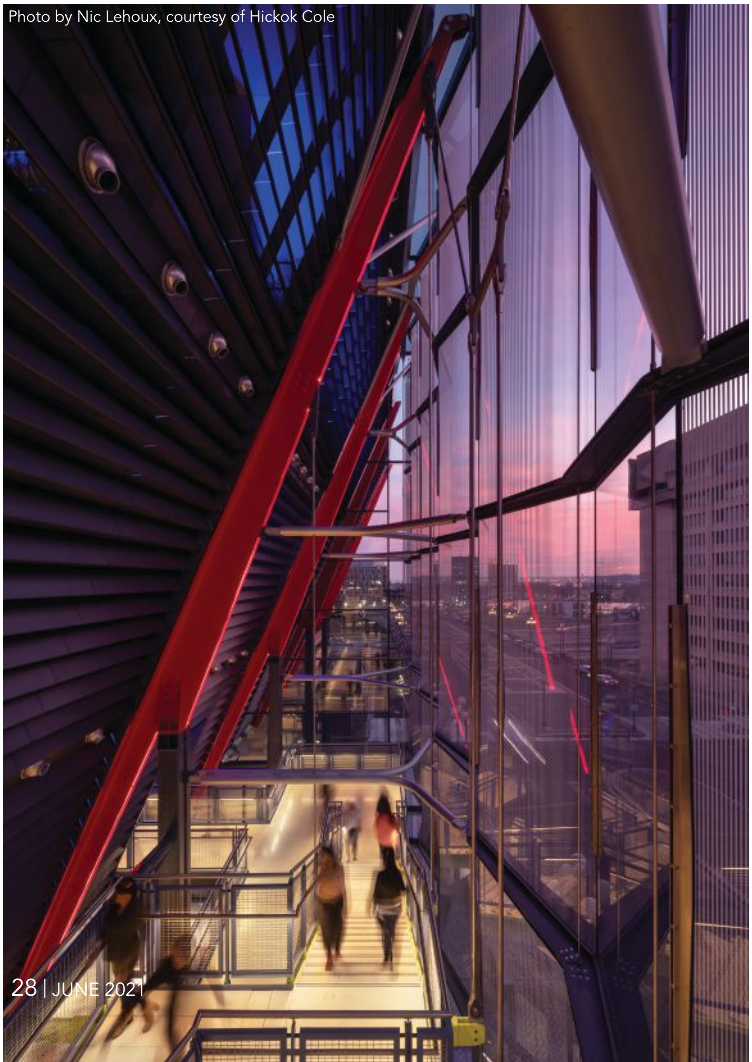


Photo by Nic Lehoux, courtesy of Hickok Cole

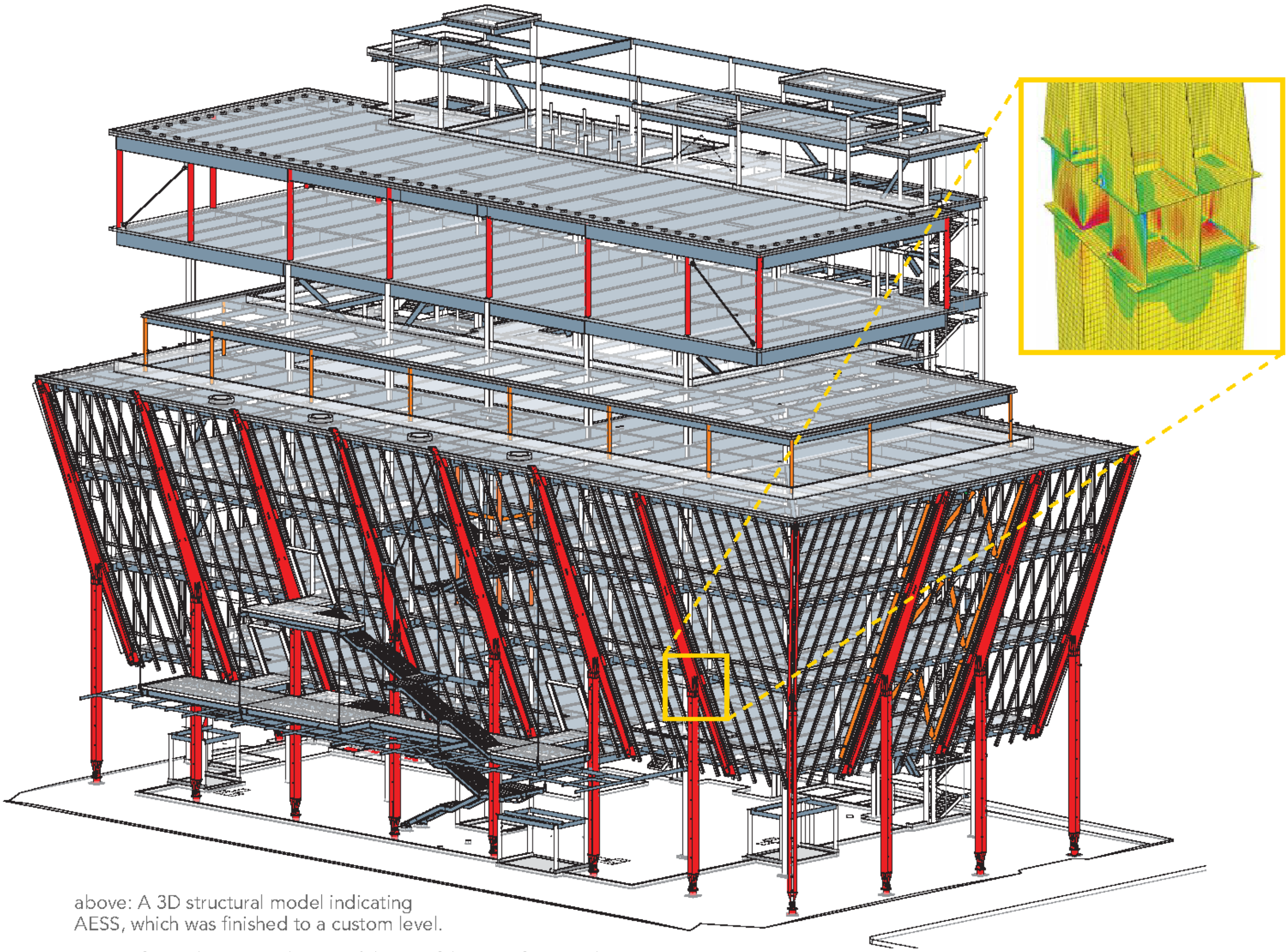
above: The building's "inverted pyramid" section is topped by an events level that cantilevers as far as 20 ft, 6 in.

left: The five-story "Veil" atrium is suspended in front of an enclosed exhibit box and feature staircase.

loads. Further compounding this issue, museum programming prevented placing traditional braced frames near the sloping south and west building faces, resulting in significant diaphragm torsion. To help address these issues, full story-depth "hat trusses" were placed above the highest museum level within the mechanical plant in line with primary building core braced frames. In addition, a three-story, sloping braced frame that is discontinuous to the ground was used at the south edge located just inboard of the façade to avoid intrusion on museum space, which required careful coordination between structural engineer SK&A, SteelFab, and the architects to implement successfully. The structural team also worked closely with other contractors to establish a construction sequence aimed at limiting lateral building drifts during construction due to the unbalanced sloping nature of the west and south building faces.

The events space, which is located above the museum spaces at Level 7, includes a 20-ft, 6-in. cantilever protruding above the roadway below to provide striking views of the U.S. Capitol. In order to alleviate vibrational concerns for potential rhythmic excitations, a combination of cantilevered beams, perimeter built-up steel box beams for torsional rigidity, and 3-in.-diameter stainless steel diagonal tension rods was used.

From a constructability perspective, steel construction had several advantages over cast-in-place concrete. The construction schedule for the project was aggressive from the start,



above: A 3D structural model indicating AESS, which was finished to a custom level.

inset: A finite-element analysis model view of the top of a pin column where it meets a sloping L-column (this connection also occurs at similar locations on the south and west faces).

and the use of structural steel allowed the building superstructure to be completed in a faster timeframe than would have been possible with cast-in-place concrete options. In addition, by implementing a design incorporating structural steel with un-shored composite metal deck construction, the need for expensive and intricate concrete formwork was eliminated. By not requiring formwork, the owner's goal of maintaining occupancy of the garage, retail areas, and office space below during construction was preserved.

Spying Challenges

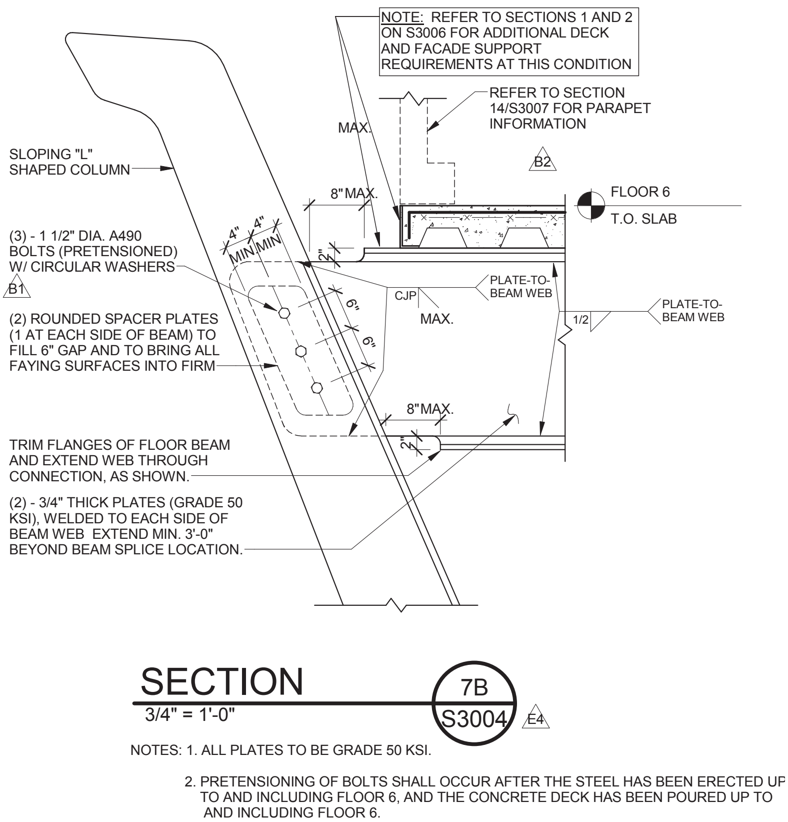
The museum's unique design came with its share of challenges, starting with the building site itself, which was not much larger than the building footprint and was also nestled in the middle of a dense area, requiring extensive planning and coordination in order to make the project a success. The tight site could not accommodate much steel on the ground, and active roadways surrounding the site limited the ability to stage trucks for unloading. And in order to meet the project schedule, the mill order needed to be placed and the model started well ahead of demolition of the existing topping slab/roof structure that the new building sits on. Once as-built information of the existing structure was available, some fairly significant modifications needed to be made to the base plate patterns and column heights to accommodate the existing conditions.

Meeting the aggressive project schedule established by ownership meant that in some instances, certain steel members needed to be released for fabrication prior to completion of all design elements. For example, SK&A worked closely with SteelFab to permit the release of the primary floor and braced frame framing members before finalizing all façade steel concepts. This required thoughtful planning and discussion to avoid subsequent coordination issues.

In order to maximize headroom, numerous mechanical duct openings were required through steel beams and girders at all floors. This required careful coordination between the engineers and SteelFab to ensure openings were located and adequately strengthened with welded plates in the shop prior to the members arriving in the field.

The team was also tasked with ensuring that the finishes of sloping interior columns and exterior columns matched when the latter required the extra process of hot-dip galvanizing (this included coordinating with intumescent paint requirements and fabrication/erection tolerances that differed between the two).

Another complication became evident during non-destructive testing of the splices between the main structural framing and the sloping column cantilevers, which are W30×124 sections with ¾-in. web doubler plates on each side of the web. These cantilevers were



The profies of the sloping "L" columns vary between 1 ft to 3 ft to follow the architectural design intent.

then spliced to main building beams made with the same built-up section with a CJP splice. When ultrasonic testing was performed, the interface between the doublers and the web of the W30 beams created false-negative results. Structural engineer SK&A and the testing agency eventually developed a testing procedure that would satisfy the design requirements.

AESS Isn't Top Secret

One of the most outstanding aspects of the museum is that the AESS is featured as a prominent portion of the design and not just used as a highlight or an accent. This steel, particularly the vibrant red exterior sloping columns, is the premier architectural feature seen not only by museum patrons and D.C. visitors and residents but even those passing by on nearby I-395.

These 11 perimeter columns, which support the building's "upside-down pyramid" shape—and which became known to the project team as the "red slopers"—are 85 ft tall and built from 1-in.-thick grade 50 plate. The columns are located along the south and west faces, which slope at an angle of approximately 2.5 vertical to 1 horizontal and act as part of the building's gravity load-carrying system. They taper and have reduced depths at the top where structural demand diminishes to reduce material cost and for aesthetics.

The cross sections of the columns look like back-to-back L's while the profiles vary between 1 ft to 3 ft to follow the architectural design intent. The slopers connect to double HSS16×8×⅝ vertical columns, referred to as "pin columns," at the fourth floor and are attached to a pedestal of HSS16×⅝ members by way of a 5.5-in.-diameter pin at the plaza level.

With the visual exposure and prominence of these AESS steel members and their connections, it was imperative for the team to get it right. To facilitate this process, SteelFab constructed a full-scale mock-up of the Level 4 connection early in the design phase to ensure structural and aesthetic compliance. This type of early and productive collaboration between SteelFab, SK&A, and the architects helped greatly with the project's success.

In order to fully understand the structural behavior of these complex pin and sloping column connections, SK&A conducted a detailed finite element analysis using SAP2000 to ensure stresses were within acceptable ranges for all load combinations.

Due to the structural steel being such a significant part of the façade itself, significant coordination was necessary between the steel package and the other elements that make up the façade system. It was especially crucial at the sloping front of the building, where the curtainwall veil and monumental stair are both connected back to the sloping steel columns. Connection points for the curtain wall and stair had to be incorporated into the shop fabrication of these columns, meaning that the connection points had to be coordinated with each supplier's internal tolerances and also allow for the project-specific steel erection tolerances. Both the stair hangers and curtain wall connections were attached to the columns by a 2-in. pin, so there was no room for error once the structural steel was fabricated and erected.

Another façade system that had to be coordinated was the aluminum panel rain screen system. In order to support this system, vertical W6 girts were placed around the entire building perimeter at 5 ft on center. Due to the tight project schedule, these panels could not wait for field dimensions to be taken between sloping columns prior to production, so the location of the steel columns had to fall within the prescribed AESS tolerances. The majority of this coordination took place by way of model sharing between individual subcontractors and a weekly (sometimes daily) 3D BIM (building information modeling) process in which SteelFab established allowable tolerances and individual system requirements.

There also were many different finish requirements for structural steel on the project, some of which necessitated different fabrication and erection details in order to accommodate various coating types and thicknesses. The following surface-prep and finish conditions had to be implemented for different elements:

- Uncoated for fireproofing
- Interior AESS prime painted for finish coats
- Interior AESS prepped for intumescent coatings
- Exterior AESS hot-dip galvanized prepped for finish coats
- Exterior AESS hot-dip galvanized prepped for intumescent coatings

To make sure the finish requirements for each piece of steel were correct, SteelFab traded color-coded models with the design team to visually check and ensure each piece came to the field with the correct finish, and the exposed steel was finished to a project-specific custom AESS level. (For details on the various AESS levels, see "Maximum Exposure" in the November 2017 issue, available at **www.modernsteel.com**.)

Early Involvement

SteelFab's involvement in the International Spy Museum project began approximately one year before it was awarded the contract for the structural steel package. During this time, conceptual and schematic design-level feedback regarding some of the feature elements was provided to Clark Construction and the rest of the design team. The willingness of the project team to engage a steel fabricator well ahead of the procurement stage helped steer certain design decisions in directions that maintained the architectural intent but allowed for more fabrication- and erection-friendly details.

Had this project been procured under a typical design-bid arrangement, it is not an exaggeration to say that three to four months would have been added to the structural steel schedule alone. A significant portion of the up-front work involved delving into the details of earlier discussions about coatings, connections, tolerances, and AESS expectations in general, and only with the full buy-in of all project team members was this kind of progress achieved in such a short amount of time.

Ironically, a museum dedicated to espionage sticks out like a sore thumb—a modern, steel and glass jewel box amongst brutalist buildings and concrete monuments. But in such a high-profile city, it doesn't hurt to draw a bit of attention to yourself. ■

For more images of the International Spy Museum, see the Project Extras section at ***www.modernsteel.com***.

Owner
The International Spy Museum

Development Manager
JBG Smith, Chevy Chase, Md.

General Contractor
Clark Construction Group, LLC,
Bethesda, Md.

Architects
Hickok Cole, Washington
(Architect of Record)
Rogers Stirk Harbour + Partners, London
(Design Architect)

Structural Engineer
SK&A, Potomac, Md.

Erection Engineer
Boston and Seeberger, Pennsville, N.J.

Steel Team

Fabricator
SteelFab, Inc. AISC CERTIFIED FABRICATOR,
Charlotte, N.C.

Detailer
Prodraft, Inc., a AISC DETAILER, Chesapeake, Va.

Taking on the need for speed in welding applications.

Accelerated Welding: Part One

BY DUANE K. MILLER, PE, CURTIS L. DECKER, SE, PE, PhD, AND MICHAEL S. FLAGG

AISC IS IN THE SECOND YEAR of an unprecedented six-year plan to increase the speed at which a steel project is designed, fabricated, and erected.

The goal is to increase the speed of delivery of a project by 50% by the end of 2025. Dubbed "Need for Speed" (or N4S), this initiative is examining all elements of the steel design and construction process, optimizing each step in a way that gives the owner a completed project more quickly.

In some circles, this concept is called increased "throughput" or an increase in "the amount of material or items passing through a system or process." In terms of N4S, the "item" is a building or bridge, and the "process" includes all of the design, detailing, fabrication, erection, and inspection activities.

The key metric behind N4S is, of course, time, and the goal is to reduce the time, from the start of design to delivery of a completed project to the owner. On the surface, this may seem like a renaming of "cost reduction" activities or "production enhancement" efforts—and in some ways, it is. However, N4S adds a new twist. Since the goal is to reduce the *overall* time of the delivery process, individual steps in the process may be more costly but result in an overall increase in throughput. This necessitates some changes in thinking.

Welding is a critical step in the steel construction process. In this article, twelve concepts are presented to reduce the time associated with such operations—and twelve more in a follow-up article. No one concept is a game-changer, but collectively these steps can contribute to the overall N4S goal.

A caveat: Each of the 24 concepts presented in these two articles is worthy of a full article, so additional investigation into the details of each one will be required. Nevertheless, these ideas will help anyone start to reduce the time associated with welding-related operations, whether your primary focus is on meeting the N4S goal or simply looking for ways to reduce costs and increase efficiency.

The 24 ideas are assigned to four broad categories: minimizing weld volumes, minimizing welding time, minimizing non-productive welding-related activities, and minimizing weld quality problems. Six concepts are provided in each category.

Minimizing Weld Volumes

The first category focuses on reducing the amount of welding required. Designers, detailers, fabricators, and erectors can all assist in achieving this goal.

Concept 1. Specify the smallest weld size possible, consistent with design requirements. The concept is simple: If a ¼-in. fillet weld is sufficient, specify ¼ in. If a PJP (partial-joint-penetration) groove weld is acceptable, do not specify a CJP (complete-joint-penetration) weld.

Consider this example: Using a 0.045 in.-diameter gas-shielded flux-cored arc welding (FCAW-G) electrode with optimized welding procedure specification (WPS) parameters for making a $^5/_{16}$-in. fillet (520 in. per minute, or ipm), the weld in Figure 1, Part a, was made with a travel speed of 11 ipm. In Part b, using the same electrode with an optimized WPS for a ¼-in. fillet (400 ipm), the travel speed was 13.5 ipm, with an increase in productivity of 17%. The time to make each of the welds in Figure 1 was the same. In this case, the productivity increased even though the smaller fillet weld was made with a lower wire feed speed than was the larger weld.

Mature specifications and codes, like the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360, **aisc.org/specifications**) and AWS D1.1 (**www.aws.org**), have dependable design criteria for the capacity of various weld types. There is no need for designers and detailers to specify larger than necessary welds "just to be safe."

Fig. 1.

Concept 2. Fillet welds versus PJP groove welds: Make the right choice. Both fillets and PJP groove welds can be used in tee joints, so which one is the right choice? For the same weld throat dimension, PJPs require half the metal as do fillet welds, giving PJPs an edge. However, PJPs require time-consuming beveling options ahead of the welding operations.

Two rules of thumb are helpful. First, if the weld can be made in a single pass, fillet welds are nearly always faster to make since they do not require beveling operations. Second, when the required weld throat dimension exceeds ¾ in. (which equates to a 1-in. fillet leg size), a PJP will likely be completed faster than a fillet.

Figure 2, Part a, shows a ¼-in. PJP on each side, while an equivalent strength fillet weld (5/16-in. each side) is shown in Part b. In this case, the fillet weld is the preferred option.

In contrast, Part c shows a 1 1/16 in. PJP weld on each side while part d shows equivalent-strength fillet welds (1½-in.). While the 2:1 ratio of weld volume remains the same as the weld sizes increase, the cost to bevel for the PJP remains fairly constant and the extra passes required to make the fillet weld greatly increase the time of production. For large weld throat dimensions, PJPs can be made faster than fillet welds.

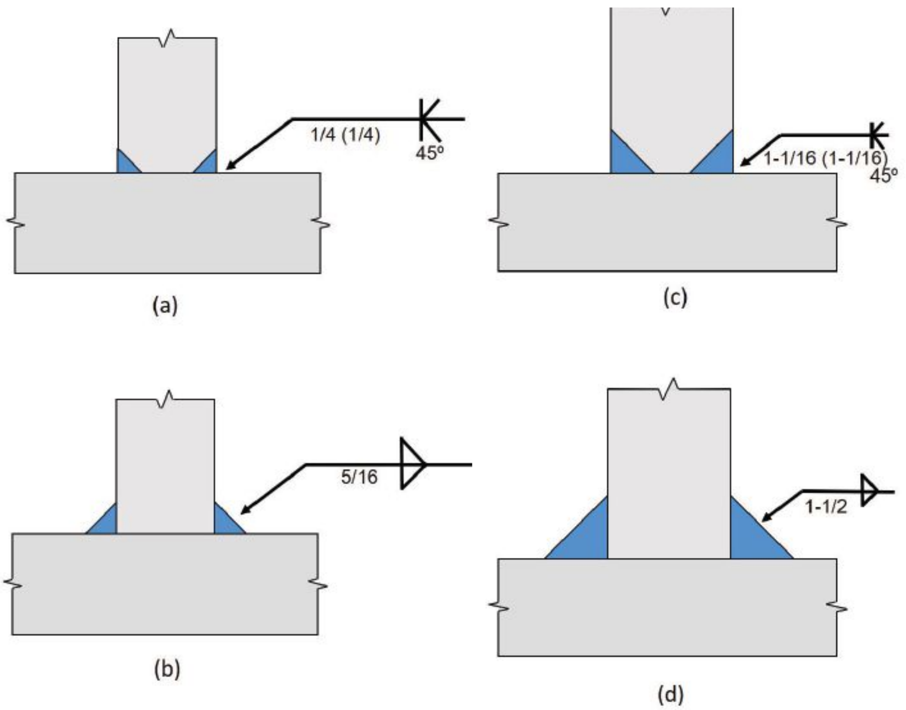


Fig. 2.

Concept 3. Select optimal groove weld geometries. Everyone knows that double-sided CJP groove welds require half as much welding as is required for single-sided CJPs, a 2:1 difference, right? Figure 3 seems to make this concept clear. But this figure is misleading, despite the common use of such illustrations. More thinking is needed, and detailers should be aware that some well-established ideas are simply not true.

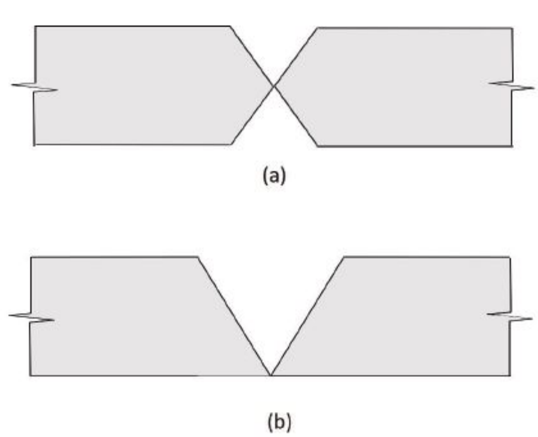


Fig. 3.

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NEED FOR SPEED

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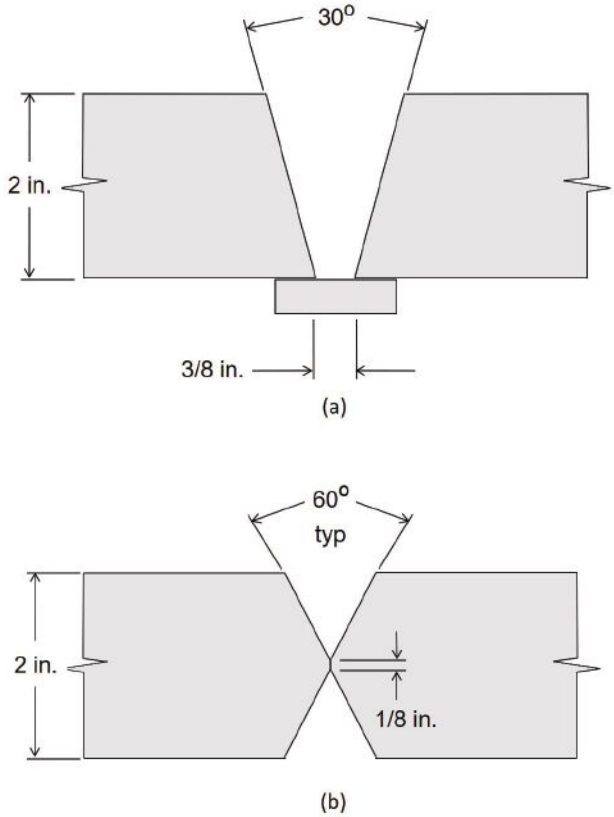


Fig. 4.

Consider the two prequalified groove weld details for a 2-in. plate, as shown in Figure 4. The single-sided prequalified detail (B-U2a) in Part a has a ⅜-in. root opening and 30° included angle, requiring 6.54 lb of deposited weld per ft. The double-sided option (B-U3b) in Part b has no root opening and a ⅛-in. root face, requiring 5.37 lb per ft. While the double-sided option requires less weld metal, the difference is not the 2:1 ratio as implied by Figure 3; the actual ratio, in this case, is 1.22:1. The single-sided CJP will likely be the faster, more economical choice because the single-sided joint can be more quickly prepared (i.e., less flame cutting time) and does not require time-consuming plate handling to reposition the work for flat position welding.

The joint details need to be evaluated case by case, considering not only weld volumes but also joint preparation costs, material handling costs, the costs of backing and backgouging, and other factors. In some cases, increased throughput is achieved with single-sided details that require more welding but fewer associated activities.

Concept 4. Optimize joint fit-up. AWS D1.1 provides "as detailed" and "as fit" tolerances for prequalified joint details. For many fabricators and erecters, so long as the actual fit-up is within the "as fit" tolerances, life is good. But how do fit-up tolerances affect fabrication and erection speed?

Consider a typical field-produced beam-to-column connection, as shown in Figure 5. Part a shows a prequalified groove weld detail (TC-U4a-GF) with a ⅜-in. root opening and 30° bevel angle. Using the AWS D1.1 tolerances, the root opening could increase to ⅝ in. (Part b), and the bevel angle could increase to 40° (Part c); these permitted tolerances increase welding time by 38% and 20%, respectively. Increasing both dimensions to the maximum permitted increases welding time by 58% (Part d).

While poor fit-up is often viewed as a problem caused by the welder, many of these problems originate on the cutting table. Collaboration between the fabricator and erector is encouraged to gain a mutual understanding of how speed can be maximized by minimizing excessive fit-up dimensions.

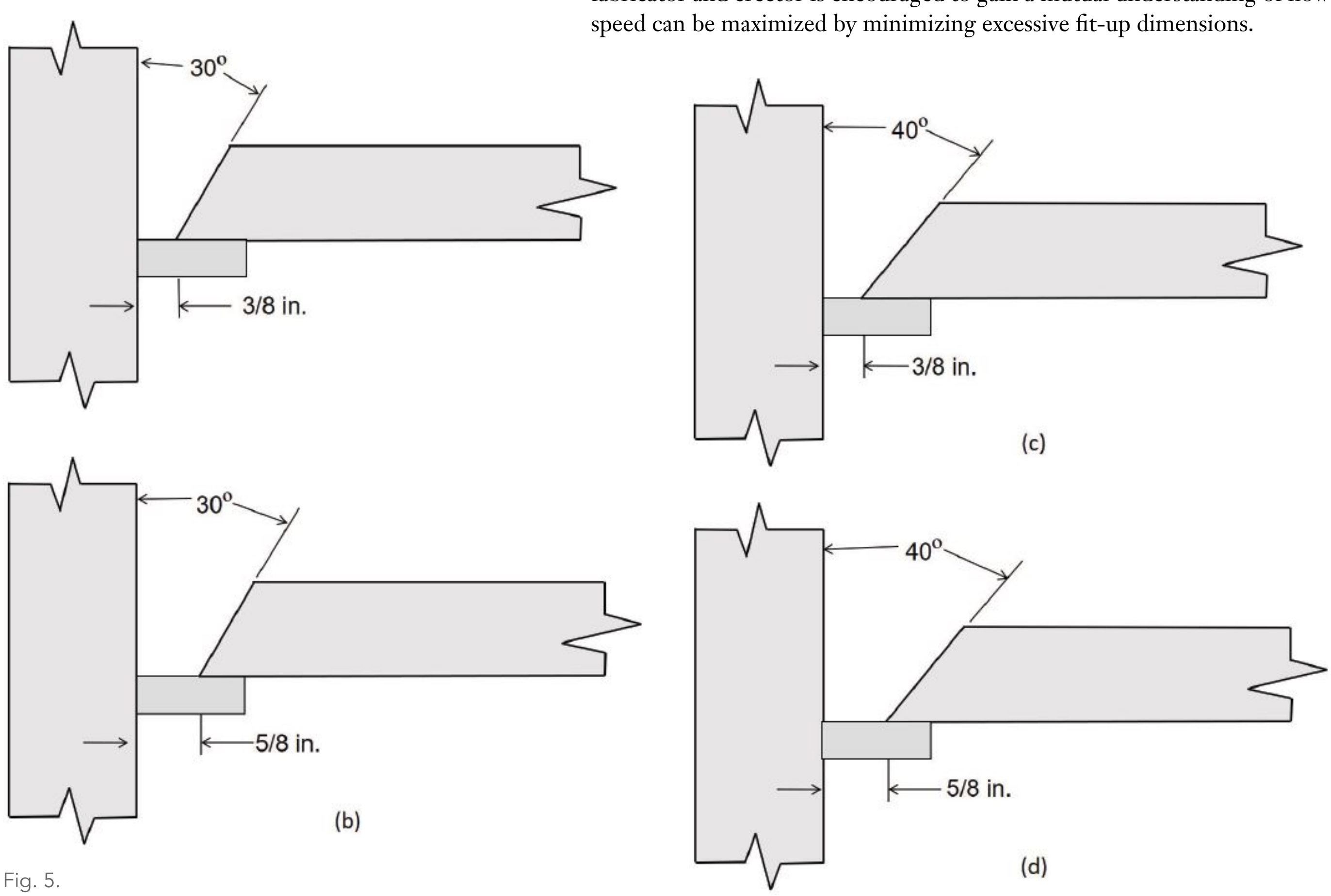
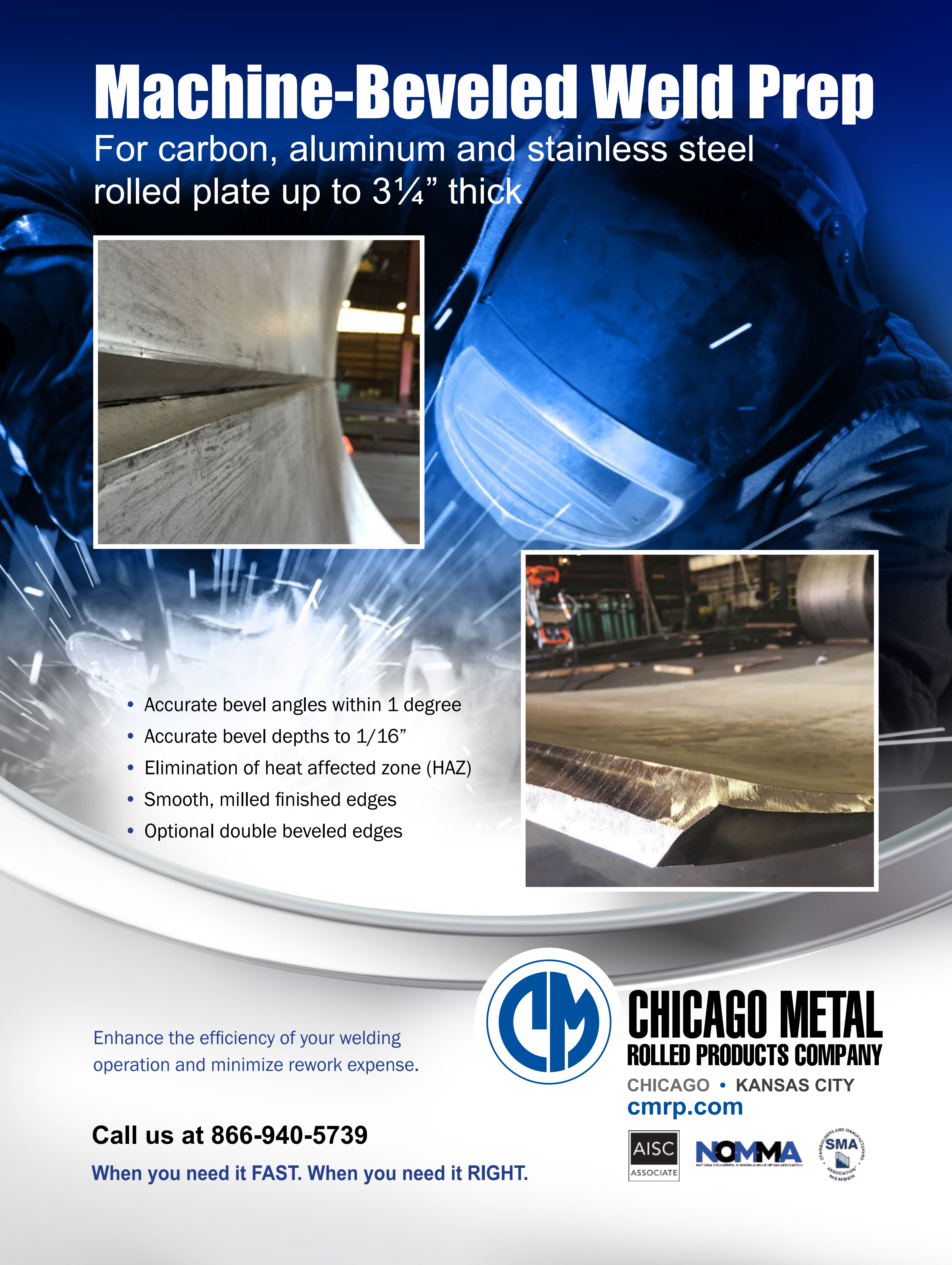


Fig. 5.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16. **Angle Heel Up** — MEAN DIA. — 8" x 8"x1" Angle
17. **Square Tube** — INSIDE DIA. — 24" x $^{1}/_{2}$" Tube
18. **Rectangular Tube The Easy Way (Y-Y Axis)** — INSIDE DIA. — 20" x 12" x $^{5}/_{8}$" Tube
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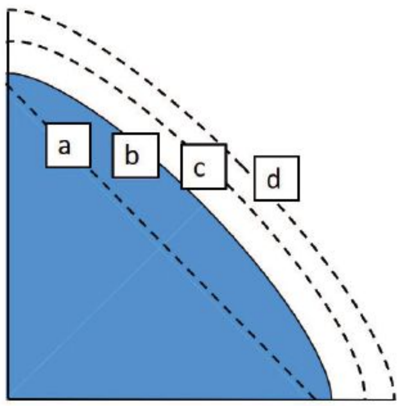


Fig. 6.

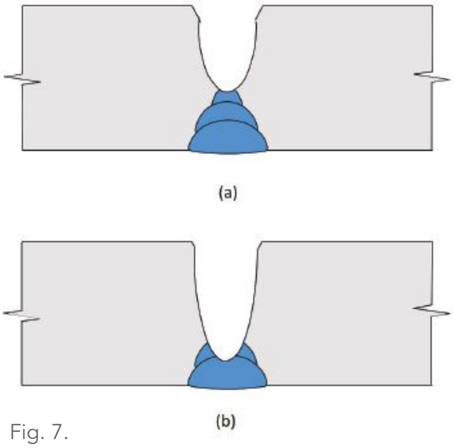


Fig. 7.

Concept 5. Make welds of the proper size. Concept 1 is directed toward designers and detailers. Concept 5 concept is directed toward fabricators and erectors. The idea is simple: Make the weld size required on the drawings.

AWS D1.1 allows for up to 10% of the length of a fillet weld to be undersized within certain limits (see D1.1:2020, Table 8.1, item 6). There is, however, no allowance for the whole length of a weld to be slightly undersized, which is unfortunate. As a result, welders routinely make welds that are slightly oversized to avoid the probability of rejected welds. A slightly oversized weld does not significantly reduce speed, and generously oversized welds needlessly slow welding operations.

Consider the $5/16$-in. fillet welds shown in Figure 6. An ideally sized, flat-faced weld is shown on Line a; such a weld is impractical to make in production on a repeated basis. The weld on Line b has legs that are oversized by 10%, with $1/16$ in. convexity. Line c shows a $5/16$ in. fillet, with legs oversized by $1/16$ in., whereas Line d shows a $5/16$-in. fillet, oversized by $1/8$ in.; both have $1/16$ in. convexity.

If the slightly oversized and slightly convex weld (Line b) is considered the norm, then speed is decreased by 17% when the weld on Line c is made. Speed is decreased by 56% when weld d is made instead of weld b.

While a flat-faced, perfectly sized fillet weld (Part a) is an unrealistic expectation of a semiautomatic welder, it is not unreasonable for a robot. A comparison of weld b to weld a suggests a productivity increase of 45% should be possible when robotic welding is used.

Concept 6. Limit backgouging on double-sided CJP groove welds. Prequalified CJP groove welds require backgouging to sound metal before the root pass on the second side is made. It is essential that the backgouging be complete; failure to backgouge to sound metal will typically result in defects in the weld root.

The air arc gouging (AAG) process is capable of removing metal 10 to 20 times faster than typical welding processes can deposit metal. When welders become too aggressive backgouging weld joints, it is easy to over-gouge the joint, creating unnecessary time-consuming work downstream. Unfortunately, it is often the most quality-conscience welder who does this, just to ensure a fully backgouged joint.

Consider the example of the 2-in. joint in Figure 7. In Part a, an optimal backgouge is used, removing metal to $1/16$ in. beyond the incomplete fusion. In Part b, the backgouge is ¼ in. deeper than necessary. The result of the excessive backgouge is an approximate 25% decrease in speed.

Two practical suggestions are offered to limit this tendency. First, the selected carbon size (diameter) and current (amperage) should be appropriate for the amount of backgouging that is expected. For example, a root face of $1/8$ in. will not need the same amount of backgouging compared to a root face of ¼ in., and the gouging parameters should be adjusted accordingly. Second, after initial backgouging, grinding can be used to complete the operation; grinding is usually easier to control and will naturally limit the tendency to remove more metal than is needed.

Also, keep this rule of thumb in mind: The time to restore the removed metal will be 10 to 20 times more than the removal time.

Minimize Welding Time

The second broad category involves reducing welding time. This is, of course, the traditional focus of most cost reduction/productivity improvement activities, and much has been written on this topic. Here, the concepts presented are specifically directed at the fabricator and erector wanting to increase throughput.

Concept 7. Process selection: universal versus optimized. In many ways, structural steel fabrication facilities are big job shops; the nature of the work changes continually, and the exact nature of some steel configurations may never be seen again. The same could be said for erectors. The typical contractor is drawn to welding processes that are flexible, allowing them to deliver welds of the required quality on an everyday basis. It may be, for example, that submerged arc welding (SAW) may be ideal for a specific application, but the shop's standard process of FCAW-G may be used just to keep things simple. That decision may be best, given the various facts that need to be considered, including capital investment, welder training, WPS development, welder qualification, etc.

On the other hand, the cost of such decisions should be recognized. Consider a typical shop situation: $\frac{5}{16}$-in. fillet welds made on a plate girder. If tandem SAW is used on a gantry with two sets of welding heads traveling at 40 ipm, then two web-to-flange welds on a 100-ft girder can be made in 30 minutes. Once the start button is pushed, there is no need for the welding to stop, and one operator can oversee the two sets of welding equipment. Remember that two welds are being considered for a total of 200 ft of welding in this example; the plate girder would likely have four such welds for a total of 400 ft of welding.

Compare that to a situation with four welders, each using $\frac{1}{16}$-in. diameter FCAW-G, making $\frac{5}{16}$-in. fillet welds, each with a travel speed of 18 ipm. The welders could be distributed along the length of the girder. In the same 30 minutes that the two welds could be made with tandem SAW, the four semiautomatic welders would make only 45 ft of weld, providing each welder kept the arc lit 25% of the time.

In this example, the use of an "optimized" welding process (tandem SAW) versus the "universal" process (FCAW-G) increased productivity by over 300%, even though four welders were engaged in welding with the semiautomatic alternative. For reasons like these, most fabricators have gantries or welding tractors that may be idle a good part of the year but become invaluable when a girder job arrives.

Next, consider a field application. Most erection projects will require both "in position" welding (that is, flat or horizontal) as well as "out of position" welding (vertical and overhead). With self-shielded flux-cored arc welding (FCAW-S) being the process of choice for field erection, one option for erectors is to have two wire feeders on the job, one with a high-productivity down-hand electrode and the second equipped with an electrode for all-position welding.

There is a second option that is simpler: Use one wire feeder for the whole job, incorporating an all-position electrode for all welding. While this may be a good choice, particularly for small projects, the production consequences need consideration.

Visualize a column splice of a W14×211. The two flange welds would require about 20 lb of weld metal. If made with FCAW-S and a $\frac{5}{64}$-in. E70T-6 electrode at a deposition rate of 11.5 pounds per hour, the total arc time would be about 1.7 hours. At an operating factor of 25%, it would require about 7 hours to complete.

An erector may alternately select an all-positon electrode, such as 0.072-in. E71T-8 with a deposition rate of 5.4 lb per hour. Arc time becomes 3.7 hours and the total time with an operating factor of 25% would be about 15 hours to complete the two flanges. A speed increase of 110% is achieved when the optimized electrode versus the universal electrode is used in this example.

Many fabricators have a standardized shop electrode size, typically 0.045-in. FCAW-G. The flexibility on a single electrode cannot be disputed, but the productivity implications are often overlooked. Consider the two welds made in Figure 8, both $\frac{5}{16}$-in. horizontal fillets. Each sample represents one minute of welding. The weld in Part a was made with the 0.045-in. electrode at a travel speed of 13.5 ipm, whereas the more optimal $\frac{1}{16}$-in. electrode made the weld in Part b at a rate of 18 ipm, a productivity increase of 33%.

To make it easier to use two electrodes, dual-headed wire feeders, as shown in Figure 9, provide the necessary production flexibility while minimizing the need for additional power supplies and the clutter of multiple wire feeders on a shop floor.

Concept 8. Optimize WPS parameters. According to AWS A3.0: *Standard Welding Terms and Definitions*, a WPS is "a document providing the required welding variables for a specific application to assure repeatability by properly trained welders and welding operators." To many contractors, a WPS is a document whose primary purpose is to keep the welding inspector happy. Properly used, however, WPSs are important productivity control tools.

Fig. 8.

Fig. 9.

Small changes in welding parameters can significantly affect productivity. Consider the simple 5/16-in. fillet welds, each made with the same process and same electrode, as shown in Figure 10. Each assembly represented one minute of welding. The weld in Part a was made with a 0.045-in.-diameter FCAW-G electrode, with a wire feed speed of 450 ipm and a travel speed of 9.5 ipm. In Part b, the weld was made with a wire feed speed of 520 and a travel speed of 11 ipm, or a 16% increase in productivity. The difference in productivity was achieved simply by using optimized parameters, which should be listed on the WPS.

To gain speed, optimize the welding parameters.

Concept 9. Limit WPS variable options. Figure 11 contains the welding variables as listed on a recently reviewed WPS. The electrode diameter used on the project was 5/64 in. (even though the WPS listed three different diameters). Five sets of amperage and voltage values for the 5/64-in. electrode were listed; no travel speeds were shown. The welding parameters were taken from the filler metal manufacturer's product literature, which is a good starting point. The WPS allowed the welder to use wire feed speeds from 90 to 240 ipm, with welding currents ranging from 210 amps to 380 amps.

The application involved a column splice of a W14×257 with a flange thickness of 1 7/8 in. Each flange splice requires 8.6 lb of weld metal. If the welder selects to use a wire feed speed of 90 ipm, then the weld requires 71 minutes of arc time to weld one flange. On the other hand, with a wire feed speed of 240 ipm, one flange requires 27 minutes of arc time. This is an increase in productivity of 167%.

WPSs should list welding parameters that are specific to a given application as opposed to the general parameters supplied on the filler metal spec sheets. The selected values should be capable of generating the required quality but also at a productivity level that will ensure appropriate rates of throughput.

Fig. 10.

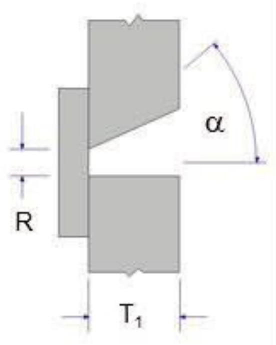
Concept 10. Enforce WPS parameters. Once a good WPS has been established, good productivity depends on welders following the WPS. Enforcement of compliance to WPS parameters should not be solely relegated to the welding inspector, or the AISC auditor, but should also be the responsibility of the supervisor that oversees the welding operations.

Today's welding equipment can be programmed and locked to permit welders to only use specific parameters for a given weld or allow the welder to adjust the welding parameters only within acceptable ranges.

The proper application of this concept requires that welders have access to a WPS and know how to follow it. Welders should be trained to make quality welds with established WPS parameters. If welders cannot make quality welds with a given WPS, either the WPS needs to be adjusted or the welder needs further training.

Pass or Weld Layer	Process	Class	Filler Metals Diam.	Filler Metals Type & Polarity	Current Amps	Current Volts	Wire Feed Speed (in/min)
All	FCAW	E71T-8-H8	1/16"	DC-	220	17-19	150
All	FCAW	E71T-8-H8	1/16"	DC-	245	19-21	200
All	FCAW	E71T-8-H8	1/16"	DC-	270	21-23	250
All	FCAW	E71T-8-H8	1/16"	DC-	295	23-25	300
All	FCAW	E71T-8-H8	1/16"	DC-	315	25-27	350
All	FCAW	E71T-8-H8	0.072"	DC-	184	17-18	100
All	FCAW	E71T-8-H8	0.072"	DC-	250	18-19	150
All	FCAW	E71T-8-H8	0.072"	DC-	295	20-21	200
All	FCAW	E71T-8-H8	0.072"	DC-	330	22-23	250
All	FCAW	E71T-8-H8	0.072"	DC-	355	23-24	300
All	FCAW	E71T-8-H8	5/64"	DC-	210	18-19	90
All	FCAW	E71T-8-H8	5/64"	DC-	260	19-20	125
All	FCAW	E71T-8-H8	5/64"	DC-	300	20-21	150
All	FCAW	E71T-8-H8	5/64"	DC-	340	21-22	200
All	FCAW	E71T-8-H8	5/64"	DC-	380	22-23	240

Joint Details



Tolerances	
As Detailed (See 3.13.1)	As Fit-Up (See 3.13.1)
R=+1/16,-0 α=+10°, −0°	1/4 -1/16 +10°, -5°

Preheat	≤ 3/4 in	> 3/4 in, < 1-1/2 in	> 1-1/2 in, < 2-1/2 in	> 2-1/2 in
	NONE	50° F	150° F	225° F

Fig. 11.

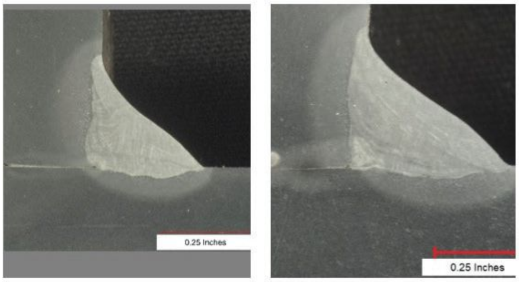


Fig. 12. (c) (d)

Fig. 13.

Concept 11. For single-pass welds, think travel speed (not deposition rate). Welding deposition rates are measured in units of pounds per hour, while welding travel speeds are expressed in units of inches per minute (ipm). For single-pass welds, the best metric for evaluating productivity is travel speed. An all-too-common error occurs when deposition rates are maximized, but travel speeds are not proportionately increased.

Assume a ¼-in. fillet weld is required, as shown in Figure 12. Using a 0.045-in.-diameter FCAW-G electrode, the weld in Part a was made with a wire feed speed of 400 ipm and a deposition rate of 9.1 lb per hour. Using the same electrode, the weld in Part b was made with a wire feed speed of 520 ipm and a deposition rate of 12 lb per hour, which is 32% higher. However, the travel speeds for both of the welds were 13.5 ipm. Why did productivity not increase?

As is apparent from the weld cross sections shown in Parts c and d, the higher deposition rate simply resulted in over welding. No productivity gains were achieved and more weld metal than needed was deposited. This error occurs when undue emphasis is placed on deposition rates instead of travel speeds when single-pass fillet welds are made. In this case, the contractor should increase the travel speed listed on the WPS to take advantage of the productivity gains. Alternately, if the weld cannot be made at the higher travel speed, then the wire feed speed listed on the WPS should be reduced; while no productivity gain is seen, the over welding can be controlled.

Concept 12. Investigate robotic welding technology. Welding equipment and filler metal manufacturers are constantly innovating, looking for ways to enhance weld quality, reduce welding costs, and increase welder safety. A major focus of the past ten years has been on automation and robotics. What was not possible a few years ago is now a reality, even for fabrication shops with small runs of identical subassemblies.

Steel fabrication shops have recently shown an interest in collaborative robots ("Cobots"), like the one illustrated in Figure 13 on page 38. A Cobot is a robotic welding system that is designed for interaction with a human operator. It is a smart tool that bridges the gap between manual operation and full automation. Cobots can be easily programmed and are a safe, mobile, flexible option that can increase productivity, quality, and safety. They are particularly useful for repetitive welds and welds that require an extra level of quality and safety. Cobots are being considered as a part of the solution to the projected welder labor shortage. (See the articles "Robotic Revelations" in the January 2019 issue and "Robot Ready" in the January 2020 issue, both in the Archives section at **www.modernsteel.com**, for some perspective from fabrication robot manufacturers and steel fabricators considering or using robots.)

Little by Little

Again, the goal of AISC's N4S initiative is to increase the delivery speed of a constructed steel project by 50%. Some of the increases will come from innovative breakthroughs, while other increases will come from the collective effects of smaller changes.

These smaller changes, such as the 24 welding-related concepts described in this article and its follow-up, are practical and can be implemented today. Innovative welding equipment and consumable manufacturers and their welding distributor partners are willing to assist forward-thinking steel fabricators and erectors in making these concepts into realities. While N4S may not be your primary focus right now, producing quality welds at a low cost and in a safe way will always be a challenge—and implementing even a handful of these concepts will materially improve welding operations for most fabricators and erectors. Stay tuned for Part Two of "Accelerated Welding" in the July issue. ■

The low environmental impacts of fabricated structural steel have been reaffirmed, and the most up-to-date associated documentation is now available for use.

Environmental Transparency

BY MAX PUCHTEL, SE, PE

Photo courtesy of SteelFab

SOME OF YOU MAY REMEMBER a time when a box of crackers didn't have a nutrition label prominently displayed on the outside.

While tastiness no doubt played a factor, you probably also wanted to choose crackers that were healthier for your body—but you were left to weigh the nutrition claims made by the cracker makers. It's a good thing that in 1990, the FDA mandated nutrition labels be displayed on food products.

Similarly, the building construction industry is increasingly interested in the environmental impacts associated with the products that end up in our built environment—and including a nutrition label of sorts. In fact, disclosing those impacts may actually be a hard and fast requirement during a project when seeking a green building certification like LEED, complying with codes and standards, or even when meeting customer-specific requirements—e.g., large technology companies have begun adding standard environmental impact language to their specifications.

As a service to our members, AISC produces three industry-wide environmental product declarations (EPDs) for fabricated steel products that can be used to satisfy project requirements. The EPDs are valid for five years from the date of issue; fabricated hot-rolled structural sections and fabricated steel plate EPDs were reissued on March 31, 2021, and a fabricated hollow structural sections EPD will be reissued in December 2021. Below are some common questions and answers regarding EPDs.

I'm late to the party. Just what exactly is an EPD?

An EPD is a document that reports a standard set of environmental impacts occurring during a product's life cycle. The results come from a standardized methodology aptly called life-cycle assessment (LCA). Rules on how to produce a fabricated structural steel EPD in North America are found in the UL document *Product Category Rule (PCR) Guidance for Building-Related Products and Services, Part B: Designated Steel Construction Product EPD Requirements*.

opposite page: Some structural steel fabrication shops, such as this SteelFab facility in Dublin, Ga., are reducing their reliance on the grid via rooftop solar arrays. (For more on SteelFab's solar efforts, see "Solar Steel" in the February 2020 issue, available in the Archives section at **www.modernsteel.com**.)

right: AISC's EPD for fabricated hot-rolled structural sections.

below: EPDs report a standard set of environmental impacts that occur during a product's (such wide-flange shapes or HSS) life cycle.

ENVIRONMENTAL PRODUCT DECLARATION

FABRICATED HOT-ROLLED STRUCTURAL SECTIONS

AMERICAN INSTITUTE OF STEEL CONSTRUCTION

March 2021

The United States structural steel industry annually supplies, fabricates and erects structural steel framing for more than 10,000 buildings, bridges and industrial projects through a network of producers, service centers, steel fabricators and erectors.

The National Steel Bridge Alliance, a division of the American Institute of Steel Construction (AISC), is a national, not-for-profit organization dedicated to advancing steel bridge design and construction. NSBA is a unified industry organization of businesses and agencies interested in the development, construction and promotion of cost-effective steel bridges. We represent the entire steel bridge community.

Long committed to the principles of sustainable manufacturing, the industry remains the world leader in the use of recycled materials and end-of-life recycling, with the recycled content of hot-rolled structural beams and columns produced at US mills averaging in excess of 93% and an end-of-life recovery rate of 98%.

The American Institute of Steel Construction is a not-for-profit technical institute and trade association established in 1921 to serve the structural steel design community and construction industry. AISC currently represents 3 producers of hot-rolled structural sections and nearly 1,000 structural steel fabricators in the US.

Hot rolled structural steel sections complying with the definition of structural steel in AISC 303-16 produced in the United States and fabricated by an AISC member fabricator.

Use of this EPD is limited to AISC members. Member names are available online at www.aisc.org/epd

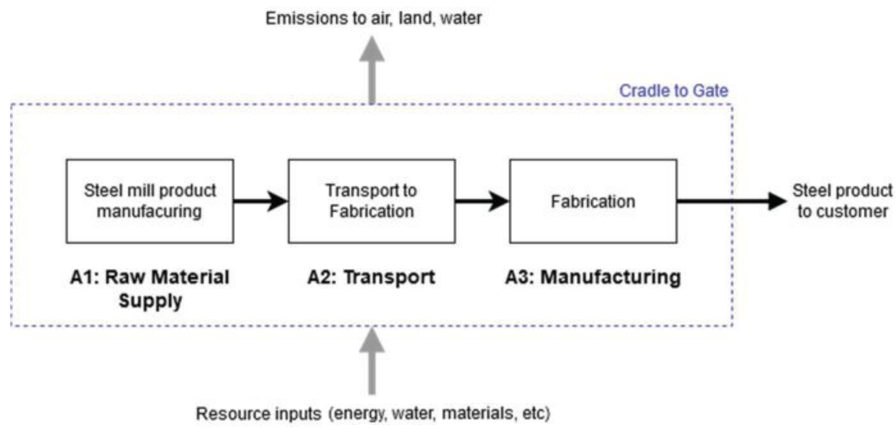
CERTIFIED
ENVIRONMENTAL PRODUCT DECLARATION
UL.COM/EPD

What's included in AISC's industry-wide EPDs?

Here's where the nutrition label analogy starts to make more sense. Let's use the example of a hot-rolled W-section. That beam—which is created from 93% recycled scrap material (cars, appliances, toasters, etc.)—was melted in a modern electric arc furnace (EAF) and rolled at a mill, traveled either to a service center or went straight to the fabricator, and then received the finishing touches (cutting, drilling, welding) at the shop. Those three LCA stages are referred to as A1: Raw material supply, A2: Transport, and A3: Manufacturing. The A1 values for fabricated structural steel include all the "cradle to mill gate" impacts, averaged from American steel producer data. A2 average transport values are based on common steel supply chain distances and modes of transport. A3 values are based upon an AISC member survey of environmental impacts such as electricity and welding consumable usage.

Max Puchtel (**puchtel@aisc.org**) is AISC's director of sustainability and government relations.

Flow Diagram



A basic environmental flow chart of the "Product" stage of the structural steel supply chain, broken down into raw material supply, transportation, and manufacturing. This stage is followed by the "Construction Process," "Use," and "End-of-Life" stages.

What story do the reissued numbers tell from the last version?

Overall, the values are virtually unchanged. Close observers will note slight increases in the A1 and A2 values, but these are due to changes in required LCA background datasets rather than real changes in impacts. For example, electricity use is now based on regional power grid data rather than a national average. The A3 value for average fabrication impacts has decreased but within what one would consider an acceptable margin of error for an estimate such as an EPD.

But how can I differentiate between fabricators?

Our third-party-produced and verified numbers show that 90% of the environmental impacts of fabricated structural steel occur before it leaves the mill, with less than 10% attributed to fabrication. (Also, keep in mind that the majority of steel's carbon footprint can be attributed to the electricity used to heat the electrodes that melt the scrap in an EAF—and as national, state, and local municipalities begin to use more green energy, that carbon footprint will continue to drop.) Not only that, but the fabricator doesn't control the design of the steel project, which can have a significant impact on the effective carbon intensity per ton of fabricated structural steel. For example, a project with heavy sections and low labor needs will have a much lower impact per ton than a project with light sections and high labor needs. American fabricators are already largely efficient in terms of energy use and scrap recycling, and differentiating environmental impacts between them isn't an effective or appropriate strategy.

How can specifiers use these EPDs?

AISC member fabricators provided the data for the study and are therefore represented by our EPDs. So specifiers who want contractors that transparently disclose their environmental impacts should specify the AISC industry-average EPDs or its equivalent in their bid packages. Sample specification language is provided at **aisc.org/epd**.

How can fabricators use the EPDs?

AISC member fabricators have the confidence of knowing they can disclose the impacts of fabricated structural steel to meet project requirements. As with sample specification language, the EPDs are published for use at **aisc.org/epd**.

In the end, it's all about transparency. Whether you buy crackers because they're delicious, because they're gluten-free, because they're low in sodium, or any other reason or combination of reasons, a nutrition label allows you to make an educated, informed decision about what you're buying and what you're eating. It's the same with EPDs for fabricated structural steel or any other material or product going into a building, from windows to carpet tiles to lighting. And when it comes to the next project you work on that has high environmental standards, you won't just be telling your teammates that steel has a relatively low impact. You'll have the proof. ■

In addition to the EPDs, you can learn more about steel and sustainability in general at ***aisc.org/sustainability***.

UL
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ENVIRONMENTAL PRODUCT DECLARATION
UL.COM/EPD

Augmenting Productivity

BY LUKE FAULKNER

Luke Faulkner (**faulkner@aisc.org**) is AISC's director of technology initiatives.

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.

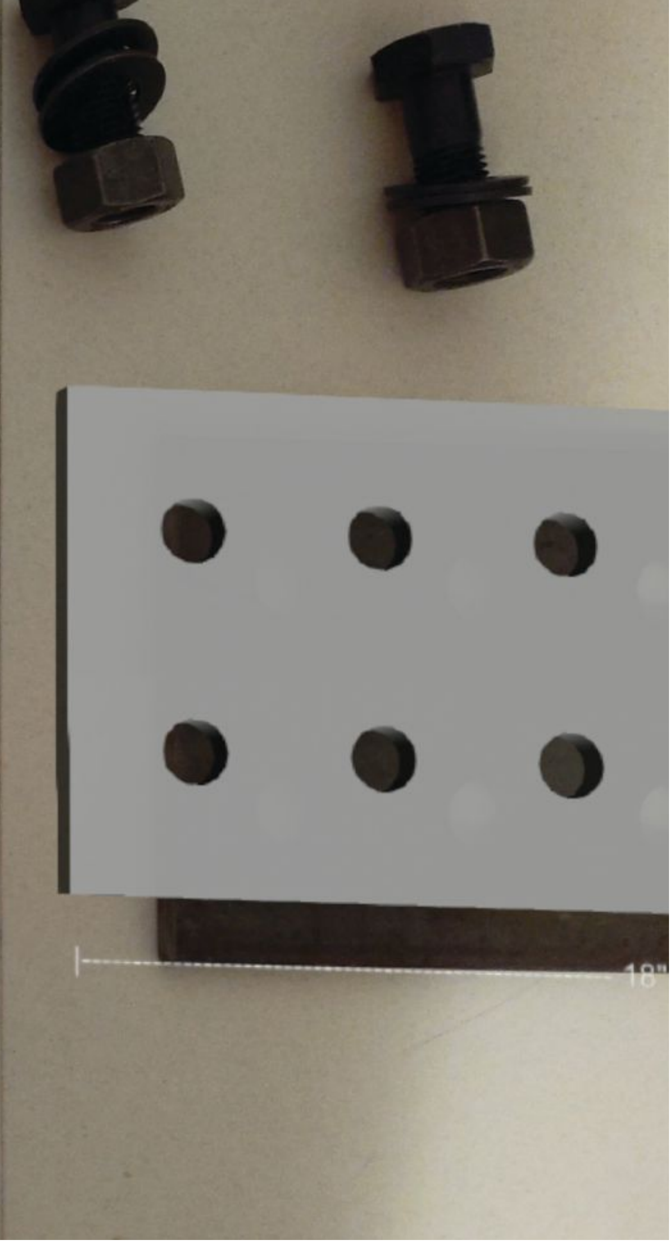
IT'S NO SECRET that the construction industry has a productivity problem.

There isn't a singular root cause for this issue, though technology—or a lack thereof—is likely the largest factor.

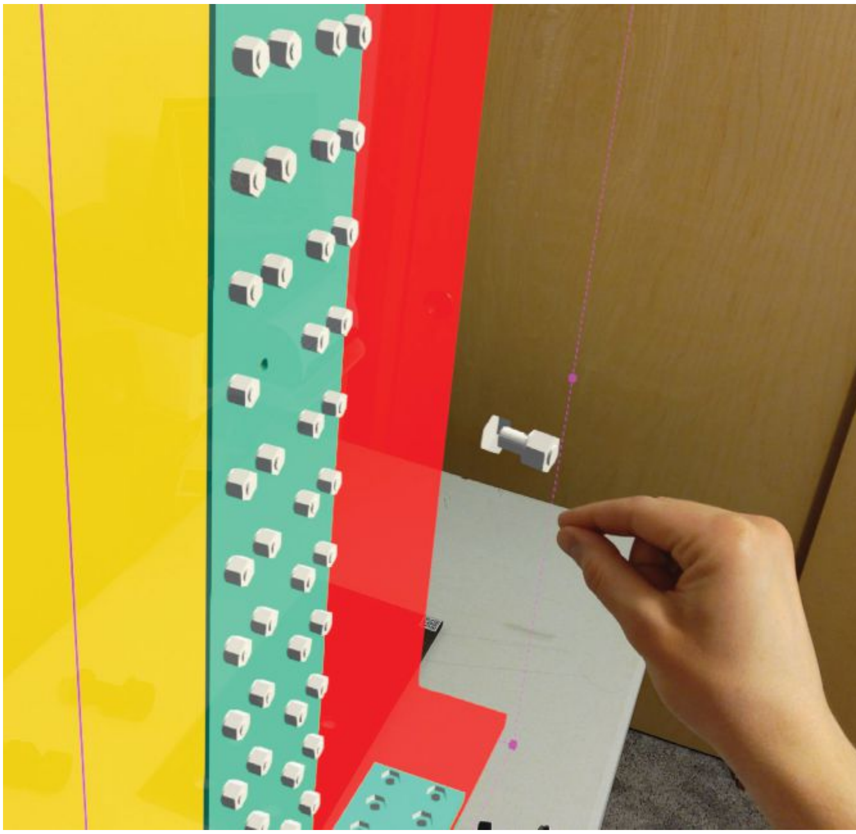
The bespoke nature of design and construction projects, along with the fragmented nature of the construction industry, makes it particularly difficult to adopt new technologies at both large and small scales. Nevertheless, it's absolutely critical for individual players in the industry to explore and attempt to leverage new technologies as they become available.

Technology as a term can encompass quite a lot and can be interpreted in many ways—and there are multiple opinions on how long something can be considered "new." Here, we'll discuss one of the more exciting, high-reward, and relatively newer technologies that can facilitate more efficient steel construction projects: augmented reality (AR) via smart glasses.

So what is AR? Is it like VR (virtual reality)? Somewhat. Where VR creates a simulated environment, AR combines elements of such an environment with the real world, typically overlaying a virtual object onto a real environment. It may sound exotic, but you've almost certainly seen it—particularly on Saturdays and Sundays if you ever happen to watch college or professional football—in the form of the yellow first-down line. Or perhaps you partook in the Pokemon Go phenomenon that was all the rage a few years back. And if AR can be used for entertainment purposes such as these, it's not hard to imagine how a more sophisticated version could be useful in the structural steel industry.



Augmented reality is showing potential for increasing productivity when it comes to designing and building steel projects.



left and above: Augmented reality (AR), enabled by technologies such as smart glasses, can overlay virtual structural models on top of real-world scenarios to help designers and builders visualize the physical relationship between various elements in a project.

Construction Applications

There are actually several opportunities for implementing AR in a steel project.

Visualization and field coordination are probably the simplest applications of AR and include overlays of work to be installed on top of work that's already in place, as well as visualization of complex connections. There are a number of applications and programs that allow for visualization and coordination of 3D models both on-site and remotely.

Fit-up and layout work can also benefit from AR. Shop machinery performing these tasks can potentially be mated to smart glasses technology (more on that in a minute) so that layout work is transferred directly to a steel element rather than having to go through a more tedious marking process. AR hardware is also capable of measuring the physical area of an object like a steel member, though AISC is still investigating whether it is accurate enough for steel fabrication (stay tuned for updates).

Training. AR can also be used as a training mechanism for skilled labor students and employees (consider flight simulators, for example). For example, it can be used to simulate the operation of heavy equipment or tasks like welding, which is much more costly when using actual equipment. In addition, it allows the training to take place in a safe, controlled environment.

Safety. Finally, AR can also bring safety advantages to the field, especially when enabled by a library of data and images of unsafe conditions, helping to identify potential hazards in the field before they come to fruition.

AR Hardware

While the environment that AR creates is very, well, augmented, the hardware that brings it to life is very real and takes a few different forms:

Smart glasses/headsets, such as Microsoft HoloLens 2, Google's Glass Enterprise Edition 2, Vuzix products, and others. While some, like HoloLens 2, are more immersive, similar to donning a mask, and functionally act as a computer on your head, others like, Google Glass Enterprise (not to be confused with the first edition, which was aimed at consumers), look more like traditional glasses and require connectivity to a computer. Pricing for AR headsets typically ranges anywhere from $500 to $4,000, with the low-end representing consumer-grade headsets with less functionality. At the other end of the spectrum is HoloLens 2, which retails for $3,500 or nearly $5,000 when coupled with Trimble's XR10 hard hat via Trimble Connect. Autodesk also offers an AR app that links Revit with HoloLens 2.

Handheld devices. Basically, implementing AR technology on your smartphone or tablet—e.g., virtually seeing how new furniture might fit in a room or how new paint colors might look on walls.

Combination. There are AR headsets designed with a slot to hold your smartphone and create an AR or VR environment.

Heads-up display. This is probably most familiar to users in the form of dashboard information on a touch screen in a car, perhaps being used for navigation purposes.

Limitations of AR

As promising as AR is, it is still a relatively young technology, and there are limitations:

Accuracy. As with almost any application, the workflow is significantly easier when building widgets as opposed to one-off steel frames. AISC has partnered with the University of Wisconsin to demonstrate proof of concept for AR in the steel industry—i.e., to ensure that the hardware being used is capable of identifying steel beams and assemblies with sufficient fabrication-level accuracy to be of use (typically, accuracy within $\frac{1}{16}$ in.) for purposes such as visualizing cuts, holes, or weld marks on a beam. This is largely governed by a headset's ability to track and monitor eye movement to ensure that AR overlays remain in a constant position relative to any movement of the wearer. We'll release more information on the findings of this partnership as they become available.

Field view. Most currently available AR headsets have a field view in the range of 40° to 50° and some only 10° (a typical human peripheral vision is 170° to 180°).

Connectivity. While some smart glasses products are standalone and, again, include a computer within the device, others may need to be tethered to a computer or smartphone via WiFi, Bluetooth, or mobile networks such as 5G. This has obvious implications for more remote job sites or fabrication shops where access or bandwidth is a concern. These devices can be used offline, but without a connection there is no ability to collaborate.

Battery. Like many other pieces of technology, smart glasses and AR headsets are tied to their battery life. Depending on their use, some may have a battery life of two hours or less, while others might have a battery life of up to eight hours.

Safety. Most headsets aren't explicitly designed to be used with hard hats (with the exception of Trimble's XR10), which can make for clunky fits and a reduced field of vision.

Despite these issues, AR via smart glasses shows plenty of promise and is already seeing use on real-life projects—and this use will only increase. But it needs to be accurate enough to provide useful overlays and information. And while most current hardware is accurate enough to give a good picture of a 3D model BIM overlaid on an actual construction site, it's not yet accurate enough to meet fabrication tolerances. But again, the aforementioned partnership between AISC and the University of Wisconsin is hoping to verify that

hardware will be able to achieve steel fabrication shop-worthy tolerances.

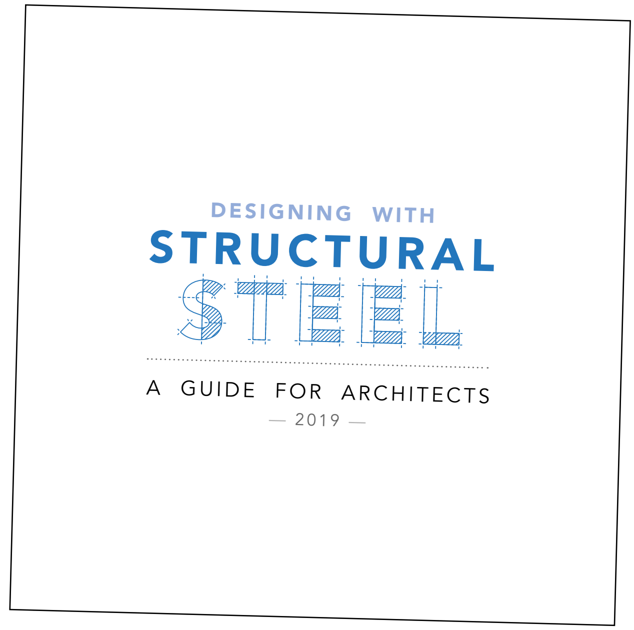
So while it is currently suitable for "big picture" application in steel projects, know that AR is on its way to being useful when it comes to the more detailed aspects of a steel project as well. And when that happens, we will begin to see a dynamic productivity improvement when designing and constructing steel buildings and bridges. ■

Have you used AR in any capacity on a steel project? If so, let us know! Email me at ***faulkner@aisc.org****.*

Wearable AR technology provides an immersive experience for workers in the field, linking overlay capabilities with 3D model software, goggles, and a hard hat.

Staying in Sync

BY DAVE E. ECKMANN, SE, PE, FAIA



AISC's latest *Guide for Architects* works to ensure that architects and engineers are on the same page when it comes to designing steel buildings.

ARE YOU A STRUCTURAL ENGINEER who would benefit from working with architects who knew a bit more about designing with steel—such as calculating preliminary beam depths and/or allocating sufficient structural depths for the spans?

If so, fear not! AISC has a new tool for you to share with your architectural friends and clients: The Third Edition of *Designing with Structural Steel: A Guide for Architects*. The attractive, 9-in. by 9-in. coffee table-style book is filled with useful steel information geared toward architects.

The first two editions of the *Guide for Architects* were published in the late 1990s and early 2000s as three-ring binders that could supplement an architect's notes and other collected steel resources. The latest version is organized a bit differently, providing overviews and nuggets of information in a hard-bound booklet supplemented with links to relevant websites that offer robust resources and tools for architects. It includes information on preliminary sizing of beams, steel coating systems, sustainability, architecturally exposed structural steel (AESS), enclosure system detailing, and much more. Simply put, this guide should be on every architect's desk (or coffee table). The publication was originally organized into seven chapters (as shown in Figure 1), though a new chapter

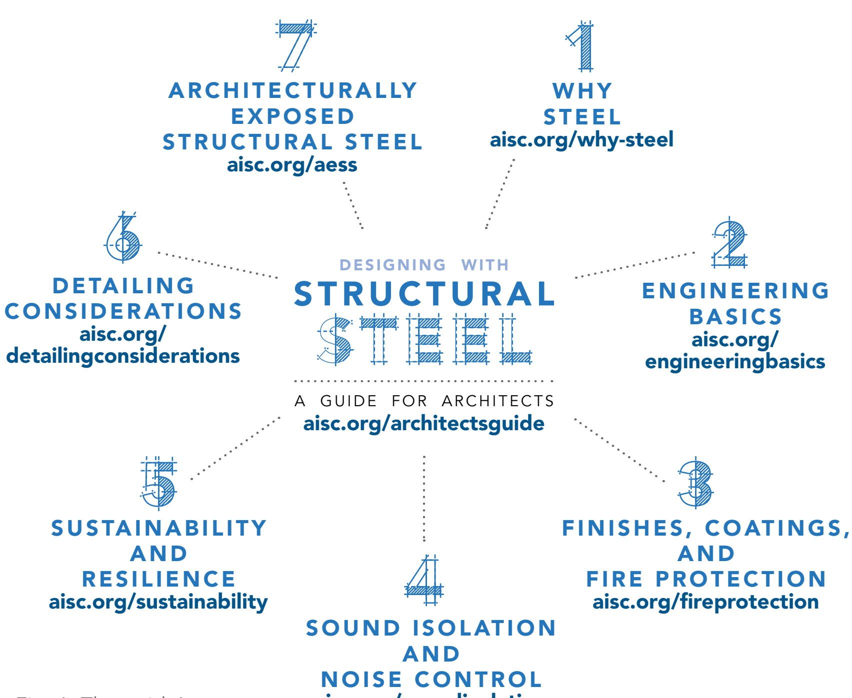


Fig. 1. The guide's organization.

Aislinn Weidele

has recently been added to the online version and will also appear in the next printing of the hard copy (see page 50 for information).

A 2019 IDEAS[2] Award winner, the University of Texas at Austin Engineering Education and Research Building is featured in the guide.

Basics and Tools

The guide provides insights about when and why steel structures are advantageous. Here are a few highlights.

The Engineering Basics section is a refresher on fundamental structural engineering concepts but is presented in layman's terms and with graphics. A concise recap of basic concepts such as how loads flow through buildings, both vertically and horizontally, will be familiar to most professional architects. In addition, this section offers architects a refresher on lateral system options to consider, including moment frames and different braced frame configurations. Also included are diagrammatic bracing details that remind architects to consider gussets and other connection components in their details.

This section also references specific pages at **aisc.org/why-steel/architect**, pointing architects to robust design tools like the Steel Dimensioning Tool and the Preliminary Beam/Column Sizing Tool. The Steel Dimensioning Tool is an online, one-stop dimensioning resource for all the rolled sections listed in the 15th Edition AISC *Steel Construction Manual* (**aisc.org/why-steel/architect/engineering-basics**). The actual member

Dave E. Eckmann (**deckmann@mka.com**) is a senior principal with Magnusson Klemencic Associates.

depth, width, flange thickness, web thickness, and cross-sectional area for virtually every steel shape is only a click away with this tool. This information is not only useful to architects as they design and detail around the steel frame but also to structural engineers.

The Preliminary Beam and Column Tables are two particularly useful tools in the Engineering Basics section. Prior to engaging a structural engineer, architects are sometimes required to make structural depth assumptions when crafting their initial concepts. The Preliminary Beam and Column Tables provide approximate beam and girder depths for various bay sizes and loading conditions, helping architects to better "ballpark" floor-to-floor heights and structural depth requirements. The tables capture different floor loading classifications, such as office, assembly, and storage loadings (see Figure 2). The tables define the design criteria for the values provided and consider different beam spacings for both lightweight and normal-weight concrete topping on steel deck.

Detailing Considerations and Floor Assemblies

It's critical to consider enclosure systems and detailing options early in a project. Even determining the perimeter slab edge dimensions from the primary structure can be the difference between the need for a light-gauge deck edge

New for 2021

PRELIMINARY BEAM, GIRDER AND COLUMN SIZE TABLES

aisc.org/architectsguide

This chapter is now available online and will help you approximate column sizes and floor and roof system depths in the early stages of a project, before a structural engineer is engaged.

Table B, Beam Sizes								
	Beam Span: B1 (ft)							
Live Load, psf	15	20	25	30	35	40	45	Classification
50	W10	W12	W14-W16	W16-W18	W18-W21	W18-W21	W21-W24	Office
100	W10-W12	W12	W14-W16	W16-W18	W18-W21	W18-W21	W21-W24	Assembly
150	W10-W12	W12	W14-W16	W16-W18	W18-W21	W18-W21	W21-W24	Storage

Fig. 2.

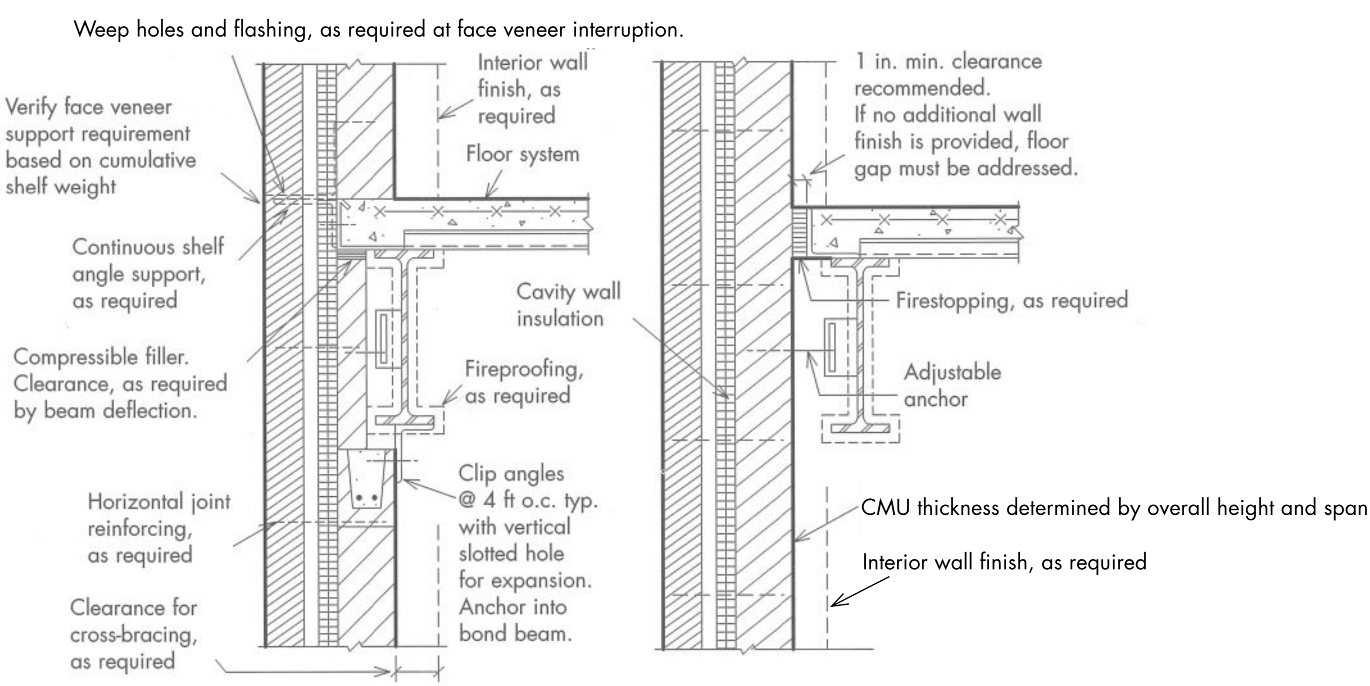


Fig. 3. Sample masonry wall section details at floor framing.

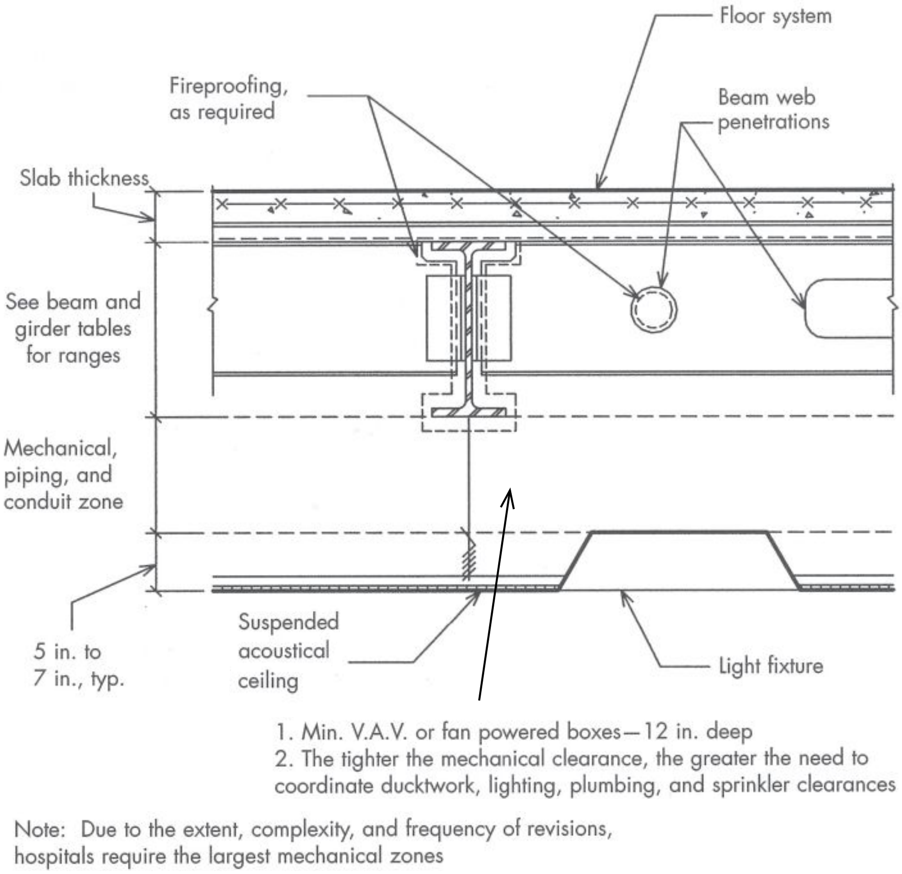


Fig. 4. Sample section detail for floor/ceiling assembly.

and a steel bent plate. Carefully considering these choices with the architect can result in significant cost savings to a project.

The Detailing Considerations section of the guide focuses on enclosure systems and various attachment details that should be considered. It includes wall sections for various enclosure (façade) materials and provides commentary on issues to be considered when attaching to the steel frame (see Figure 3 on page 50). This section also provides insight on allocating adequate space for structural, MEP, and lighting systems when evaluating floor-to-floor heights and the interstation space required for the steel building's systems (see Figure 4).

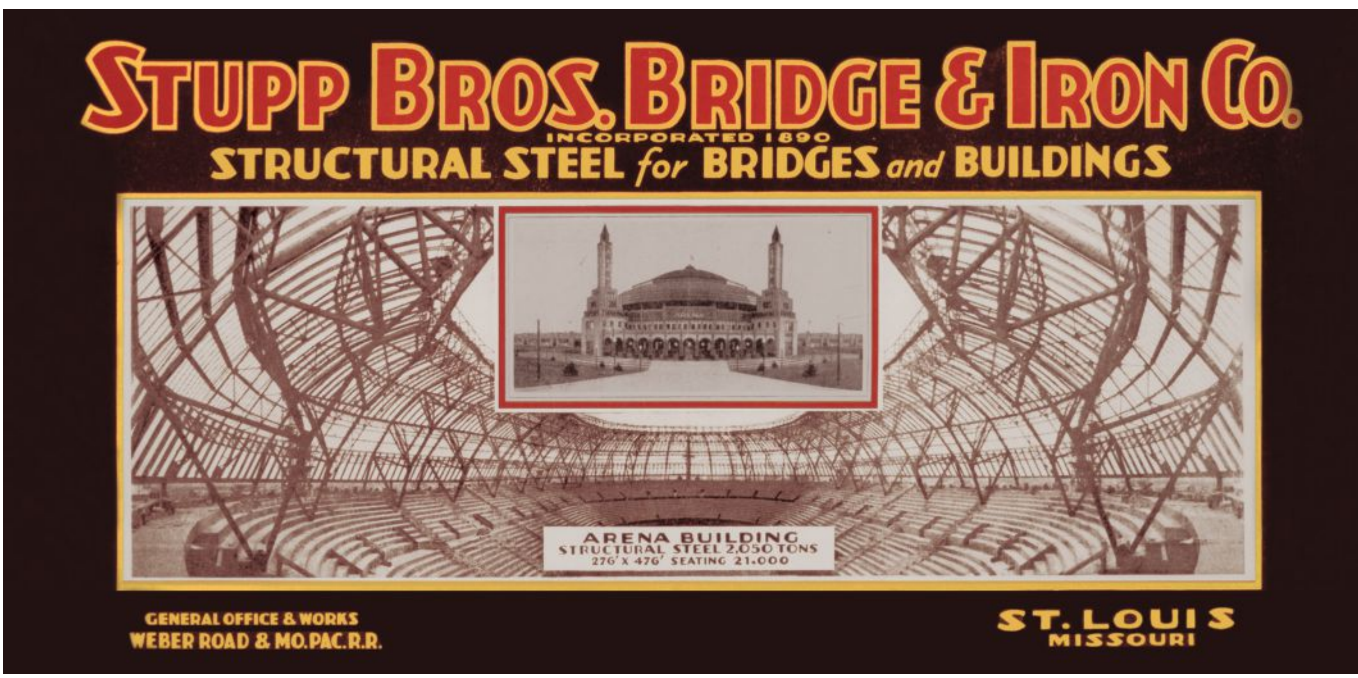
These are only some of the topics covered in the new edition of *Designing with Structural Steel: A Guide for Architects*. You can contact AISC for a hard copy or download a free PDF version at **aisc.org/why-steel**. ■

This article summarizes the session "Architect's Guide to Designing with Steel," which was presented at the 2021 NASCC: The Virtual Steel Conference in April. To watch a video of the session, visit ***aisc.org/2021nascconline****.*

Century Club: Stupp Brothers

BY GEOFF WEISENBERGER

AISC is 100! And we're featuring our longest continuously running member fabricators throughout 2021.



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

IN CELEBRATION OF AISC turning 100, throughout the year we're highlighting member fabricators that are even older than we are.

This month's century clubber is **Stupp Bros., Inc.**, a family-owned St. Louis fabricator whose origin predates the Civil War.

Answers provided by Phil Stupp, executive vice president of Stupp Bros., Inc.:

How and when did your company start?

My great-great-grandfather, Johann Stupp, was a guild-trained blacksmith in Köln (Cologne), Germany, and immigrated in 1854. He was originally opposed to leaving because he felt he had the talent to make it in his home country even though economic conditions and religious persecution were troubling. But persistent letters from fellow guild craftsmen encouraged him to come to America, where the opportunities seemed endless. Within two years of landing in New York, Johann Stupp was in business for himself.

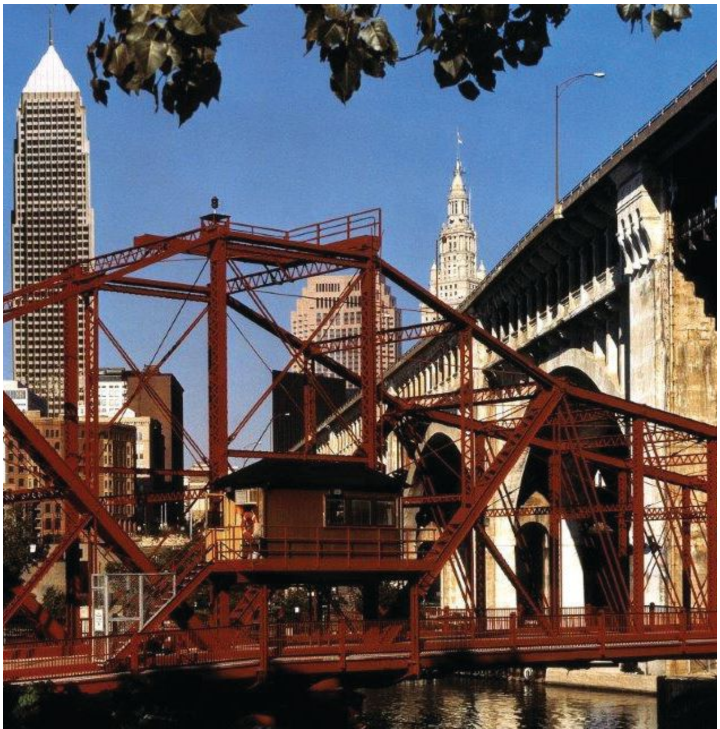
Your company has been able to weather challenges for more than a century and a half. How has this helped you weather the current pandemic?

Johann lost the business during the panic of 1873. This taught him and all family members that followed to stay conservative and build adequate reserves. The current pandemic and energy slump are just as severe as the Great Depression was for Stupp, but we have the financial strength to get through to the other side.

opposite page: St. Louis Arena, which opened in 1929 and was demolished in 1999, was one of Stupp's most prominent projects of the early 20th century.

right: The George P. Coleman Memorial Bridge across the York River between Yorktown and Gloucester Point, Va., a major Stupp bridge project.

All images courtesy of Stupp Bros.



above: Stupp Bros. fabricated the Hurricane Deck Bridge over Lake of the Ozarks, a 1936 AISC Prize Bridge Award winner.

left: Another Stupp bridge project, the renovation of the Cleveland's Center Street Bridge, circa 1988.

What's the best business advice you've received from past leadership at the company?

"Don't burn your bridges." This was the best advice my father, Robert, gave me. Whether personal or business, always keep an open mind when it comes to rekindling a relationship that has once gone bad.

AISC is 100 this year. How long has your company been involved with AISC and taken advantage of its resources?

Erwin Stupp served on the AISC board of directors from 1939 to 1965 and was its treasurer from 1957 to 1963, so we've been very involved for a very long time. ■

For more content related to AISC turning 100 this year, visit ***aisc.org/legacy****.*

A 3D-printed bridge is the winner of this year's AISC Forge Prize.

Printing a Winning Bridge

AISC'S FORGE PRIZE knows no boundaries.

Established in 2018, the program recognizes visionary emerging architects for designs that embrace steel as a primary structural component and capitalize on steel's ability to increase a project's speed. It presents a unique opportunity to experiment with a conceptual design without boundaries on scope or complexity; the sky really is the limit here. And for the second year in a row, a bridge concept took the top prize.

The finalists for this year's competition are rounded out by a civic mixed-use plaza and urban housing that blends in with nature. The final presentations from the 2021 Forge Prize finalists were streamed live on YouTube on March 31 and are available at **youtube.com/AISCsteelTV**. Each finalist won $5,000 and got to work with a steel fabricator before presenting their ideas to the judges, who selected an overall champion. The winner received a $10,000 grand prize and presented their design at the Architecture in Steel conference, which took place in conjunction with NASCC: The Virtual Conference in April (see **aisc.org/nascc** for more information).

"The Forge Prize competition gives younger architects a unique opportunity to develop new concepts and applications for one of the core materials of building design and construction—steel, in its many forms and manifestations," said judge Robert Cassidy, executive editor of *Building Design+Construction*.

This year's judges were:

- Bob Borson, FAIA, Associate Principal, BOKA Powell, Dallas.
- Robert Cassidy, Executive Editor, *Building Design+Construction*, and Editor, *Multifamily Design+Construction*, Chicago.
- Pascale Sablan, AIA, Associate, Adjaye Associates, New York

These individuals also generously devoted their time and mentorship efforts to the program:

- Jeff Pate, Owen Steel
- Kimberley Robinson, FabSouth Group
- Glenn R. Tabolt, PE, President, STS Steel, Inc.

The 2022 Forge Prize is open for entries until November 1, 2021. Visit **www.forgeprize.com** for more information. Read on for descriptions and images of this year's overall winner and the two finalists.

WINNER

Florida Canyon Bridge

Hunter Ruthrauff, T.Y. Lin

Hunter Ruthrauff, a senior design associate with T.Y. Lin International's Architecture and Visualization Group (AVG) in San Diego, designed a 3D-printed steel pedestrian bridge that spans Balboa Park's Florida Canyon. Ruthrauff chose 3D-printed steel because it offers better tensile strength than 3D-printed concrete and lessens the complexity of the design process.

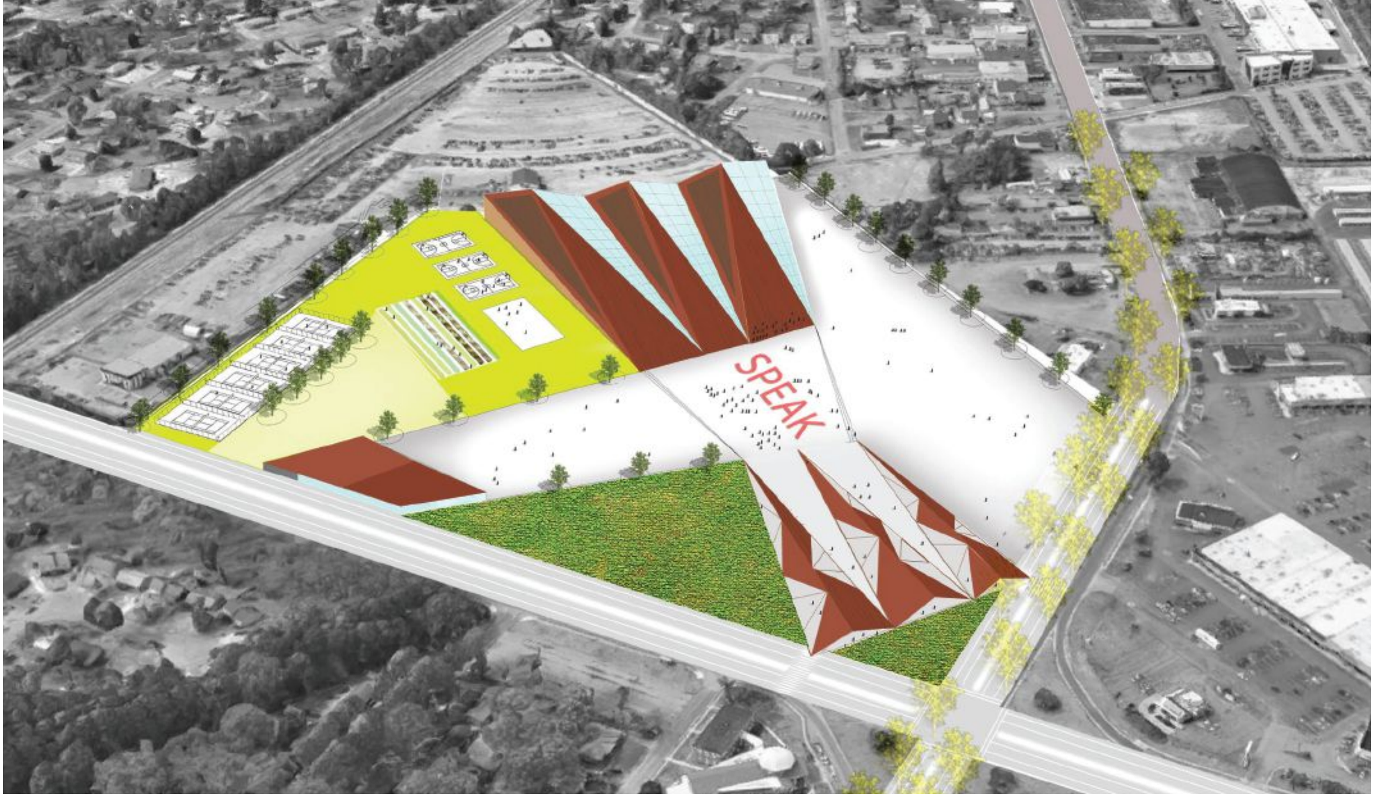
Ruthrauff's design draws on Spanish-inspired architecture in the Prado, local flora, and the nearby Cabrillo Bridge. The bridge's organic form reflects the network of trails in Florida Canyon.

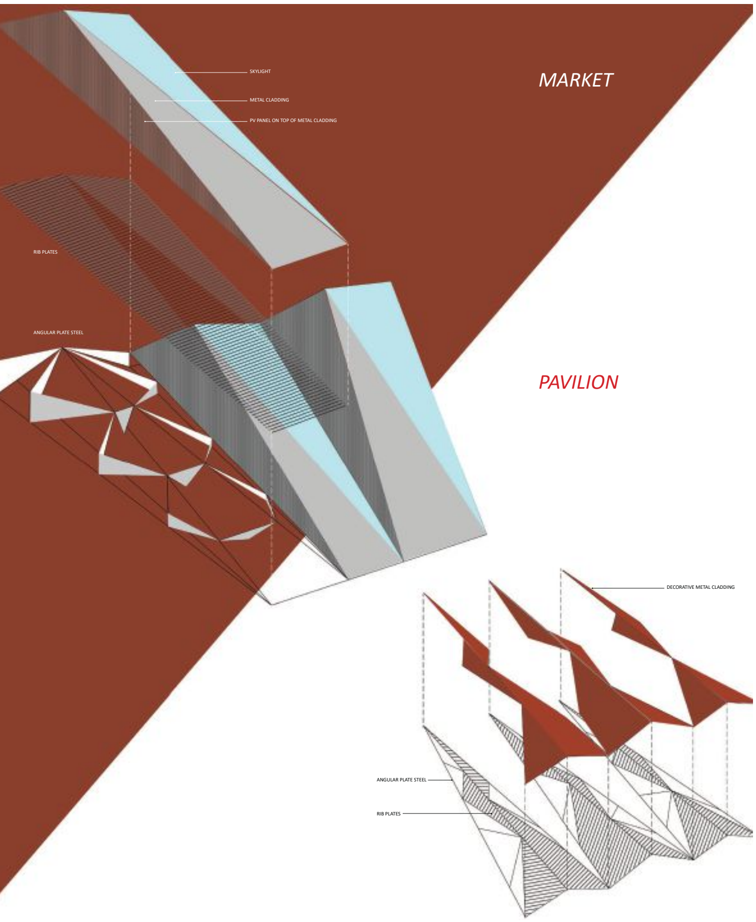
The bridge's open deck offers uninterrupted views and some unconventional public space: large hammocks over four apertures that look down into the canyon. The project would take advantage of the unconventional shapes that are possible with 3D-printed structural steel.

Although the Forge Prize is a conceptual competition, the judges all expressed confidence that Ruthrauff's bridge will be built someday. "I don't think any of us have a doubt in our mind that it's going to come together and be a catalyst for the rest of us across the country," said Pascale Sablan, FAIA, an associate at Adjaye Associates Architects. "He really convinced us that he could actually help solve some of the infrastructure issues that are plaguing our nation."

"Over the last 37 years since our founding, we've fabricated some unique and interesting projects, but the projects we've enjoyed most involve finding solutions to challenges created by architects' innovative use of steel," said STS Steel, Inc., president Glenn Tabolt, who served as Ruthrauff's mentor during the competition. "I was not that familiar with the use of 3D printing in such a large structure, but the more I worked with Hunter and understood the technology, the more enthusiastic I became about his design."

"From an innovation standpoint, our day jobs require that we remain somewhat grounded, and this can impact the speed at which we implement technology. By encouraging forward-thinking design and innovation, the Forge Prize advocates for the evolution of steel structures and therefore improves the industry. There is a revolution on the horizon for our industry that will occur when 3D printing and other advanced fabrication methods are fully embraced. Steel 3D printing specifically will transform how we view steel as a structural material and unchain architectural design. It will ultimately lead to a more harmonious process between engineers and architects. There is a lot to figure out, but we are at the precipice of an exciting future."
—Hunter Ruthrauff





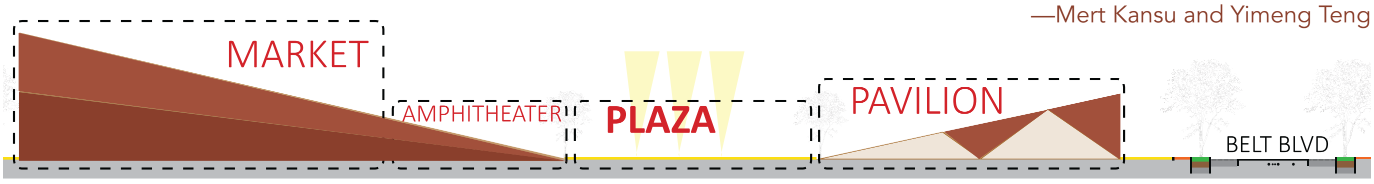
RUNNER-UP
SpeakPlaza
Mert Kansu and Yimeng Teng, VMDO Architects

Mert Kansu and **Yimeng Teng** of VMDO Architects proposed a civic mixed-use plaza in Richmond, Va., that focuses on public engagement, community programs, and sustainability. Their design incorporates steel plates to create an expressive folding form. The folding form design of the project aligns perfectly with structural steel, with an expressive plate structure inside and decorative metal cladding on the exterior.

Together with the development of Belt Blvd., the core of the design aligns with the Richmond 300 Masterplan for walkability, connectivity, and growth. The center of the plaza remains open and accessible, as a free place for movement and expression, and surrounding the plaza is an indoor marketplace to accommodate commercial needs, a pavilion for events and future connection across Belt Blvd., a park and community program zone, and underground parking. On the very edge next to the parking entrance, a smaller structure houses changing rooms and a coffee shop and also provides electric car charging stations.

"It is a great opportunity and tremendous learning experience to participate in the Forge Prize. The two months after being selected as a finalist is a journey of creativity filled with research, discussion, and design. We are lucky to be guided and advised by our three jury members in the early stage and really start to think of ways to enrich the design with features that will have a long-term community impact. As designers, we will keep using creativity as a powerful tool to understand and interact with the environment we live in."

—Mert Kansu and Yimeng Teng



RUNNER-UP

Signal Park

Jieun Yang, AIA, Habitat Workshop

Jieun Yang, AIA, of Habitat Workshop imagined Signal Park in San Jose, Calif., a cluster of urban villages that seamlessly blend into the area's natural landscape. The steel scaffolding structure in the park would collect and filter rainwater to be used for cooling mist stations and site irrigation.

The park is created by overlapping topographical mounds that reflect the uninterrupted vista of San Jose's surrounding natural landscape. The project is made of layers of rings forming hills and valleys that are connected by a series of walkways, landscaped areas, cooling stations, and small and large gathering spaces. It also maintains existing amenities and monuments.

Inspired by the San Jose Electric Light Tower, a series of vertical ring ties that held together vertical scaffold structure is reimagined through a horizontal extension that envisions the full site as a must-see landmark. The scaffold structure in Signal Park not only works as a structure to create hills and valleys but also works as an environmental infrastructure, collecting and filtering rainwater used for cooling mist stations and general irrigation for the site. Low-water native plants are used throughout to minimize water use, and a balanced distribution of shaded and non-shaded spaces considers a range of thermal comfort. Low-water native plants are used throughout to minimize water use. And the scaffold structure transforms into a light source at night to provide a dramatic backdrop for the city.

"The collaboration with a mentor added a whole new dimension and depth to the project. What started as an idea for a light and airy public outdoor structure transformed into a series of topographical terrains with a lattice-like underside. The project embraced the constraints of constructability and efficiency as a rigorous design tool to create variety within modularity. The experience from accessible walkways on top of the structure provides a close-up view of the spaceframe. In contrast, the experience in the underbelly of the latticework structure maintains the design intent of a light-filled and airy public gathering space. It was a privilege to work with AISC and my mentor, Jeff Pate from Owen Steel Company, to highlight steel as form-shifting and terrain-making material that touches the ground lightly and creates space for the community."
—Jieun Yang

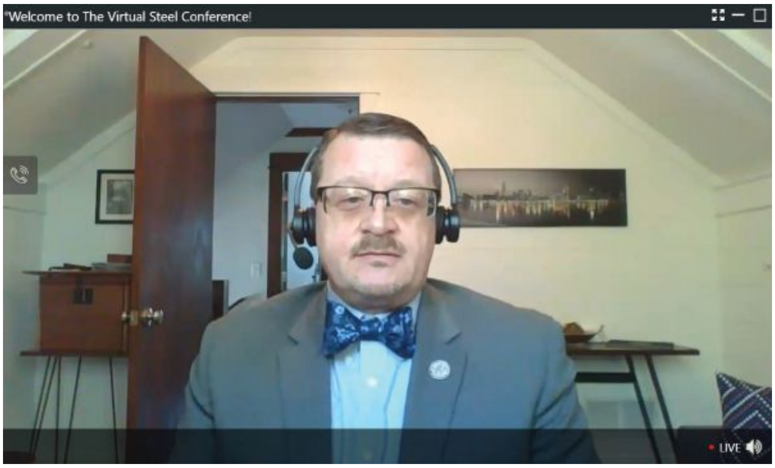
Virtual NASCC, Take Two

BY GEOFF WEISENBERGER

For the second year in a row, NASCC went online. And for the second year in a row, thousands of attendees made the most of the annual learning experience.

IN A TYPICAL YEAR, we're used to seeing AISC president Charlie Carter standing behind a podium in a vast hall, introducing the NASCC: The Steel Conference's opening keynote speaker.

2021 was our second atypical year in a row, and so instead we were treated to a live feed of Charlie sitting behind his laptop in his attic office, introducing the NASCC: The *Virtual* Steel Conference's opening keynote speaker. While he appeared to be in a suit, I do wonder if he was wearing shorts and flip-flops. (No judgment! I'm guessing a lot of us were.)



Going online was a bit of a shock last year. Not so this year, as we've all become seasoned pros at this online meeting thing—though whether we're fans of it is a matter of debate. Nevertheless, we've proven that we can do it. Humans are adaptable and resilient, often much more so than they think, and nearly 4,500 people signed into the virtual version of NASCC—which is on par with our typical in-person shows in recent years. And when we're able to hold the conference in person next year in Denver (this *will* happen; it *has* to), we'll be able to adapt back to that landscape as well—and hopefully see an even larger attendance!

Back to the opening keynote (K1: Jim Fisher's Keys for Successful Designs: Quips and Myths), presenter Jim Fisher of CSD Structural Engineers, whose career spans more than half a century, offered plenty of wisdom, including the following:

- Teamwork is important in steel (or any) projects, and communication is important to teamwork. "*Talk* to people," he urged. "Don't just text and email."

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

- Design isn't a success until the project is complete and functions as it is intended to.
- Are you asking the right questions during design?
- When giving a presentation, memorize the first three minutes. Most people are naturally nervous, and if you memorize the beginning, it gives you a little time to settle down and settle into the presentation.
- "Don't make an early, stupid decision in a design, because you will then make more stupid decisions," (quoting his colleague, Mike West).
- Don't worship the "weight god."
- "If you can't rough it out on an envelope, you shouldn't design it," (quoting William LeMessurier).
- "The product of an arithmetical computation is the answer to an equation; it is not the solution to a problem," (quoting Ashley-Perry Statistical Axiom No. 5).

Jim's keynote, as well as the rest of the 2021 NASCC sessions, can be viewed at **aisc.org/2021nascconline**. There were plenty of highlights and takeaways from the sessions and, like last year, AISC staff moderators shared some of their own. Below are a few. (Special thanks to Devin Altman, Rex Buchanan, Art Bustos, Jeff Carlson, Stacy Chu, Joe Dardis, Nate Gonner, Dennis Haught, Rachel Jordan, Jason Lloyd, Margaret Matthews, Maria Mnookin, Maureen Steffey, Jonathan Tavarez, and Jennie Traut-Todaro for providing their feedback!)

B2: Durability of Present-Day Corrosion Protection Systems

Following this session, a department of transportation representative emailed NSBA and indicated that they are going to explore using uncoated weathering steel more in their state.

B5: Steel Bridges Can be Easy with NSBA's Guide to Navigating Routine Steel Bridge Design

Speaker Domenic Coletti showed just how easy navigating the AASHTO *LRFD Bridge Design Specifications* can be with NSBA's new *Guide to Navigating Routine Steel Bridge Design*. Co-presenter Brandon Chavel also presented on NSBA Design Resources.

B18: Competitive Short-Span Steel Bridges

Five speakers from around the country shared academic studies on many past projects and individual case studies demonstrating the competitiveness of steel for the short-span market. The audience's response was fantastic, with many attendees wanting to know more about press-brake tub girders (PBTGs), rolled-beam bridge case studies, and current pricing.

CS2: A Baselift for a Second City Icon: The Willis Tower Repositioning Project

This was a recreation of a presentation given on SteelDay last year, which had about 150 attendees. The attendance for this version was nearly double that number! (To read about this amazing structural renovation project, see the August 2020 article "A Steel 'Base-Lift'" in the Archives at **www.modernsteel.com**.)

E2: A Frame-Spine System with Force-Limiting Connections for Seismic Resilience

The five speakers presented very interesting details on the development and testing of a new seismic force-resisting system. This project, which is the result of collaboration with Japanese researchers, is sure to "yield" great results for healthcare facilities and other structures in high-seismic areas.

I5 and I6: SpeedCore—Lessons from Research and Implementation, Part One: Research and Part Two: Implementation

Deepening interest in SpeedCore was very apparent in these sessions, and fantastic questions were submitted from the audience. Presenters Amit Varma and Michel Bruneau had the benefit of each other's company at the mic and were clearly having a blast engaging with the audience and each other.

J1: Students Connecting with Industry Sessions: Career Insights

Both Alberto Marquez (Hatfield Group) and Erica Fischer (Oregon State University) delved into their respective career progressions, providing students with some excellent insights into career possibilities and where open doors may lead.

K2: T.R. Higgins Lecture: SpeedCore and Steel-Concrete Composite Construction—The Best of Both Worlds

While highly technical in nature, Purdue University professor and this year's T.R. Higgins Award winner, Amit Varma, couldn't resist a joke or two in his presentation on SpeedCore. "I wanted to add some humor to this technical presentation," he said, "but due to the pandemic and lockdown, all I could come up with were *inside* jokes."

Q14: How to Perform an Effective Management Review

Anna Petroski's presentation included a (prerecorded) dramatic reenactment of a review in progress, demonstrating some of the mistakes that are often made—and it was done in a fun, entertaining way.

R4: Cranes: Good for More than Just Erection

McLaren Engineering's presentation included a spectacular segment on how they set up a wrecking ball to destroy some vehicles for a scene in one of the *Fast & Furious* movies. No CGI!

S1: Advances in Stability Analysis

The first session of the Structural Stability Research Council (SSRC) Annual Stability Conference track drew more than 450 attendees, which is incredibly impressive for an SSRC session. (And to read about an SSRC member, Kara Peterman—including her love of the clarinet and dim sum—check out this month's Field Notes article on page 22.)

T5: Mind the Gap: Addressing the Tech Disparity in Construction

Presenter Luke Faulkner did an excellent job of quelling fears of a Skynet-like takeover and explained the importance of technology in advancing the construction industry. (See "Augmenting Productivity" on page 44 for his thoughts on a forward-thinking technology.)

Z10: 10 Tips to Manage Conflict

Presenter Jim Reeves provided keen insight that everyone could benefit from when it comes to effective listening, particularly the following two pieces of advice: 1) we need to shut up to listen well and 2) we need to remain curious about what the person is talking to us about.

In addition, there was one 60-minute session for which the speaker was very efficient—to the tune of finishing his presentation 25 minutes in. Did this result in crickets or all attendees abruptly signing out? No. It resulted in the speaker answering more than 40 audience questions, one by one, in an engaging, impromptu Q&A session—another example of adaptability and resilience.

Next year's NASCC will take place in Denver, March 23–25. We hope to see you there! ■


CALLING
ALL
INNOVATORS!
If you recently worked on an amazing project that featured structural steel, we want to hear from you. Submit it for a 2022 IDEAS² award! Entries close on September 8, 2021.
Enter now at aisc.org/ideas2
2021 IDEAS² Merit Award
Ballston Quarter Pedestrian Walkway
Arlington, Va.
Photo: studioTECHNE
AMERICAN INSTITUTE OF STEEL CONSTRUCTION
AISC
FOUNDED 1921
2022
IDEAS²
AWARDS
Innovative Design in Engineering and Architecture with Structural Steel

new products

This Month's new product offerings are all related to welding. If you'd like to learn more about how to leverage welding to shorten your steel project schedule, see "Accelerated Welding" on page 32.

Hobart FabCO Triple 7

The FabCO Triple 7 gas-shielded flux-cored wire builds on a proven formulation and now offers expanded mechanical properties. In addition to the American Welding Society (AWS) E71T-1 C/M H8 classification the wire previously held, it now also meets the requirements for an AWS E71T-9 C/M H8 classification. Users can continue to expect the consistent performance Triple 7 wire is known for as a T-1 product while gaining the opportunity to address T-9 applications without extra inventory. The T-9 designation provides greater impact strengths at low temperatures for critical jobs: 20 ft-lb at -20 °F. The new wire excels at welding with mixed gases (75% to 85% argon/CO_2 balance) and is also usable with straight CO_2.

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

Miller ArcReach Heater

The new ArcReach Heating System allows contractors to insource weld joint preheating and bakeout, improving productivity and profitability. The system uses ArcReach-enabled welding power sources that many contractors already have on-site. With induction heating, the system can bring a joint to temperature four times faster than preheating with flame. It can also deliver savings, as contractors typically spend $15 per hour for flame fuel consumed in preheating; the system can help contractors see a return on their investment by the 11th joint they preheat. The system is designed for job-site weld preheating and bakeout with temperature maximums of 600 °F.

For more information, visit **millerwelds.com/arcreachheater**.

Cerbaco Flexback Conformable Weld Backing

Cerbaco, Ltd.'s new pliable weld backing is designed for use in CJP open-root welding. This new technology provides full support for a weld puddle and produces a symmetrical back bead while conforming to any geometry. Suitable for use with MIG, TIG, flux-core, and stick electrode welding processes, the backing is intended for general purpose use as well as unique applications where rigid ceramic backings cannot be used. Flexible, pliable, user-friendly, it can satisfy most of your CJP welding needs.

For more information, please visit **www.cerbaco.com**.

EDUCATION

AISC Education Foundation Seeks Help in Growing the Future of Steel Design and Construction

A new fundraising drive by AISC's Education Foundation is designed to provide new opportunities for both students and faculty.

"Funding the Future is a new program to help future designers gain more experience with structural steel," explained Christina Harber, SE, PE, AISC's director of education.

The AISC Education Foundation is a 501(c)(3) not-for-profit organization that already awards more than $150,000 in scholarships annually to juniors, seniors, and graduate students. But we don't want to stop there, Harber explained.

"Reflecting on AISC's centennial has driven us to think about what we can do to foster innovation for the next century," she said. "The Foundation is putting the finishing touches on a variety of new programs designed to inspire both students and educators, as well as a major fundraising campaign to make it all possible."

This new fundraising campaign will provide ongoing support to a variety of initiatives, including:

- A new undergraduate research fellowship program
- Expanded Adopt-a-School activities
- A new faculty internship program
- A new travel grant program to help students learn outside the classroom
- A new program of traveling steel experts to help students learn inside the classroom

"We're launching this campaign to grow the Foundation's ability to award funds for the future," added Charles J. Carter, SE, PE, PhD, AISC's president. "Your support today will pay off in perpetuity, enabling us to provide scholarships and other programming support to students and educators for decades to come.

"I urge you to visit **aisc.org/giving** to help the AISC Education Foundation bring these new programs to life," Carter said.

The AISC Education Foundation has no overhead costs. Every penny goes straight to educational programming that fosters the next generation of steel industry leaders.

People & Companies

The **American Iron and Steel Institute (AISI)** announced that **Harry W. (Hank) Martin** has been recognized with the **Excellence Award of the National Institute of Building Sciences (NIBS) Building Seismic Safety Council (BSSC)**. NIBS recently recognized leaders who have provided significant direction to the BSSC mission and contributed to the organization's success. Martin is retired from AISI, where he was managing director of construction codes and standards.

The **Steel Bridge Task Force Oversight Council** of **AISI**, the **National Steel Bridge Alliance (NSBA)**, and the **American Association of State and Highway Transportation Officials (AASHTO) T-14 Technical Committee for Structural Steel Design** have selected **Matthew Yarnold, PE, PhD**, assistant professor in the **Zachry Department of Civil and Environmental Engineering at Texas A&M University** in College Station, Texas, as the recipient of the 2021 **Robert J. Dexter Memorial Award Lecture**. The program was instituted in 2005 in memory of **Robert J. Dexter**, an associate professor of civil engineering at the University of Minnesota, who was an internationally recognized expert on steel fracture and fatigue problems in bridges. The Robert J. Dexter Memorial Award Lecture program provides an opportunity for individuals early in their careers in structural engineering to present a lecture on their steel bridge research activities to the **Steel Bridge Task Force**. Dr. Yarnold will present a lecture on his findings at the next meeting of the Task Force, scheduled for August 12 in Philadelphia.

MEMBERSHIP
AISC Board Announces New Members

Full

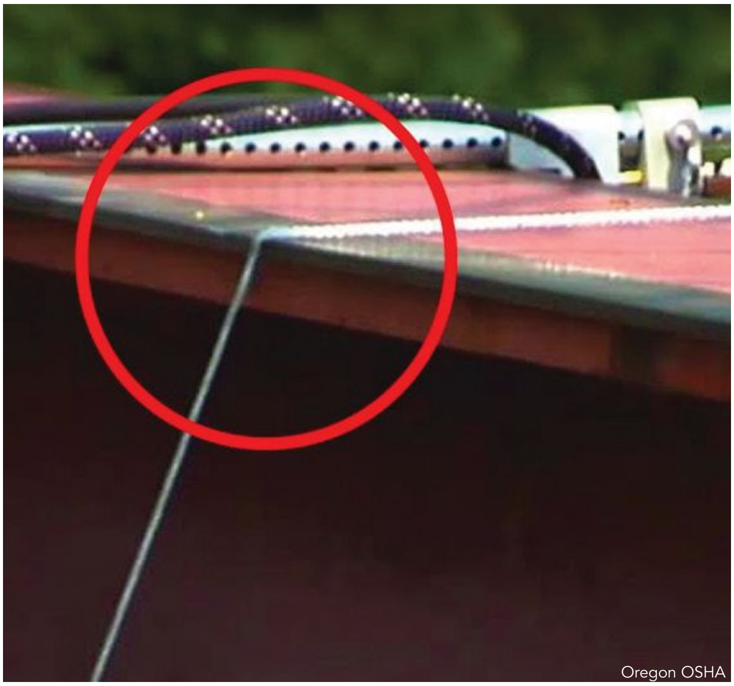
1888 Industrial Services, Ault, Colo.
Arc Rite Welding and Fabrication, LLC, Pipe Creek, Texas
Castillo Iron Works, Inc., Bronx, N.Y.
Cutting Edge Steel, Inc., Dacono, Colo.
Dynamic Isolation Systems, Inc., McCarran, Nev.
Elite Welding and Industrial Services, LLC, Millwood, Ky.
Melvin Wrought Iron, Inc., Ontario, Calif.
RMV Structural Steel, LLC, Mission, Texas
Triad Fabricators, LLC, Evansville, Ind.
W. A. New Steel, LLC, Harpersville, Ala.

Associate

Arcusion, Laguna Hills, Calif., *Detailer*
Fabtech Consultant USA, Inc., Houston, *Detailer*
IDEA StatiCa, Brno, Czech Republic, *Software Vendor*
J. Mac Steel Detailing and Design, LLC, Cape Girardeau, Mo., *Detailer*
Marqway Steel Services, Inc., Redmond, Wa., *Detailer*
MLowe Services, LLC, Claremore, Okla., *Detailer*
MoldTek Technologies, Inc., Cumming, Ga., *Detailer*
Prestige Equipment, Melville, N.Y., *Equipment Dealer*
R.M.D. Technical, Clearfield, Utah, *Detailer*
Taylor Devices, Inc., North Tonawanda, N.Y., *New Equipment Manufacturer*
TurnBIM Engineering Services, LLP, Bangalore, India, *Detailer*

AISC CODE
2022 AISC *Code* Available for Public Review

A draft of the 2022 AISC *Code of Standard Practice for Steel Buildings and Bridges* (AISC 303) will be available for public review from June 1 until June 30. This is the second public review of the 2022 edition, which is expected to be completed and available in the summer of 2022. The draft and review form are both available for download at **aisc.org/publicreview**. Hard copies are also available (for a $35 charge) by calling 312.670.5411. Please submit comments using the form provided online to Jonathan Tavarez (**tavarez@aisc.org**) by June 30 for con-



Oregon OSHA

Welcome to Safety Matters, which highlights various safety-related issues. This month's topic is fall protection.

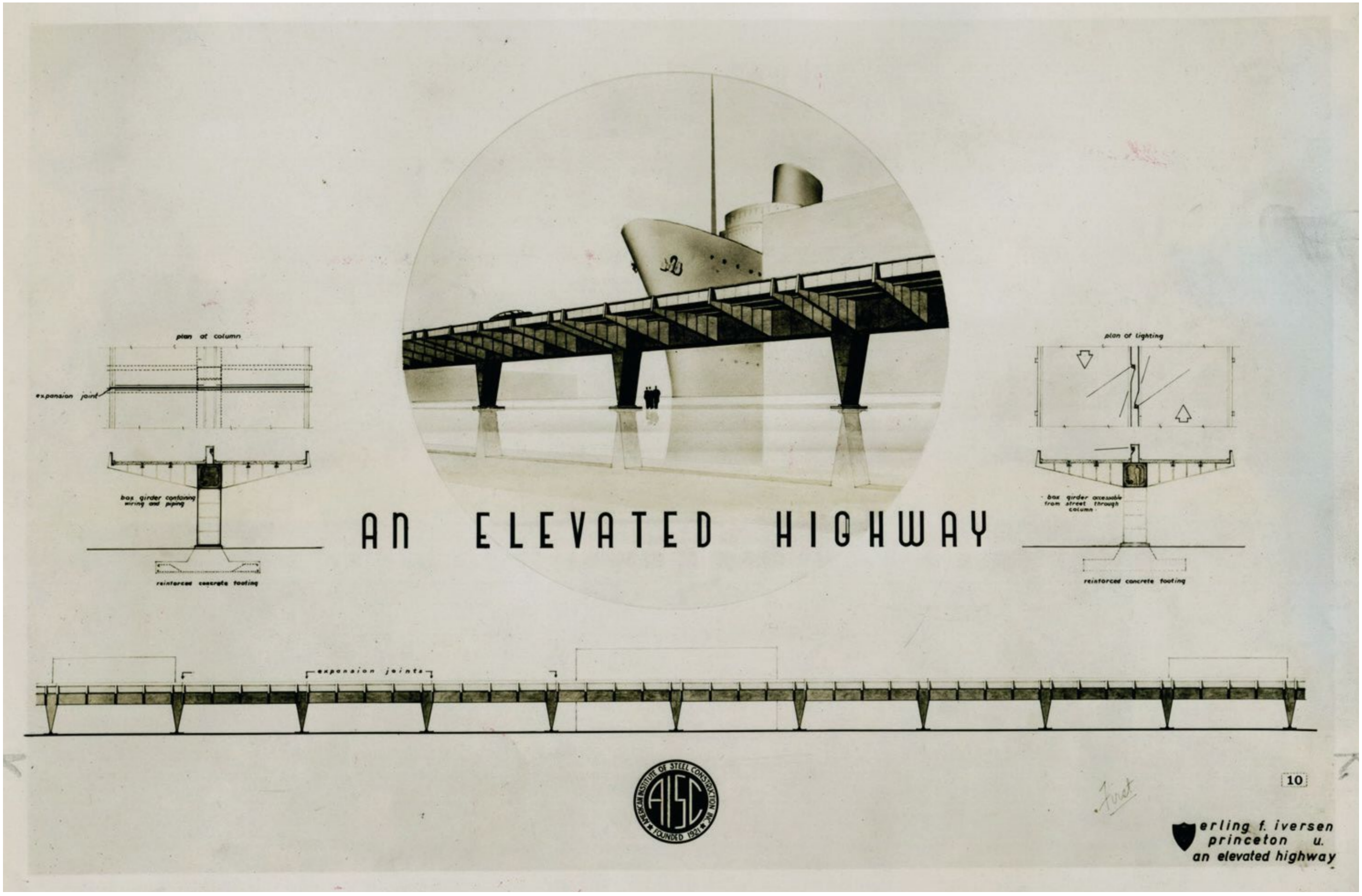
Fall protection and the duty to provide fall protection are always on the top ten list of citations for steel erectors. In 2016, OSHA (Occupational Safety and Health Administration) reported that out of 4,693 deaths in private industry, 991 (more than one-fifth) were in construction. And of those 991 construction fatalities, 384 (more than one-third) were the result of falls.

Leading-edge work has special hazards associated with it—including the edge itself. In many cases, that edge is sharp, with either a very small radius or a sharp 90° angle. Should a crew member fall, their lifeline will come in contact with that edge, which could cut or fray the cable or webbing. This could happen on initial impact, but it's also likely that the worker will sway back and forth while dangling over the edge, which could also cut a lanyard that is not designed for such stress. This is why a complete fall-protection system is necessary.

Complete fall protection systems include a lanyard, deceleration device, and a lifeline. Some use personal fall limiters (PFLs) while others employ self-retraction lifelines (SRLs). SRLs can be tested and labeled for leading-edge work (this testing includes verifying that the lifeline doesn't deteriorate due to sharp corners). Note that with any fall-protection system, anchorage below the D-ring is discouraged and requires special equipment when it's absolutely necessary.

We are always on the lookout for ideas for safety-related articles and webinars that are of interest to AISC member companies. If you have safety-related questions or suggestions, we would love to hear them. Contact us at **schlafly@aisc.org**. You can also visit AISC's safety page at **aisc.org/safety** for various safety resources. In addition, visit **aisc.org/nascc** to see videos of safety-related sessions from the 2021 NASCC: The Virtual Steel Conference, which took place in April.

advertiser index



STUDENT BRIDGES, YESTERDAY AND TODAY

AS AISC TURNS 100 YEARS OLD THIS YEAR, we can't help but feel nostalgic.

Luckily, we've got lots and lots (and lots) of archival materials to look through.

We've unearthed countless treasures, including this winning project from the 10th annual AISC Student Bridge Competition—in 1938—submitted by a student at Princeton University. Note that this is a different competition from both the current Steel Design Student Competition (SDSC) and the Student Steel Bridge Competition (SSBC).

Speaking of the latter, the 2021 SSBC National Finals Awards Presentation will take place on June 3. See **aisc.org/ssbc** for a link to the presentation as well as the results of the various regional competitions.

And for content related to AISC's century of existence, visit **aisc.org/legacy**.

September 24, 2021

SteelDay USA