Modern
Steel Construction

September 2024

AMERICAN INSTITUTE OF STEEL CONSTRUCTION
AISC
FOUNDED 1921

S&S WELDING
ROBOTIC FABRICATION FAST TRACK
ROD RAMER
Plant Manager
SHARON PIECHOWIAK
VP and CFO
DALE PIECHOWIAK
President
MARK TRACEY
VP of Sales
"One morning when I came to work I found I had four fitters missing that day, and I had a lot of work to do. So I picked up the phone and called up Peddinghaus and ordered the PeddiAssembler."
-DALE PIECHOWIAK
THE PEDDIASSEMBLER
Peddinghaus
STRONGER THAN STEEL®
www.peddinghaus.com | info@peddinghaus.com | (815) 937-3800

Modern Steel Construction

September 2024

in every issue

departments

resources

columns

features

ON THE COVER: The Morgan Center for Research and Innovation in Philadelphia is built on a repurposed steel podium. (Photo: CannonDesign)

MODERN STEEL CONSTRUCTION (Volume 64, Number 9) ISSN (print) 0026-8445: ISSN (online) 1945-0737. Published monthly by the American Institute of Steel Construction (AISC), 130 E Randolph Street, Suite 2000, Chicago, IL 60601. Single issues $8.00; 1 year, $60. Periodicals postage paid at Chicago, IL and at additional mailing offices. Postmaster: Please send address changes to MODERN STEEL CONSTRUCTION, 130 E Randolph Street, Suite 2000, Chicago, IL 60601.

Printed on paper made from a minimum of 10% recycled content.

Flush-frame INNOVATION

Vibration performance equal to wide-flange beams at up to a 35% weight savings

Smart engineering reduces material costs and improves performance. New Millennium flush-frame connections feature a more efficient design that eliminates beam torsion concerns. Our published set of standard flush-frame connections simplify design and specification. Now, structural engineers can quickly and accurately specify flush-frame connections, streamlining fabrication and erection. **Together, let's build it better.**

Flush-frame connection designed for efficiency

Standardized connections reduce design time

Joist reaction point occurs at beam centerline

Download the new Flush-Frame Design Guide

NEW MILLENNIUM

A Steel Dynamics Company

newmill.com

editor's note

A couple of big things happened for me in June.

First of all, I had a significant birthday (one that ends in a zero—though, rest assured, I'm not as old as the bridge in the photo).

Secondly, my family and I took a trip to the UK, where we visited London (going there never gets old), Edinburgh, and Glasgow (first time in Scotland; please take me back ASAP).

I love to travel, but this trip in particular—combined with the big birthday—got me to thinking more about how to plan for it. We previously tended to take a rather opportunistic, somewhat freewheeling approach to picking travel destinations, especially international ones. But for the first time, it dawned on me that it may be a good idea to have a long-term plan, even a loose one, moving forward.

I say this because now that it's all downhill from here, so to speak (though it'll be a lovely ride), I'm acknowledging that I just might not make it to every global destination that I'd hoped, and I can't keep saying, "We'll go there *someday*!" At the very least, I need to start prioritizing locations or developing a travel bucket list.

The problem is this: There are still lots of places I'd like to visit… but I also love a lot of the places I've already been. I want to see more new destinations… but at the same time, I've had so much fun visiting certain locations that I also want to go back and do some of the exact same things I did on my previous trips to those places.

Take London for example. I stated earlier that it never gets old. I've been four times now, and I feel like I've only scratched the surface. I can't wait to go back and see more of it but also return to some familiar places there (many of them pubs) on my next visit. There's something to be said about having "your" spot in another city or country.

It's a good (and, frankly, privileged) problem to have. Because there are no wrong answers. I'll have a great time whether I go to London for a fifth (or eventually 10th) time or to Croatia, which I am now obsessed with visiting (thanks, Instagram algorithms).

You know where else you can't go wrong? Wait for it… steel construction! Our old tagline used to be "There's always a solution in steel." While we changed that to "Smarter. Stronger. Steel." a few years back, the original line still rings true. And the September issue of *Modern Steel Construction* highlights two types of steel solutions that can help enhance a project from an aesthetic standpoint: exposed steel, specifically architecturally exposed structural steel (AESS), and curved steel—both of which I saw quite a lot of on my trip to the UK.

There are some misconceptions regarding the affordability and practicality of both areas, yet when properly planned (with no freewheeling mindset), both can be performed efficiently and within a project budget. Want to learn more? Check out "Curved Steel Curiosities" and "Out In the Open" on pages 48 and 54, respectively!

Geoff Weisenberger
Editor and Publisher

Modern Steel Construction

Editorial Offices
130 E Randolph St, Ste 2000
Chicago, IL 60601
312.670.2400

Editorial Contacts
EDITOR AND PUBLISHER
Geoff Weisenberger
312.493.7694
weisenberger@aisc.org

ASSOCIATE EDITOR
Patrick Engel
312.550.9652
engel@aisc.org

SENIOR DIRECTOR OF PUBLICATIONS
Keith A. Grubb, SE, PE
312.804.0813
grubb@aisc.org

DIRECTOR OF GRAPHIC DESIGN
Kristin Hall
773.636.8543
hall@aisc.org

EDITORIAL DIRECTOR
Scott Melnick
312.804.1535
melnick@aisc.org

AISC Officers
CHAIR
Hugh J. McCaffrey
Southern New Jersey Steel Co.

VICE CHAIR
Glenn R. Tabolt, PE
STS Steel, Inc.

SECRETARY/LEGAL COUNSEL
Edward Seglias, Cohen Seglias Pallas Greenhall & Furman, PC

PRESIDENT
Charles J. Carter, SE, PE, PhD

SENIOR VICE PRESIDENTS
Scott Melnick
Mark W. Trimble, PE

VICE PRESIDENTS
Todd Alwood
Brandon Chavel, PE, PhD
Carly Hurd
Mike Mospan
Christopher H. Raebel, SE, PE, PhD
Brian Raff

Editorial Advisory Panel
Nat Killpatrick
Basden Steel

Christina McCoy, SE
Oklahoma State University School of Architecture

Allison Shenberger, PE
ruby+associates

Justin Smith, PE
Dekker Perich Sabatini

Advertising Sales
Geoff Weisenberger
312.493.7694
weisenberger@aisc.org

Address Changes and Subscription Concerns
312.670.2401
subscriptions@aisc.org

Reprints
Kristin Hall
hall@aisc.org

If you've ever asked yourself "Why?" about something related to structural steel design or construction, *Modern Steel*'s monthly Steel Interchange is for you!

Send your questions or comments to **solutions@aisc.org**.

Appearance of Unpainted Class B Faying Surface

What does an unpainted Class B faying surface look like?

A reference showing visual representations of surface preparations is SSPC-VIS1: *Guide and Reference Photographs for Steel Surfaces Prepared by Dry Abrasive Blast Cleaning* (available from AMPP at **https://store.ampp.org/sspc-vis-1**). An April 2008 SteelWise article titled "Properly Prepared" described this surface as, "It is more intense than brush-off blast cleaning but not as rigorous as near-white or white metal blast cleaning. No surface contaminants may be visible. In a 9-sq.-in. area, no more than 33% of the area can be stained due to rust. It is required for most epoxy primers and polyurethane finish coats."

One option that can be used to provide a Class B surface is "unpainted blast-cleaned steel surfaces." There are coatings that can provide a Class B surface, but the surface must be blast-cleaned and the blast cleaning must be consistent with the coating being used. For an unpainted Class B surface, a fabricator may follow SSPC-SP6: *Commercial Blast Cleaning*.

The RCSC *Specification for Structural Joints Using High-Strength Bolts* (download for free at **aisc.org/publications**) provides useful information. It describes the surfaces that must remain unpainted, and RCSC *Specification* Figure C-3.1 shows the perimeter of the contact area of the faying surfaces.

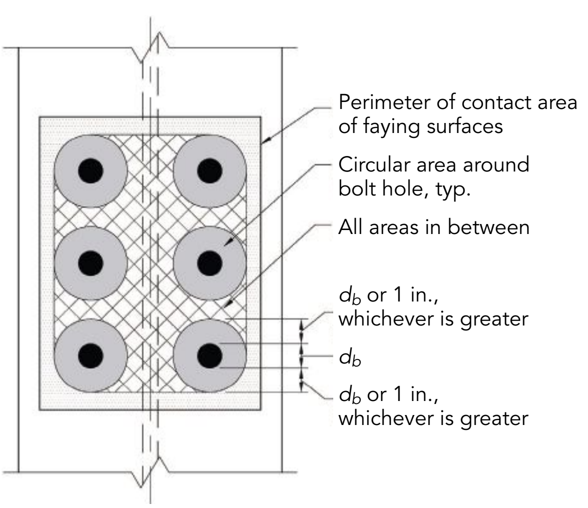


Figure C-3.1. Areas of faying surfaces of slip-critical joints to remain uncoated with unqualified coatings (d_b = bolt diameter).

A blast-cleaned surface will begin to "flash" rust immediately. By the time the piece is erected there may be considerable rust present. The Commentary to RCSC *Specification* section 3.2.2 states, "Corrosion often occurs on uncoated blast-cleaned steel faying surfaces (Class B, see Section 5.4) due to exposure between the time of fabrication and subsequent erection. In normal atmospheric exposures, this corrosion is not detrimental and may actually increase the slip resistance of the joint. Yura et al. (1981) found that the Class B slip coefficient could be maintained for up to one year prior to joint assembly."

If the flash rust is not desired for aesthetic reasons, the application of a Class B coating may be used after blast-cleaning.

References

Yura, J.A., Frank, K.H., and Cayes, L. (1981), "Bolted Friction Connections with Weathering Steel," Journal of the Structural Division, *Vol. 107, No. ST11, November, ASCE, Reston, Va.*

Larry Muir, PE

Unstiffened Seated Connection Weld Strength

Table 10-6 of the 16th Edition AISC *Steel Construction Manual* provides the available weld strength of all-welded unstiffened seated connections. How is this weld strength calculated? What is the assumption for eccentricity?

The available LRFD weld strength provided in Table 10-6 is calculated using Eq. 10-4a:

$$\phi R_n = 2\left(\frac{1.392Dl}{\sqrt{1+\dfrac{20.25e^2}{l^2}}}\right) \qquad \text{Eq. (10-4a)}$$

where,

D = number of sixteenths-of-an-inch in the weld size

e = eccentricity of the beam end reaction with respect to the weld lines, in.

l = vertical leg dimension of the seat angle, in.

The eccentricity of the beam end reaction depends on the assumed bearing stress distribution. Salmon et al. (2009) discusses several possible bearing stress assumptions for seated connections.

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

A conservative approach is adopted for finding the weld strength provided in Table 10-6 in which the eccentricity is taken as e = (horizontal leg dimension of the seat angle – beam setback)/2 + beam setback, as illustrated in Figure 1:

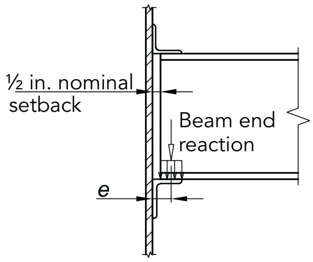


Fig. 1

Note the nominal setback is shown as ½ in. Regarding unstiffened seated connections, Part 10 of the *Manual* states in the "Shop and Field Practices" section, "to provide for overrun in beam length, the nominal setback for the beam end is ½ in. To provide for underrun in beam length, this setback is assumed to be ¾ in. for calculation purposes."

For example, the first entry in Table 10-6 on page 10-37 of the 16th Edition *Manual* indicates the LRFD available weld strength for an L4×3½ seat angle with a ¼-in. fillet weld (70 ksi) is 17.2 kips. The eccentricity in this case is taken as:

$$e = (3.5 \text{ in.} - 0.75 \text{ in.}) / 2 + 0.75 \text{ in.} = 2.125 \text{ in.}$$

Using Eq. 10-4(a),

$$\phi R_n = 2\left(\frac{1.392Dl}{\sqrt{1+\dfrac{20.25e^2}{l^2}}}\right) = 2\left(\frac{1.392\,(4)\,(4 \text{ in.})}{\sqrt{1+\dfrac{20.25\,(2.125 \text{ in.})^2}{(4 \text{ in.})^2}}}\right) = 17.2 \text{ kips}$$

References

Salmon, C.G., Johnson, J.E. and Malhas, F.A. (2009), Steel Structures: Design and Behavior, *5th Ed., Prentice Hall, Upper Saddle River, N.J.*

Heather Gathman

Heather Gathman (gathman@aisc.org) is a staff engineer in AISC's Steel Solutions Center. **Larry Muir** is a consultant to AISC.

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

steel quiz

This month's quiz is all about filled composite members. Learn more in Chapter I and Appendix 2 of the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360-22). Download a free copy today at **aisc.org/publications**.

1 Match the correct section classification using options **(a.)**, **(b.)**, and **(c.)** with respect to the HSS wall slenderness for each of the following figures. Each figure illustrates the typical stress block for determining the nominal flexural strength of the filled section. Options:

a. Noncompact composite section
b. Slender-element composite section
c. Compact composite section

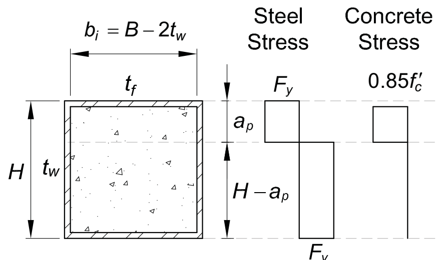


Fig. 1.

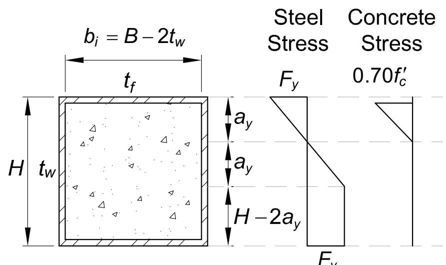


Fig. 2.

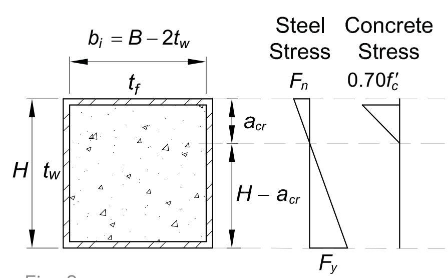


Fig. 3.

2 According to the *Specification*, which of the following methods may be used for determining the nominal strength of composite sections?

a. Plastic stress distribution method
b. Strain compatibility method
c. Elastic stress distribution method
d. Effective stress-strain method
e. All of the above

3 **True or False:** The equations provided in the *Specification* for calculating the design flexural and axial strength of rectangular filled composite members require that the minimum yield strength of structural steel does not exceed 75 ksi.

4 **True or False:** When using the plastic stress distribution method for rectangular composite sections, it is permitted to assume that the concrete components in compression have reached a stress of $0.95f'_c$.

5 **True or False:** Superposition of the available strength provided by the force transfer mechanisms of direct bond interaction, shear connection, and direct bearing is not permitted.

6 **True or False:** If longitudinal reinforcement is provided in a filled composite member, minimum internal transverse reinforcement must also be provided.

7 **True or False:** According to the *Specification*, the nominal shear strength of a filled composite section is computed considering the contributions of the structural steel section, concrete infill, and internal reinforcement (when internal reinforcement is provided).

TURN TO PAGE 12 FOR ANSWERS

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

NUCOR®
VULCRAFT

VISION MEETS

VERSATILITY.

Break from the norm with Vulcraft steel specialty joists. Our team of experts can help you find unique, custom-engineered joist solutions for even your most complex designs. Our products are manufactured for durability and versatility, transforming your vision into a building that makes a statement.

Contact an expert today.

Contact our experts to find the specialty joist solution for your next project.

Answers reference Chapter I and Appendix 2 of the *Specification.*

1 **Fig. 1. (c.) | Fig. 2. (a.) | Fig. 3. (b.).** Compact composite sections can develop the full plastic strength, M_p, in flexure as indicted in Figure 1. The nominal flexural strength, M_n, of noncompact composite sections can be determined using a linear interpolation between the plastic strength, M_p, and the elastic strength based on the yield strength, M_y, with respect to the HSS wall slenderness. Slender-element composite sections are limited to developing the first yield moment, M_{cr}, of the composite section where the tension flange reaches first yielding, while the compression flange is limited to the critical buckling stress, F_n, and the concrete is limited to linear elastic behavior with maximum compressive stress equal to $0.7f'_c$ (Commentary Section I3.4).

2 **e. All of the above.** Section I1.2 states, "The nominal strength of composite sections shall be determined in accordance with either the plastic stress distribution method, the strain compatibility method, the elastic stress distribution method, or the effective stress-strain method, as defined in this section." This forms the basis for calculating the nominal axial and flexural strength for composite members, which are then used to determine member strength under interaction (Section I1.2 and Commentary).

3 **False.** In older editions of the *Specification*, this was true. In the 2022 *Specification*, however, Appendix 2 was revised to address rectangular filled composite members with high-strength materials. It provides methods for calculating the design axial and flexural strength of rectangular filled composite members constructed from either one or both materials (steel or concrete) with strengths above the limits noted in Section I1.3. In Appendix 2, the specified minimum yield stress of structural steel is capped at 100 ksi, and the specified compressive strength of normal weight concrete is not to exceed 15 ksi (Appendix 2).

4 **False.** For the plastic stress distribution method, the nominal strength is computed assuming that steel components have reached a stress of F_y in either tension or compression, and concrete components in compression due to axial force and/or flexure have reached a stress of $0.85f'_c$, where f'_c is the specified compressive strength of concrete. However, for round HSS filled with concrete, a stress of $0.95f'_c$ is permitted to be used for concrete components in compression due to axial force and/or flexure to account for the effects of concrete confinement (Section I1.2a).

5 **True.** Superposition of force transfer mechanisms is not permitted per Section I6.3. The experimental data indicate that direct bearing or shear connection often does not initiate until after direct bond interaction has been breached. Little experimental data is available regarding the interaction of direct bearing and shear connection via steel anchors (Commentary Section I6.3).

6 **True.** Minimum longitudinal reinforcement is not required. However, if longitudinal reinforcement is provided, minimum internal transverse reinforcement must be provided. The minimum requirements specified in Section I2.2 are based on ACI 318 provisions.

7 **False.** As outlined in the *Specification*, the nominal shear strength of filled composite members include the contributions of the structural steel section and concrete infill. The contribution of the internal reinforcement to the total shear strength was found to be marginal compared to the strength provided by the steel HSS, and is not part of the design equations (Section I4.2 and Commentary).


Design
with a
View

Bending Benefits

BY KEN PECHO

Engineers should consider these ten bender-roller tips and facts when designing with curved steel.

A curved steel glass roof is the architectural and structural highlight of the renovated Domino Sugar refinery in Brooklyn.

Field Condition

AT CHICAGO METAL ROLLED PRODUCTS, we receive near-daily inquires that remind us of the information gap between design teams and structural steel bender-rollers. The two sides collaborate often, but designers only see a small part of bender-rollers' work, which can lead to misconceptions about the work, how it's performed, and our capabilities.

There are many variables to consider when assessing the feasibility of a curved structural steel member from the viewpoint of a bender roller. As one of the nation's largest bender-rollers, Chicago Metal Rolled Products sees all types of requests. Here are ten helpful tips and facts about bender-rollers that designers should know.

1. Not all bender-rollers are the same. While all bender-rollers essentially produce the same product—curved steel—each has its own core competencies. Bending and rolling is an art form where knowledge is considered proprietary information, and since it began, bender-rollers have developed their skills and worked on those competencies to establish individual specialties. The machines and tooling required to achieve these bends are highly specialized and expensive.

Some bender-rollers have machinery designed for one type of bending, such as hardway rolled beams or beams curved against their strong axis. Chicago Metal

Rolled Products has the world's largest and most advanced dedicated beam bending machine and is often referred to for curving beams hardway. Some bender-rollers have odd ball size tooling to accommodate specialty non-commodity product sizes. Others have advanced capabilities in complex 3D Helical or compound geometries, or in equipment that can achieve high production at a fraction of the time.

Not all bender-rollers can do all types of bending in varying degrees of difficulty. If your design is special in any way, which award-winning architecture often is, you may be limiting your project to a specific group of bender-rollers, which can increase lead times and push up costs.

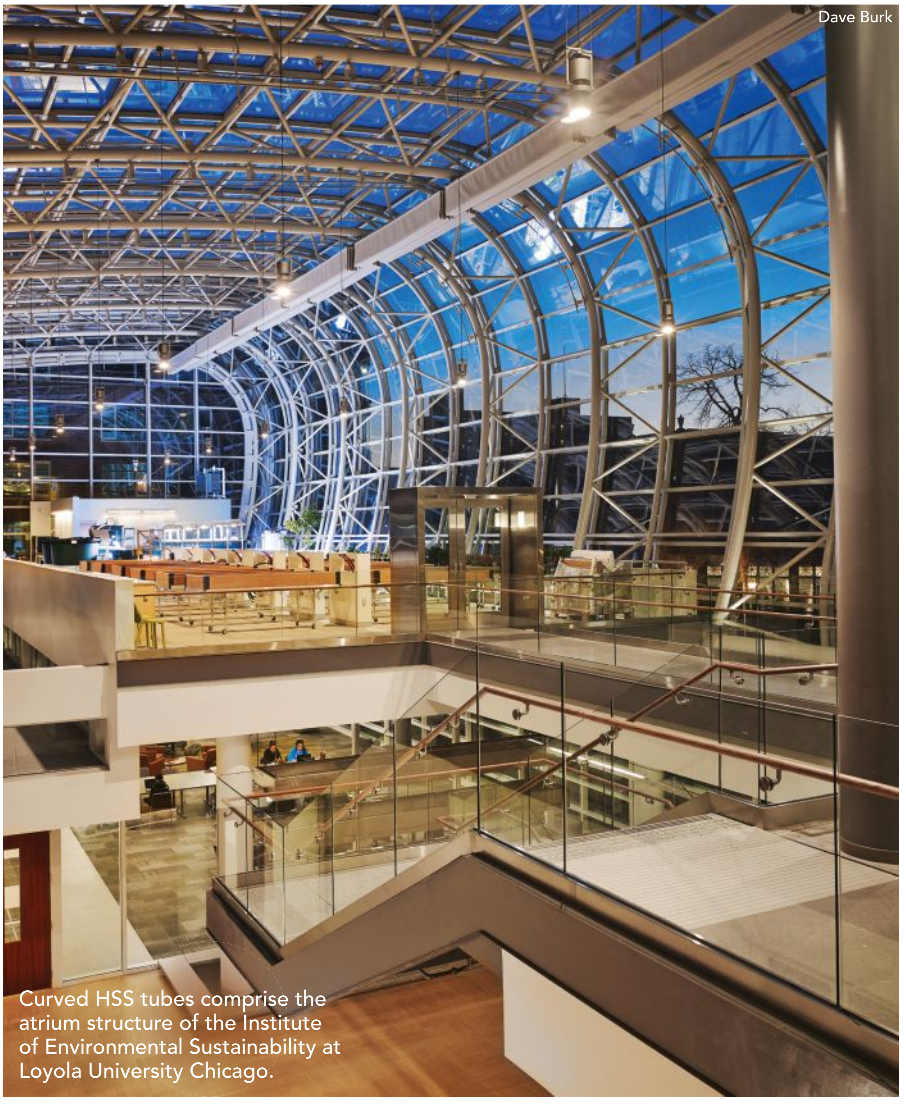
2. Feasibility of design. Some designs might be theoretically possible but practically difficult or impossible to achieve with current bending technology. Bender-rollers can achieve extremely difficult and complex geometries, but cannot do the impossible. With current technology in design software, it is easy to come up with organic free-form designs, but as designs become closer and closer to being truly organic (like the shape of waves in the ocean or the shape of starlings in murmuration), they become increasingly difficult to bend or curve.

Bender-rollers are limited to the materials specified to them and to the capacity of those materials to take a curve or bend. We were once told we could bend a tube into a pretzel, but it is highly unlikely and rather impractical because a tube member will collapse on itself. Available bending machines don't provide a method to do that forming in a proficient straightforward way. Consulting with bender-rollers during the design phase can ensure that the proposed curves are realistic and achievable.

3. CNC machines are not up to speed…yet. A vast majority of the machinery used in the structural steel bending industry are not CNC. While the machines are NC and contain positional readouts to ensure accurate forming, they are not fully autonomous and don't bend by way of plugging in a 3D .STEP file. They're operated by hand by a skilled operator. They have joysticks and buttons that control the bending rolls' positions and the direction of the member as it is pulled through the machine.


Field Condition

The Eglise Bridge in Big Sky, Mont., has two curved steel arches.


Dave Burk

Curved HSS tubes comprise the atrium structure of the Institute of Environmental Sustainability at Loyola University Chicago.

NRG Stadium in Houston has a solar energy system that doubles as a canopy over an entry and exit gate.

How much curve should be induced per pass? How much pressure should be applied? How quickly do we want to get to the radius? How many passes through the machine should we take? Does an HSS member need internal support mechanisms? How do we correctly stack the tooling to get the optimal machine setup? The operator answers all those questions by leaning on extensive experience with the machine.

There are CNC machines on the market, and most major equipment manufacturers produce machines with CNC capabilities. But their feedback measuring systems need developing, largely due to the multiple variables present when bending. Material properties differ between heat numbers and between mills, which influences the success of a CNC curved member. You can enter a tube into a CNC section bender, but repeatability and accuracy from piece to piece is not sufficient and will lead to a stack of non-conforming parts that need adjusting.

4. Collaborate to determine pickup/grip length. Design engineers must consider that nearly all structural steel curving and bending machines require an additional length added to the required good arc length and to the raw material lengths from the mills or service centers. This length is often referred to as grip or pickup length, and it's required for the machine to hold the member. It's used as leverage to induce the moment force needed to yield the material and pull it through the machine, inducing a curve or radius.

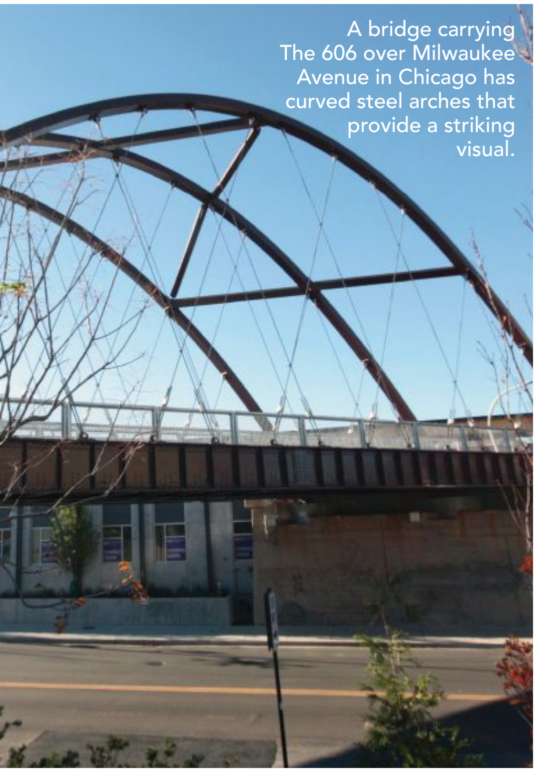
Grip lengths are necessary to manipulate the steel members, but result in unusable tangents that will be cut off and scrapped later in the rolling process. Depending on the size of the machine used in the bending operation, which is directly related to the size of the member being bent, the grip length on each end could vary from 6 in. to 10 ft. It must be accounted for during the design phase to minimize material waste and to optimize the rolling process.

The grip length is a combination of material size and shape, bend geometry, and machine manufacturing. It's not calculable for designers, so it must be determined by talking with the bender-roller. Ask which curving machine will be used and how much length will be lost in the process.

Additionally, structural steel members are typically supplied in standard stock lengths, and depending on the length of your designed curved member, it may be prohibitive. Finding stock lengths long enough to account for the desired arc length of the curved member and provide sufficient grip length can be challenging. Ensuring the design fits within available stock lengths keeps the project on schedule and avoids the mill needing to specifically produce the member to an oversize length.

5. Press-brake-formed shapes are not ideal and difficult to roll. Several factors make curving press-brake-formed shapes challenging and not ideal. It is best to use hot-rolled shapes or HSS for rolled and curved members. Most bender-rollers can use cutting torches to trim away or cut off certain features or split mill-produced shapes. In the same way bender-rollers obtain "T" shapes by splitting beams, they can cut off flanges or legs from beams, channels, and angles to make non-commodity shapes and sizes.

The residual stresses induced during the press brake operation can cause undesirable movements in the material when it's subject to constant yield forces during the bending operation, leading to unpredictable and often problematic outcomes. Additionally, the unique shapes produced by press brakes often require customized tooling and rolls for bending. Most bender-rollers don't have these specialized rolls and must develop the tooling specifically for the job, which is time-consuming and exceedingly expensive. Even after



A bridge carrying The 606 over Milwaukee Avenue in Chicago has curved steel arches that provide a striking visual.

The pick-up and drop-off area at Greater Rochester International Airport in Western New York is covered by canopies made of curved steel tubes.

JPW Structural Contracting

developing the tooling, there is no assurance that the press-brake formed shape will curve without distortion.

6. All curved members experience some degree of cross-sectional distortion. Consider and account for cross-sectional distortion of curved members during the design phase, especially when looking at connections and splice locations. All curved members experience some degree of cross-sectional distortion due to the forces applied by the bending machine and bending that occurs in the plastic phase of the metal.

To achieve the desired radius, the member must undergo plastic deformation, which plays a large role in altering its cross-sectional dimensions. Distortion is a natural consequence of the material being pushed beyond its elastic limits to take a radius. During the bending process, cross-sectional dimensions of the steel member can change or alter, deviating from nominal. That results in slight irregularities in the member's shape and affecting its ability to be joined efficiently with other structural members.

One critical issue arises in making full-penetration circumferential butt-welded connections. Distorted cross sections may not align properly, leading to gaps or misfits that compromise the quality and strength of the welds. Misalignment can prevent full penetration when subject to testing and increase fabrication costs due to the need for additional adjustments and corrective measures. Understanding and mitigating cross-sectional distortion is essential for ensuring the reliability and safety of curved steel structures. Section 3.4 and Section 5.5 of AISC Design Guide 33: *Curved Member Design* (download at **aisc.org/dg**) are helpful resources.

7. Tolerances can be accurate…on certain geometries. Bender-rollers can achieve high accuracy on simple geometries such as single bends in one plane or rolled rings in a single plane. They often hold tolerances tighter than those specified in *Code of Standard Practice for Structural Steel Buildings* (ANSI/AISC 303-22) Section 6.4.2, sometimes within as little as 1⁄16 in. on the diameter. The precision comes from the ability to control the member while still gripped in the machine and the straightforward nature of these bends.

However, when the geometry becomes more complex, such as with compound bent members, multi-radial members, helical members, or those with multiple bends on different planes, maintaining accuracy is challenging. Each bend or plane introduces its own set of tolerances, and they compound as bends accumulate or occur on different planes, leading to increased potential for deviation from the desired dimensions. The ability to hold position—and therefore bending tolerances—suffer every time a bender-roller must take a piece out of the machine to adjust the plane of bend and return the member back into the machine to make successive bends.

8. Don't be afraid to specify heavy walled members. The design team typically selects the member size after making calculations and selects the lightest member that will stand up to the calculations and achieve the member's intended purpose. That's ideal when considering a curved structural member. When designing with curved or rolled members, consider specifying curved and bent steel members with more stringent width-to-thickness ratios, because they withstand rolling pressures and stresses more effectively.

It is not rare to hear someone question the ability to bend heavy sections, but bender-rollers' machinery is strong enough and capable. Design Guide 33 Section 3.4 states that heavier-walled sections exhibit better resistance to localized buckling due to their non-slender, compact nature. That robust design reduces the likelihood of cross-sectional distortion and maintains the integrity of the curved shape.

Additionally, the increased thickness enhances the overall strength and stability of the structural members, ensuring better performance under load. Consequently, opting for thicker members in curved steel designs can lead to more reliable outcomes when considering the bending process and the effects of cross-sectional distortion.

9. Rolling and cold forming can positively impact mechanical properties. Rolling or cold forming refines a material's microstructure, enhancing its strength and hardness. That process is called work hardening or strain hardening. It increases the yield and tensile strengths, resulting in a more robust and durable final product.

But it's crucial to avoid overworking the material, because excessive deformation to the microstructure can lead to undesirable strain hardening. Increased strain hardening can make the steel more brittle, reducing its ductility and performance in structural applications. It's commonly seen when a member is designed to be taken to the limits of its capable forming capacity, such as taking large members to extremely tight radii or forming members in complex geometries where multiple forming operations are required within the same member.

Controlled cold forming can improve material properties, but careful attention must be paid to avoid overworking and to maintain the material's optimal balance of strength and ductility. Material properties can always be restored by way of a post-bend normalizing heat treatment, which the design team may consider on members with extreme geometries.

10. Use Design Guide 33. Design Guide 33, published in 2018, is the first comprehensive publication dedicated to correct design practices for curved steel members. Prior available guidance was limited, leaving engineers and architects without standardized procedures for designing and fabricating curved steel.

The guide fills a significant gap by providing detailed recommendations, design principles, and practical examples that ensure structural integrity and aesthetic quality of curved members. It addresses the unique challenges of bending and curving steel, such as material properties, cross-sectional distortion, and connection detailing. The standardized best practices enhance the reliability, safety, and innovation of curved steel structures, fostering confidence and consistency across the industry. ■

Ken Pecho (ken@cmrp.com) is the engineering and technical operations lead at Chicago Metal Rolled Products.

On the Rise

INTERVIEW BY GEOFF WEISENBERGER

Machel Morrison has become a respected voice in academia and steel design instruction within just a few short years of starting his teaching career.

Machel Morrison (left) and AISC president Charles J. Carter at the UC San Diego shake table.

MACHEL MORRISON came to the United States to study engineering, inspired by an affinity for math and an interest in structures. He hoped to design buildings or bridges himself one day.

He has instead found himself teaching future designers—and earning recognition because of it.

Morrison, a structural engineering professor at the University of California San Diego, received the Terry Peshia Early Career Faculty Award from AISC earlier this year, just five years into his career in academia. He was recognized for exceptional promise and continued excellence in structural steel research, teaching, and service to the industry. He also helps manage the UC San Diego shake table, an earthquake simulator that recently underwent significant upgrades and tested a ten-story building in 2023.

Morrison spoke with *Modern Steel Construction* about his time at UC San Diego and his journey there, which began in the Caribbean and involved a stop in the construction industry.

Let's start from the beginning. Where are you from and what made you interested in engineering?

I'm originally from Kingston, Jamaica. I grew up there and lived there until I was 18. I didn't come to the U.S. until I enrolled at Lafayette College in Pennsylvania to study engineering.

I had a love for physics and math in high school. My mentors back then told me engineering was a good path if you love physics, math, and chemistry, which I did. At that time in Jamaica, there was a lot of infrastructure work going on, and I got a look at that through some job shadowing in high school and developed an affinity for civil infrastructure. That guided me along the engineering path.

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**.

Before your academic career, were you in the design world?

Yes. It's an interesting story. I finished my undergraduate work in 2004, and I started a master's in engineering management program at Duke University. That was a one-and-a-half year program. Right after, I got a job in construction management working for Skanska USA Building, Inc., in Durham, N.C., as a project engineer. That really exposed me to the hands-on construction management process.

I worked with designers and became incredibly interested in the design process—analyzing a building, what happens if a contractor makes a mistake, how to fix that mistake, and how to make decisions on ways of fixing a mistake. My intense curiosity and low affinity for the administrative parts in project management led me to return to school and pursue a graduate degree in civil and structural engineering at North Carolina State University.

Where was your first teaching job?

I did my PhD at North Carolina State—following my master's in civil engineering there—and graduated in 2015. I immediately took a post-doctoral fellowship there, and after a couple of years, they appointed me to a research assistant professor role. That meant I could write my own proposals and do independent research for my boss. I spent about a year there and got the position at UC San Diego in 2019.

Do you remember your first time as a professor in front of a class?

I remember feeling like I was not that much older than the students. The first time I entered the room, I didn't think students knew I was a professor. They thought I was another student, and you could see their expressions change as I went to the front of the classroom. I was nervous at first, but after a couple of classes, I settled down and got comfortable.

What is your course load right now?

I teach structural steel design to undergraduates and grad students. I also teach statics, one of the early courses in our curriculum that everybody takes. I really enjoy teaching it because I interact with students who are fresh in the program and build relationships with them as they go

through the program. I teach them their first technical class. It makes or breaks you. Structural steel design is at the end of our curriculum, so I get to see their evolution.

What's your current research work?

I focus a lot on the material- and microstructure-dependent properties of steel. In terms of application, many things I've been looking at recently are related to welding. Mainly, I'm diving into improving our understanding of what happens in a heat-affected zone of the weld, how the mechanical properties change, and if we can do a better job of predicting fracture of welds. Right now, it's anyone's guess if the weld will hold. I think we can do a lot to improve our ability to predict fracture of welds.

UC San Diego is well-known in the engineering community for its shake table, highlighted in the December 2023 issue of *Modern Steel Construction*. I visited it while in town for last year's Student Steel Bridge Competition national finals, and it was fascinating to see in person. What's your involvement it?

The shake table was originally built in 2004, and at that stage, it was conceived as a single-degree-of-freedom shaker that simulates earthquakes in one direction. But it was designed to be upgraded later to a six-degree-of-freedom shaker with translation and rotations in three directions. That means it moves in three directions and rotates in three.

Right before I came to UC San Diego, the National Science Foundation awarded us a grant to upgrade the system. That's where I got involved. I was part of the upgrade team. I helped with designing some of the components and with the management aspects.

You've been in San Diego for a few years now. What do you enjoy most about it?

The weather, of course! It's close to the border, so if you want to go to Tijuana or other places in Mexico, it's easy. I've done it before to do some shopping there. For me, San Diego and working at UC San Diego is a dream come true. I don't think I'd want to live and work in many other places. The cost of living is a doozy, but everything else is great.

Do you get back to Jamaica much? And as a Jamaica native, are you a coffee drinker?

I do, at least twice per year. I still have family there and try to see them as much as possible. And I am a coffee fan. Blue Mountain, the most well-known Jamaican coffee brand, is always on my gift list to bring back for friends and colleagues. It tastes better when you get it in Jamaica! ■

*This interview was excerpted from my conversation with Machel. To hear more from him, listen to the September Field Notes podcast at **modernsteel.com/podcasts**, Apple Podcasts, or Spotify.*

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

Partnership Practices

BY SHAUN ELLER

The right partners are crucial in workforce development. One company leader offers an inside look at how to find and cultivate relationships.

FILLING POSITIONS on the shop floor—especially skilled jobs like welding—can be challenging, and finding the right talent with the necessary fabrication skills is critical. Right now, a resurgence in career technical education (CTE) programs across the U.S. is developing a pool of skilled tradespeople to fill vacancies nationwide.

How can your business access the top-tier local talent being cultivated in those programs? Build relationships.

Four years ago, Ohio Gratings, Inc. refocused its recruiting efforts and resources on building relationships with students in local CTE schools. Our first connection was with a welding program more than 30 miles from our Canton, Ohio, manufacturing facility.

Today, our strategy has shifted from simply recruiting students to partnering with schools and career development programs to build the workforce of today and the future. We remain competitive in the classroom by donating raw materials, fixing equipment, teaching interview skills, and providing mentorship opportunities for local vocational programs. So far, we have built quality relationships with school administrators, teachers, and program instructors at 22 high schools, seven career centers, and four local colleges.

Partnering with workforce development programs is not complicated, but it requires a commitment of time and resources. It takes persistence to form a relationship with the right person at the school who is willing to develop a partnership with your business and can facilitate real change in their organization.

Offers Open Doors

Offering scrap metal to welding programs is a great way to begin forming a partnership with your local CTE program. Teachers and students appreciate having real-world examples and metal on which they can practice their skills. Donations may also create opportunities to speak with students in their classrooms, offer welding advice, and help instructors reinforce key issues with tangible applications.

We also work with our welding supply vendors to provide students with welding tip cleaners and soapstone holders that display our company logo. Once a relationship has been established, school administrators and instructors gladly hand out free promotional materials to students. They may even allow you to hang a company banner in their welding lab, creating name recognition for your company.

Student-Friendly Schedules

Partnering with high schools requires flexibility. We created a new shift from noon to 8:00 p.m. to accommodate CTE students who left school at 11:00 a.m. but still needed to return home early enough to prepare for school the next day. We always prioritize school first.

Students are encouraged to enjoy their senior year and be involved. If a critical test is coming up, students have the flexibility to schedule time off work to focus on their academic studies. We believe when they excel in school, they will also excel in their career.

Many participate in sports or other after-school activities, so we have also learned to accommodate extracurricular schedules as long as students communicate their needs to their supervisors in advance. It teaches our student employees effective communication skills and establishes good work habits early.

Implement Mock Interviews

We have collaborated with several partner schools to offer mock interviews for students, providing valuable interviewing experience. These conversations also benefit your company by finding qualified students and offering insight into ways to make your CTE partnership more successful.

We learned from several interviews that transportation is one of the biggest barriers for job-seeking students. Some students do not own vehicles or have access to a car. Others may not yet have a driver's license or feel comfortable driving in the city. Some did not have access to reliable public transportation, or their school is in a neighboring county where public transportation does not cross county lines.

Transportation challenges can be overcome if you are creative. For example, we provided bus passes and transportation (at zero cost to the student) for a limited period. Students signed commitments confirming they would be responsible for their transportation by a certain date. Working full-time hours at a good wage empowers students to save for transportation. One student recently purchased a vehicle in just three months using this arrangement. Another student paid the first student gas money to carpool until he saved enough money for his own transportation.

Pay Attention to Payment

Attending school job and career fairs is another great way to engage with students and prospective employees. It's also a great way to see what other companies are offering in your area.

Many instructors keep a wage board that shows the companies employing their students in that area and their current pay rates. A glance at it will inform if you payment is competitive with other employers in your community.

Students want to see their long-term earning potential as well. We developed a career pathway chart to show workers how to advance from entry-level to more

Ohio Gratings, Inc. chief business officer Shaun Eller.

All photos courtesy of Ohio Gratings, Inc.

specialized roles, with the responsibilities and wages listed for each step.

These defined paths for advancement ensure we stay competitive in our community. Good wages and incentives remain a primary reason we can attract students from neighboring communities, too.

Other Success Factors

The more you put into a partnership, the more fruitful it will be. Our investment has been significant, from scrap metal donations to providing transportation to mock interviews to occasionally loaning our maintenance team members' time to fix equipment at partner schools. The key to our success, though, is communication, which must come from both sides of a partnership.

We recently implemented a program where students are returned to the classroom for two weeks if their job performance is not up to our standards. Ideally, those two weeks solve any issues and avoid termination of employment. Instructors have time to work with students at school and further develop their skills and workforce readiness. This process requires constructive communication between instructors at the CTE school and the employer.

We're also learning that we need communication from the school when a student is struggling academically. That way, we can offer the students time to get their grades back on track and avoid extra work or repeating courses, which threaten to delay graduation.

To help facilitate communication with partner schools and our student worker population, we created a new role at our company: associate success mentor. We hired a retired teacher passionate about developing students to support our growing list of new CTE student groups.

Our associate success mentor coordinates all CTE-related activities, including maintaining positive relationships with our student associates; facilitating school engagement activities, tours, and visits; overseeing scrap donations to schools; interviewing, job shadowing, and anything else student-related. He has helped young adult associates (students and graduates) find cars, navigate life choices and adult responsibilities, communicate with their teachers, and set up return-to-school assignments to work through performance issues.

We're excited to see so many young people who desire to work with their hands and create something with metal. They're eager to learn and grow as the workforce for today and the leaders of tomorrow.

A group of 2024 student workers accepted full-time job offers from Ohio Gratings after graduation.

The more you cultivate relationships and invest in people, the greater your chance of building success in their lives and in your business will be.

A quality, well-established workforce development partnership will earn you a positive reputation in your community and yield opportunities that shouldn't be wasted.

In 2023, a local CTE program in an economically challenged community called to inform us that its welding instructor quit over Labor Day Weekend. We did not previously have a relationship with this program, but its director of career and technical studies had heard that we were creative and collaborated well with other schools. He approached us for help.

In response, we took a bold financial risk and hired the entire senior welding class, even though the students had minimal welding skills.

The class group had more training needs and personal difficulties than nearly all others we had encountered while running a student development program. Outside of work, they faced hardships no 17-year-old should have to bear. Seventy percent of students had no support from a parent or adult, some had spotty attendance records, and others had unstable housing.

We approached the challenge by drawing on lessons learned from working with more privileged student groups while remaining flexible to this group's needs. We taught welding skills, basic fractions, how to read a tape measure, and provided PPE. The school provided transportation back and forth from the school to Ohio Gratings.

Our associate success mentor worked with students on soft skills, while our quality and welding trainer taught them welding and math skills. Many of these students accepted full-time employment with us after graduation.

It's fulfilling to see young people break the cycle of generational poverty. We offered them a clear path to success and a future they could envision and received a boost in morale and employee retention in return.

The Investment and Reward

We employ as many as 40 high school students at a time in various manufacturing facility and office roles. Including recent graduates who have completed our program, that number jumps to 70. Nearly 10% of our workforce is within two years of their high school graduation.

Our business continues to grow as our reputation in our community grows. Three years ago, we had approximately 115 open positions. With the help of our student workforce, we now average around 15 openings at any given time.

Although these numbers may seem large and overwhelming to a smaller company, they are scalable. A small fabricator can easily target their local welding and engineering programs, donate some scrap metal, offer mock interviews, and fix a piece of equipment for them. It might yield one or two student hires per year, but even that is building a workforce for the future.

Through our CTE partnership efforts, we have developed strong relationships with teachers and students that have yielded a more


Student worker Kevin Iverson.

than sufficient return on investment. Several students from our first graduating class have become valuable team members today.

I love having the opportunity to visit classrooms and develop connections with the students. It's a two-way street between our business and the school. The opportunities are limitless. As our business grows, we're tapping into new potential every day. ■

Shaun Eller (seller@ohiogratings.com) is the chief business officer at Ohio Gratings, Inc., and president of the Stark County Manufacturing Workforce Development Partnership.

A Denver office building's signature element is an AESS tower that honors the neighborhood's industrial roots.

Tremendous Tower

BY CODY SHAW AND BRAD KOCH

Beacon Capital Partners

AN OFFICE BUILDING in Denver's thriving River North (RiNo) community lives up to its name, even though it's no house.

The building, called Steel House, has exposed steel all over—most notably in the architecturally exposed structural steel (AESS) tower that covers all 12 stories and rises 150 ft to the roof on one side.

The 300,000 sq. ft of workspace with multiple private tenant terraces and floor-to-ceiling windows will continue the area's storied industrial history, as will the exposed columns throughout the building. The exterior—led by the AESS tower—gives passersby a hint of those industrial roots. A parking structure on the first five stories also has exposed structural steel picture window framework.

Steel House's exoskeleton was the design's focus since early building concepts. AISC's AESS requirements set the standard for fabrication and erection of the building's main feature. All exposed members of the feature tower were designated to meet Category 1 AESS, as defined by the 2016 *Code of Standard Practice for Structural Steel Buildings* (ANSI-AISC 303. A 2022 version has since been released). Category 1 is the lowest level of AESS finish, but the scale of the tower still presented challenges to ensure aesthetics were flawlessly presented. Other exposed canopies in the building also carry Category 1 AESS requirements.

The AESS categories in *Code* Section 10 (read about all AESS categories on Page 54) were originally developed in conjunction with Structural Engineers Association of Colorado/Rocky Mountain Steel Construction Association Steel Liaison Committee. Steel House fabricator Zimmerman Metals, Inc. and erector Total Welding, Inc. are members of both associations. The categories were developed to assist design professionals with the correct application of AESS on projects.

AESS components were identified early in the shop drawing process to flesh out details that had not yet been incorporated into opposite page: Steel House's AESS tower can be seen from its rooftop deck.

below: The tower was erected after the main frame.

Total Welding

Erecting the primary frame.
Zimmerman Metals

Morris Adjmi Architects
The tower will be lit with linear fixtures to accentuate the steel framework.


the design drawings. One important AESS item was the tower column splices. As designed, the main columns for the tower reach about 150 ft tall and were shown to be continuous. Early on, Zimmerman identified that the columns needed to be spliced in two locations each to allow for proper material procurement and fabrication. It issued an RFI to request specific design input on how the exposed splices needed to be accomplished.

The engineer, S. A. Miro, Inc., proposed wide-flange column splices based on the standards in the *Code*, with slight modifications specific to the project. Zimmerman and Total Welding proposed a full-scale mockup illustrating a bolted splice solution, which is not required for AESS Category 1 but is for Category 2 and above.

Mockups and visuals are a helpful way to communicate with the design team throughout the project and ensure the fabrication and steel erection meets their vision. On several occasions, the fabricator and erector provided 3D snapshots of the model and the bracing members at each gusset plate connection.

It was ultimately decided that the column splices would be achieved with bolted flange and web plates similar to Table 14-3 Case I in the 16th Edition AISC *Steel Construction Manual*. The direction and consistency of the bolts were also clarified (a requirement of AESS Section 10). Beam-to-column connections also follow the consistent bolt direction, which is indicated on all shop drawings.

The fabricator and erector also identified areas of the structure that, as designed, would prove cumbersome to weld while keeping a continuous appearance of uniform size and direction, another AESS requirement. Those same areas also would allow for water to pool and be trapped. Holding the MC brace members back off the faces of the intersecting beams/columns and attaching them by welds to gusset plates solved both problems.

Fabrication of AESS includes the removal of rough surfaces. Sharp edges resulting from flame cutting, grinding, and shearing were softened. Continuous welds were used, and weld spatter, slivers, and surface discontinuities were removed.

After fabrication, exposed surfaces were prepared in accordance with SSPC-SP6 Commercial Blast Cleaning prior to primer application. The steel was specified to receive a high-performance coating and received a shop application of zinc-rich primer prior to leaving the fabrication shop.

Fabrication of AESS beams included using continuous welds and removing weld spatter and surface discontinuities.

Total Welding

The steel members were handled with more care in the shop and on site—and with nylon slings—to avoid damaging the finish, all AESS Section 10 requirements. TWI, as its name suggests, has welding roots that include vast AESS experience within the region. All the main bracing members for Steel House's AESS tower were welded in place in the field, and erection aids were removed and surfaces ground for a uniform appearance.

Steel House sits on top of a five-level podium parking garage that was also part of the project. Typical coordination required for an office building atop a concrete parking structure is limited to mechanical trades and plumbing. With exposed steel as a main element, though, more coordination with components less familiar to fabricators is a must. Those include metal panels, thermal and moisture protection, glazing, drywall, and signage. Important factors considered with AESS include member visibility, viewing distance, location, lighting, coatings, style, and adjacency. Achieving them with AESS requirements requires more parties.

The AESS tower will be lit with linear light fixtures to accentuate the steel framework, and many meetings were needed to ensure the lighting was in precise position on the steel. Lighting set too close into the webs of the wide flange members would not create a desirable appearance.

The finish trades received hands-on guidance in understanding steel shop drawings, because much of those trades' scope integrated directly with the steel structure at the tower. Metal panels meeting the backside of the AESS tower had to consider the expansion and contraction the structure would have depending on temperature and the exposed bolts at certain structural connections.

Close coordination was also needed at the perforated mesh infill panels at the garage levels. The garage is the largest elevated private park in RiNo and is covered by the brilliant structural steel picture window framework filled with mesh panels.

Spacious terraces at each office level required many slab steps and changes to the top of steel elevation at all steel levels of the structure. Slab steps were accomplished with dropped beams and

The AESS tower columns reach about 150 ft tall and appear to be continuous, even though they're spliced in two spots.

Total Welding

WT or hollow structural section (HSS) members to fill the difference in elevation. Deeper beams to support the stepped slabs also involved many beam penetrations and more complex fabrication work Zimmerman has grown comfortable executing with precision.

The building, located at 31st Street and Brighton Boulevard in RiNo, topped out in April 2024. It's expected to open in early 2025. All told, it used 2,510 tons of structural steel—primarily W12 columns and W18 through W40 beams—and more than 34,000 bolts and 30,000 shear studs. ■

Owners
Beacon Capital Partners
Elevation Development Group

Structural Engineer
S. A. Miro, Inc.

Architects
Morris Adjmi Architects
Open Studio Architecture

General Contractor
GE Johnson

Steel Team

Fabricator
Zimmerman Metals, Inc. AISC CERTIFIED FABRICATOR

Erector
Total Welding, Inc. AISC ASSOCIATE AISC CERTIFIED ERECTOR

Detailer
Computer Detailing, Inc. AISC DETAILER

Cody Shaw (**codys@zimmerman-metals.com**) is the director of estimating at Zimmerman Metals, Inc. **Brad Koch** (**brad@twierectors.com**) is the president of Total Welding, Inc.

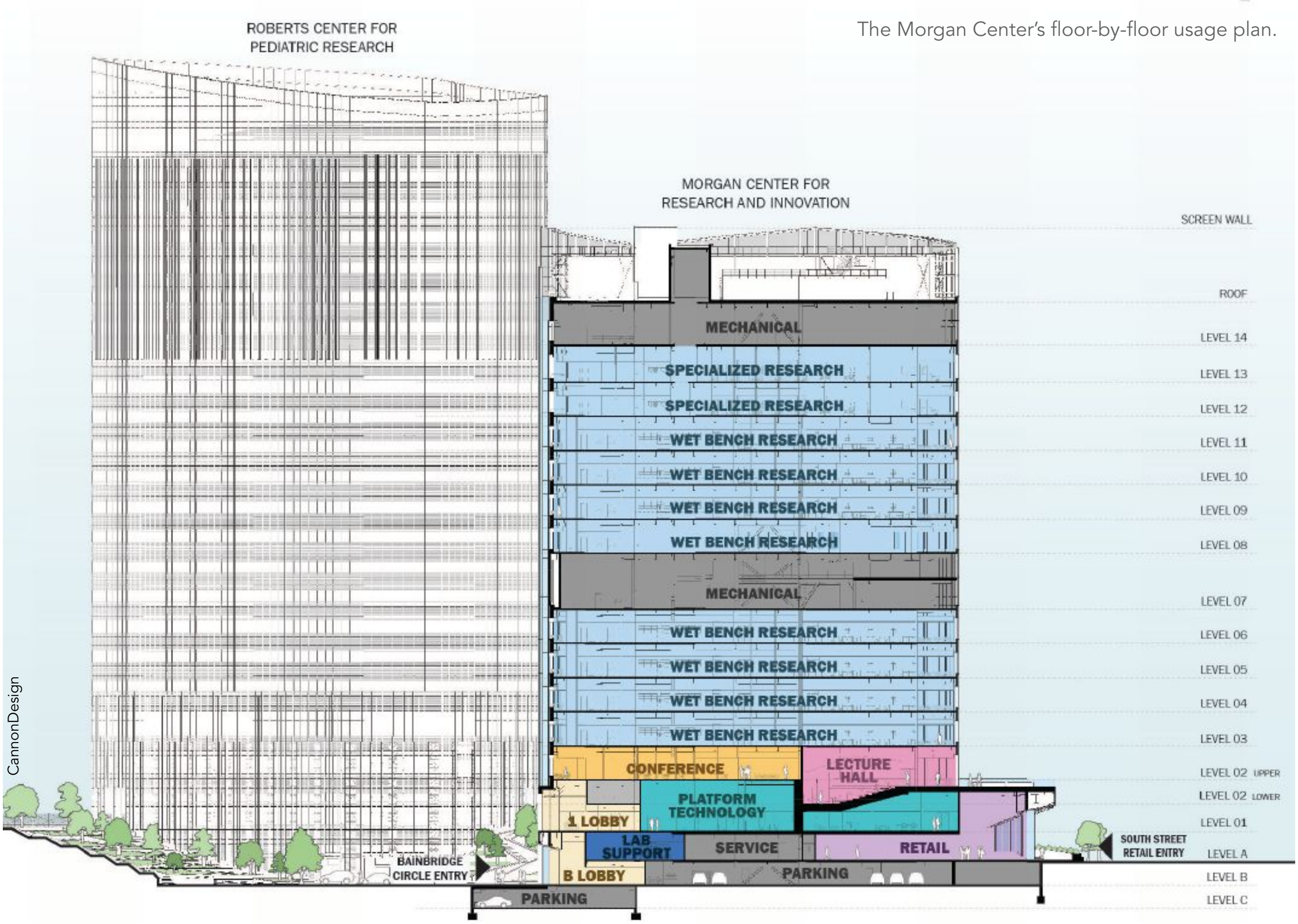
Podium Possibilities

BY JOHN ROACH, SE, PE

Adapting an existing steel podium provided a world-renowned children's hospital with more space to conduct life-saving research.

byencore

South Street Plaza separates CHOP's Roberts Center and the new Morgan Center.



The Morgan Center's floor-by-floor usage plan.

CannonDesign

AS THE NATION'S FIRST HOSPITAL dedicated to pediatric healthcare, Children's Hospital of Philadelphia (CHOP) has been at the forefront of compassionate care and innovative research for nearly 170 years.

After decades of growth and expansion in the University City neighborhood of Philadelphia, CHOP opened the Roberts Center for Pediatric Research on the opposite bank of the Schuylkill River in 2017 to house a mix of clinical and dry research spaces.

The 20-story Roberts Center was envisioned as the first of at least four buildings on the new campus, with a wet bench life sciences research facility planned for a subsequent construction phase. This second building was envisioned as a highly flexible, world-class research destination and would be constructed on a surface parking lot immediately south of the Roberts Center, facilitating a design free from the many site constraints that challenge development on the dense University City campus across the river.

Before proceeding with the full project, CHOP partnered with structural engineer CannonDesign to evaluate strategies that would reduce the cost and construction schedule of a newly proposed research facility without compromising the original goals. A series of studies made clear that the most feasible option was an alternate site at the intersection of South Street and Schuylkill Avenue—immediately north of the Roberts Center, not south.

That location is now home to the Morgan Center for Research and Innovation, a 5,100-ton steel structure that topped out in June 2024 and is scheduled to open in 2025. The design team fit the research center into CHOP's development plan by pivoting the intended use of a pre-existing, partially constructed frame, a testament to steel's adaptability.

Unlike the original location, the proposed new site for the research center contained a two-story, steel-framed podium with parking facilities and infrastructure serving the adjacent Roberts Center. While the podium was constructed with foundations and columns designed to support a future hotel or office building, the team established that a simple vertical podium extrusion could feasibly house the research center within 360,000 sq. ft of new construction.

Still, the strategy's mere viability was hardly optimal, and it quickly became clear that many structural aspects of the existing podium were obstacles to creating a vibrant and dynamic research environment.

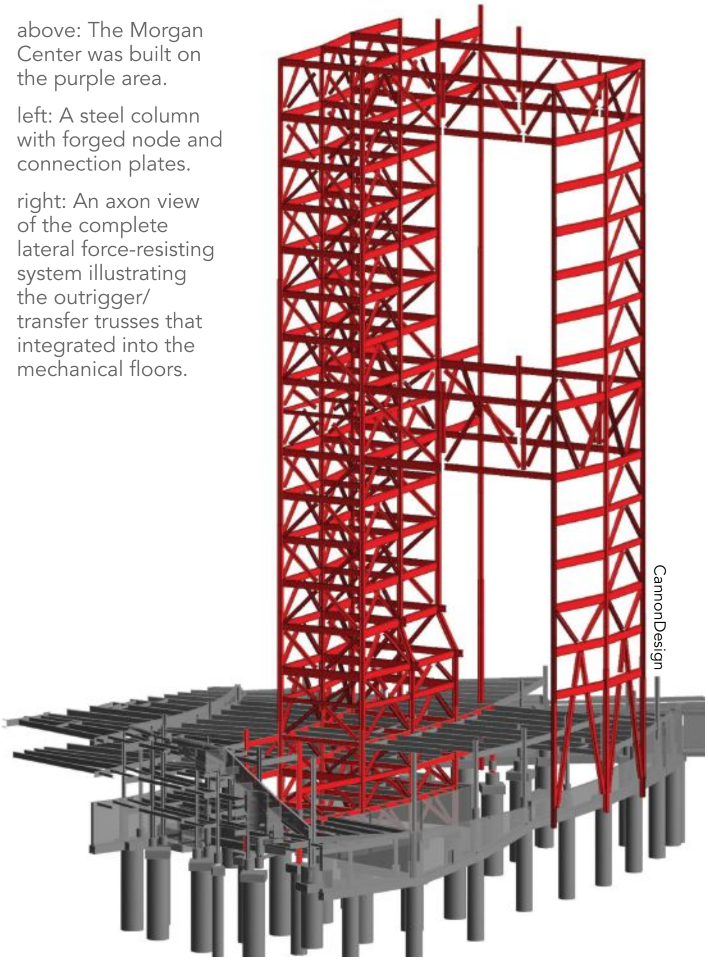
With a teardrop shape and long bays exceeding 45 ft along either side of a central core, a vertical extrusion of the podium footprint would have been far more suitable for the originally intended office use than a wet bench research center. Though not impossible, satisfying the required vibration criteria for sensitive equipment per AISC Design Guide 11: *Vibrations of Steel-Framed Structural Systems Due to Human Activity*, would require installing W33×241 typical floor beams and W36 girders to meet an acceleration limit of 4,000 mips at each lab floor.

Similarly, the existing column and foundation design demanded that the originally planned braced frame core would divide each level, creating a physical barrier between wet bench research and computational space. And while the typical floorplates of nearly 25,000 sq. ft were appropriately sized for the proposed program, the shape of the building and lack of any repeating bays meant that even an optimized design would be highly inefficient.

above: The Morgan Center was built on the purple area.

left: A steel column with forged node and connection plates.

right: An axon view of the complete lateral force-resisting system illustrating the outrigger/transfer trusses that integrated into the mechanical floors.



Standard Mill Shapes - Rolled To Your Specifications

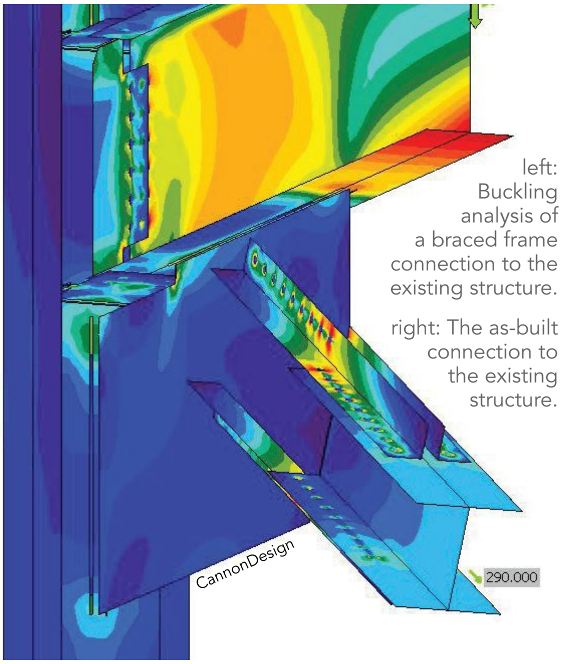
Call 866-940-5739

No.	Shape	Diameter	We bend ALL sizes up to:
1	Angle Leg Out	INSIDE DIA.	10" x 10" x 1" Angle
2	Angle Leg In	OUTSIDE DIA.	10" x 10" x 1" Angle
3	Flat Bar The Hard Way	INSIDE DIA.	24" x 12" Flat
4	Flat Bar The Easy Way	INSIDE DIA.	36" x 12" Flat
5	Square Bar	INSIDE DIA.	18" Square
6	Beam The Easy Way (Y-Y Axis)	MEAN DIA.	44" x 335#, 36" x 925#
7	Beam The Hard Way (X-X Axis)	INSIDE DIA.	44" x 285#
8	Channel Flanges In	OUTSIDE DIA.	All Sizes
9	Channel Flanges Out	INSIDE DIA.	All Sizes
10	Channel The Hard Way (X-X Axis)	INSIDE DIA.	All Sizes
11	Tee Stem In	OUTSIDE DIA.	22" x 142 1/2# Tee

No.	Shape	Diameter	We bend ALL sizes up to:
12	Tee Stem Out	INSIDE DIA.	22" x 142 1/2# Tee
13	Tee Stem Up	MEAN DIA.	22" x 142 1/2# Tee
14	Angle Heel In	INSIDE DIA.	8" x 8" x 1" Angle
15	Angle Heel Out	OUTSIDE DIA.	8" x 8" x 1" Angle
16	Angle Heel Up	MEAN DIA.	8" x 8"x1" Angle
17	Square Tube	INSIDE DIA.	24" x 1/2" Tube
18	Rectangular Tube The Easy Way (Y-Y Axis)	INSIDE DIA.	20" x 12" x 5/8" Tube
19	Rectangular Tube The Hard Way (X-X Axis)	INSIDE DIA.	20" x 12" x 5/8" Tube
20	Square Tube Diagonally	MEAN DIA.	12" x 5/8" Square Tube
21	Round Tube & Pipe	MEAN DIA.	24" Sched. 80 Pipe
22	Round Bar	MEAN DIA.	All Mill Produced Sizes

We also roll stair stringers, helical hand rails, off-axis bends, formed shapes and extrusions.

Visit cmrp.com for more information.



left: Buckling analysis of a braced frame connection to the existing structure.

right: The as-built connection to the existing structure.

Parametric Pondering

In response to the podium's hurdles, the design team embarked on an effort to reimagine the building using parametric design strategies with the help of in-house computational design specialists. That helped the team develop an algorithm to evaluate hundreds of potential building geometries that maximized the number of 11-ft square lab planning modules within a typical floor area of 25,000 sq. ft. Additional parameters were informed by structural constraints. For example, the algorithm was refined to maintain specific critical column locations while simultaneously increasing the number of repeating 33-ft structural bays that could be created. These and other enhancements helped maximize the extent to which the existing podium structure could be used, even as the tower geometry changed.

The result was the development of a 17-story tower with six curved sides featuring 15 new floors situated above the existing two-story podium. Infill framing on Level B and Level A of the podium would create new mechanical and lobby spaces while preserving much of the existing parking structure.

The first floor would house the main lobby and public areas, matching the geometry of the podium, while a conference center with symposium rooms and a lecture hall was planned for the second floor—the first level conforming to the new geometry. Mechanical spaces on the eighth and 14th floors were designed to support a research program spread across the remaining ten stories.

The 45-ft bays on the west side of the tower were maintained to avoid interfering with the existing drive aisles in the podium below. With comparably limited floor stiffness, these areas were reserved for computational research and offices. In contrast, the opposite side of the building was reshaped to improve structural and programmatic efficiency.

By expanding the floorplate to the east, the revised design yielded 26% more usable wet-bench lab space while also reducing steel tonnage by nearly 18% per floor. At the same time, pushing the north edge of the building back created a tower mass that better responded to the urban context by offering breathing room along South Street.

Adapting the existing structure allowed 16 of the original columns to be extended over the 307-ft building height with only limited modification. The remaining seven columns were realigned to the refined planning grid using a series of transfer trusses integrated into the new tower structure. Although the reshaped tower would require the construction of 12 new foundations, all but four of these were located within the footprint of the podium, significantly reducing the need for sitework that could otherwise cause disruption for the surrounding residential neighborhood.

Forging a Path

Two heavily loaded W14×605 braced frame columns required realignment before reaching the first lab program on the third floor, complicating the process of reshaping the column grid. However, the second-floor conference center provided an opportunity to execute the transition entirely within the new structure. Each braced frame column was offset 5 to 7 ft and sloped between the second and third floors to create two transfer trusses integrated into the braced frame core.

Though simple in concept, that approach introduced complexities at each end of the sloped columns where perpendicular brace members, collectors, and floor framing converged to a common node at varying angles.

Given the complex geometry, triaxial stresses, and the need to transfer nearly 3,000 kips through these locations, CannonDesign and fabricator Owen Steel Company opted for forged steel blocks at each of the four nodes. Each 9,000-lb block was precision milled and fabricated using a 50 ksi steel alloy, significantly simplifying the fabrication of each connection by saving 820 hours of shop labor.

The position of the braced frame core within the podium was tied to the location of existing beams, columns, and foundations that were sized to serve as part of the lateral force resisting system. As a result, the reshaped tower floorplate introduced significant eccentricity, resulting in unacceptably high torsional drift and overturning forces. In response, one bay of bracing was moved to the new east elevation, providing an 80% reduction in eccentricity while creating a more open floorplate for lab support functions in the center of the building.

Complex Connections

Because the reshaped floorplate first occurs at the second floor, the tower overhangs the east side of podium up to 35 ft, creating a 50-ft-tall arcade that shelters outdoor seating and amenities accessible to CHOP researchers and the wider community. At the same time, this design feature presented unique challenges where the columns and brace members meet the drilled pier foundations at the east elevation.

The aspect ratio of each bay resulted in brace members that were oriented only 32° from the columns, making a typical connection impractical. And because the braced bays follow the curved exterior of the building, none of the brace members resolve orthogonally with the columns, creating additional detailing and analysis challenges.

In response to these constraints, the design team developed a compact connection in which 2-in.-thick gusset plates were welded to each column and bolted to the braced frame flanges. The columns and gussets were shop welded to 6-in.-thick base plates to resolve shear and uplift forces. Cover plates added to each wide-flange member helped meet required slenderness limits and resist wind forces while limiting the need for heavy steel sections. The unique connection geometry led the team to validate the overall design and stresses across each interface using IDEA StatiCa finite element analysis (FEA) software.

FEA provided similar benefits when designing brace connections within the existing structure. Although the podium was designed for future vertical expansion, braces were not installed as part of the first construction phase. Instead, moment connections were provided at each beam-column interface.

Typically, these connections consisted of standard or extended shear plates bolted to the beam web and flange plates bolted to each of the beam flanges. Removing the flange plates to install gussets would have been labor-intensive and counterproductive, since their presence could be used to resolve pass- through axial forces in the beams.

However, maintaining the flange plates required each gusset to be notched over a considerable length at the beam interface. Together, these limitations made direct application of the Uniform Force Method impractical, so the team once again looked to FEA to validate each beam-column-brace connection. The rigorous FEA usage helped accurately capture stress distribution through the existing connections, limiting the need for extensive modifications or the installation of doubler plates and stiffeners.

Transfers and Temporary Trusses

The complete lateral force resisting system includes two pairs of outrigger trusses that link the braced frame core with the east braced bay at each of the two mechanical floors. These trusses intended to mitigate wind-induced accelerations that might adversely impact sensitive research areas, and they also presented an additional opportunity to reduce the need for new foundations.

Columns suspended from the seventh-floor trusses and aligned to the lab planning grid support research spaces on the third through fifth floors. Continuing to the 14th-floor outrigger and roof level above, these same columns allow the two trusses to act together for force transfer. All told, that approach created a pair of column-free, 2,000 sq. ft symposium rooms below the hanging column on the second-floor conference level.

Incorporating transfer trusses into the outriggers required a detailed analysis of construction sequencing, with particular attention given to the compound effects of truss deflection and axial shortening of the adjacent columns. Working with E&R Erectors, CannonDesign developed a scheme in which temporary trusses would be erected below the second-floor framing. Each temporary truss was designed to support a strut below the hanging column that would be removed only after the roof steel was fully erected.

Hydraulic jacks capable of supporting 500 kips were installed at the base of the strut to allow the bottom chords of the seventh-floor trusses to be erected level to within ⅛ in. of tolerance.

The Morgan Center used 5,100 tons of structural steel.

CannonDesign

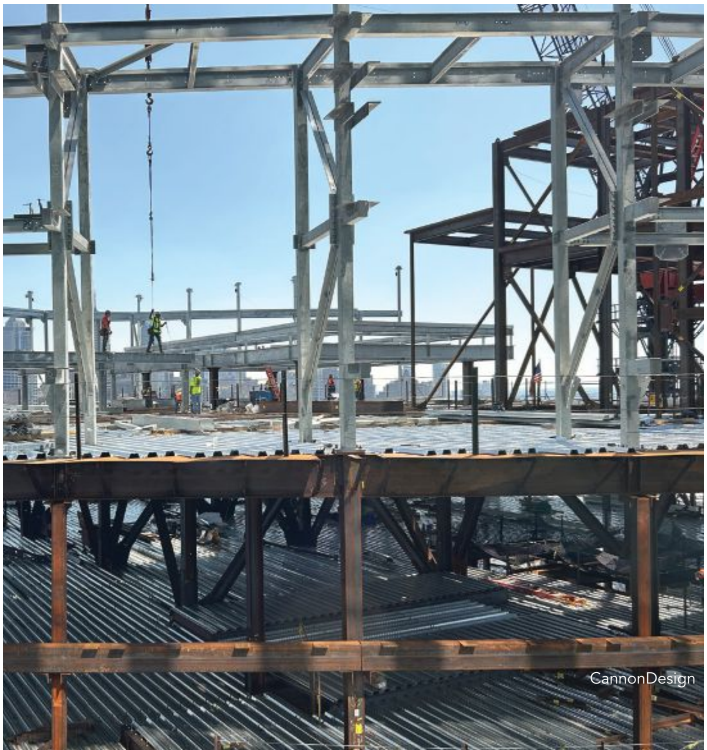

byencore

CannonDesign

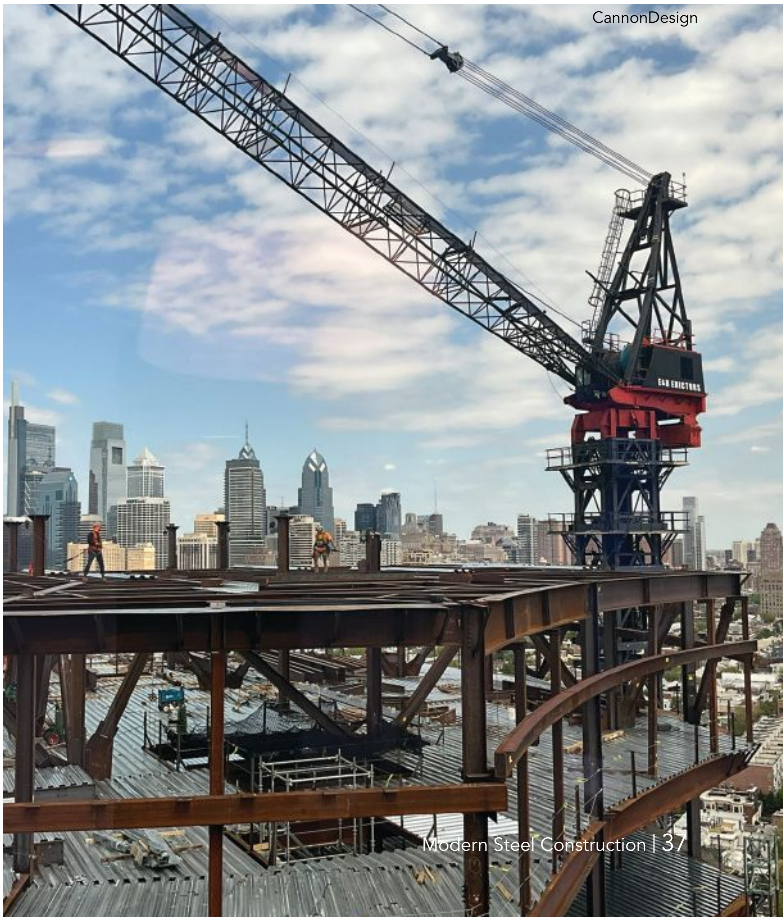
above: Sloped raker beams below the lecture hall are flanked by two of the transfer trusses above the podium.

below: Galvanized framing braces the screen wall and extends 35 ft above the roof.

right: Curved steel is prominently used in the building.



CannonDesign



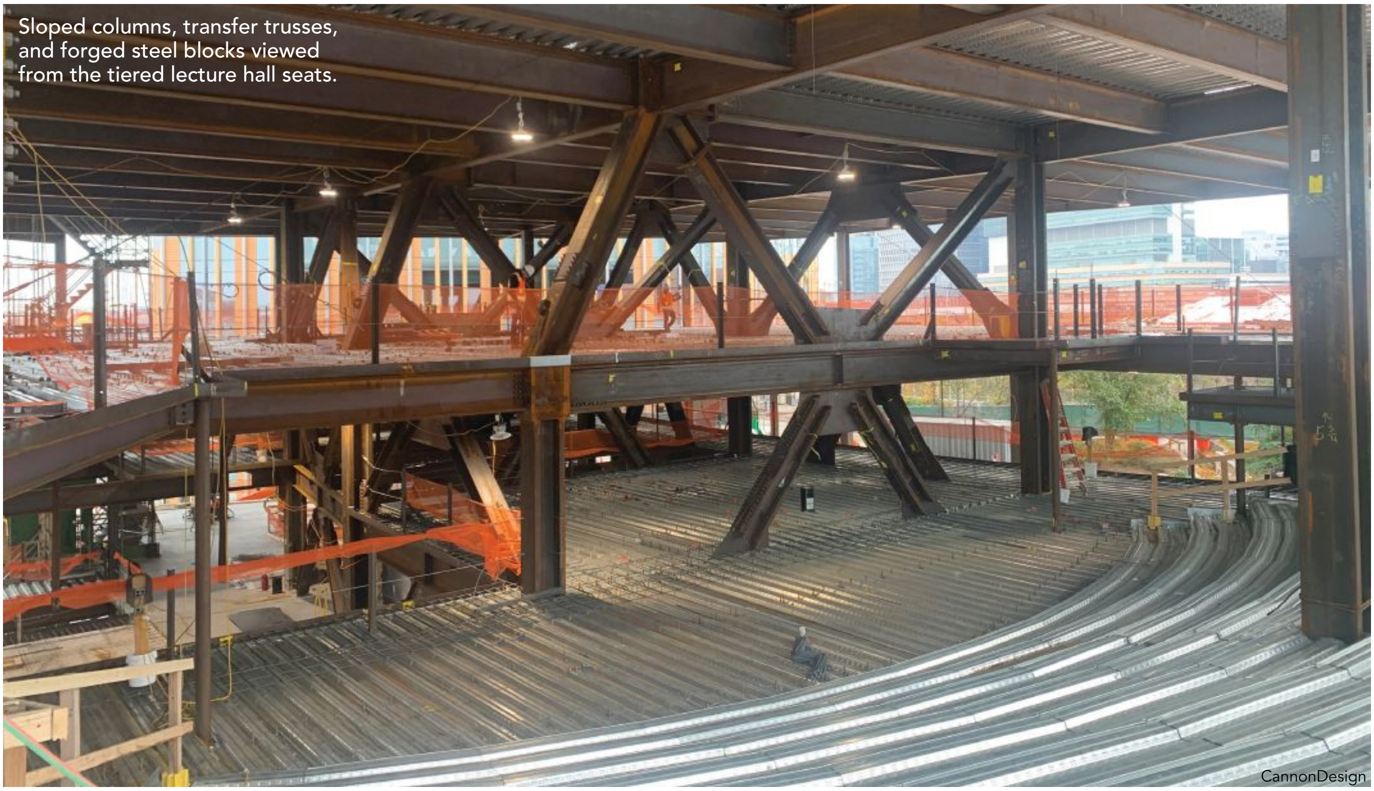
CannonDesign

Curved framing supports a landscaped terrace above a retail space.

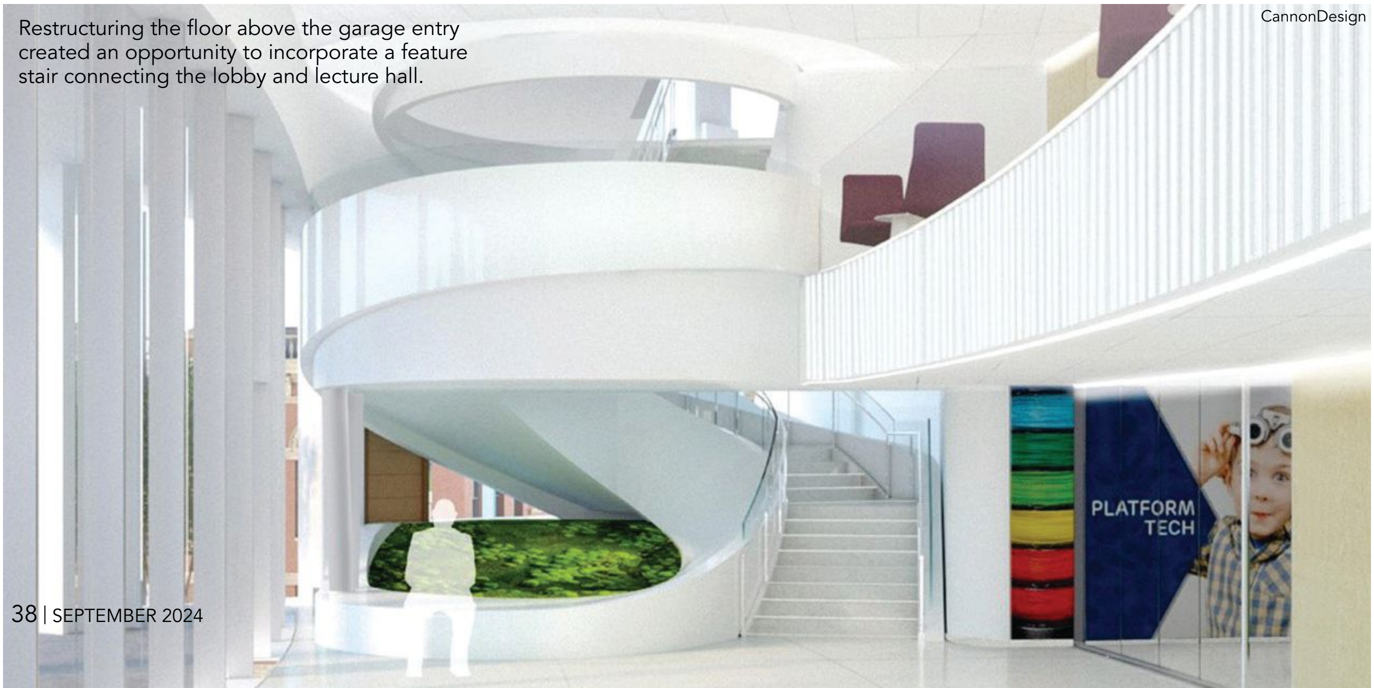
Uncovering Opportunities

Transforming the existing podium roof into a new public space presented two unique challenges early in the design process. First, tiered seating in the second-floor lecture hall meant that a second means of egress was required approximately 13 ft above the first floor. At the same time, the roof above the main garage entrance was raised 4 ft above the rest of the future first floor, significantly limiting the available lobby space and constraining circulation.

The solution to both challenges began with the introduction of a mezzanine level between the first and second floors aligned with the lower portion of the lecture hall. Limited clearances required careful coordination to



Sloped columns, transfer trusses, and forged steel blocks viewed from the tiered lecture hall seats.



Restructuring the floor above the garage entry created an opportunity to incorporate a feature stair connecting the lobby and lecture hall.

accommodate MEP systems above and below this level while minimizing the number of required beam penetrations. Sloped raker beams in the lecture hall are supported by a 27-in. plate girder to minimize structural depth above the first floor.

A narrow portion of the mezzanine extends across the lobby, where it joins a helical stair to the lobby constructed from curved steel box beams. A pair of splayed columns clad in stainless steel supports the stair's upper portion, while the stair's base sits on a steel-framed platform raised above the garage entry. A second flight of stairs follows an inclined floor that joins the lobby with the raised platform, mirroring the sloped garage ramp below.

Building for the Future

Upon completion, the Morgan Center for Research and Innovation will be home to a wide range of scientific disciplines. By creatively leveraging an existing infrastructure investment, CHOP has ensured that the diverse needs of families, patients, community, and staff remain the highest priority.

The inherent adaptability of structural steel, coupled with the innovative application of advanced analytical tools, transformed what could have been significant constraints into valuable design opportunities that will accelerate discoveries by promoting collaboration within the scientific workplace. As CHOP approaches its third century of service, the Morgan Center is poised to serve as the launchpad for a new generation of breakthroughs in pediatric medicine that will improve the lives of children throughout the world. ■

Owner
Children's Hospital of Philadelphia

Construction Manager
Gilbane Building Company

Architect and Structural Engineer
CannonDesign

Steel Team

Fabricators
Owen Steel Company, Inc. (superstructure, detailer)
Crystal Steel Fabricators, Inc. (miscellaneous metals)
Berlin Steel (miscellaneous metals)

Erector
E&R Erectors

Bender-Roller
Chicago Rolled Metal Products

John Roach (jroach@cannondesign.com) is an associate vice president with CannonDesign and was the project's structural engineer of record.

Branching Out

BY TOM MILTNER, PE

Steel brought an architect's vision for a tree-like structural centerpiece to life.

IN EARLY 2022, design architect RATIO Design approached longtime structural engineering partner O'Donnell & Naccarato with a school building concept that pushes conventional design parameters for learning space. Even for an architecture firm known for its unique take on designing distinctive buildings, this was a first.

RATIO proposed a two-story, 118,000-sq.-ft elementary school in the small, Midwestern town of Fortville, Ind., with a central two-story media center and crossroads to serve as communal gathering space where approximately 800 kindergarten through fourth grade students from could assemble, play, and learn. The learning space's principal component is a tree-shaped two-story steel column cluster acting as the building's structural centerpiece and the school's aesthetic focal point.

This learning space, known as the Central Commons Connector, would function as a link between Fortville Elementary School's various educational wings, with stadium seating for assemblies and morning announcements. It also features an abundance of curtain wall and clerestory glass to bathe the space in natural light.

Over the course of a year, the O'Donnell & Naccarato project team worked closely with RATIO, general contractor AECOM Hunt, and owner Mt. Vernon Community School Corporation to bring the ambitious plans to life. While the $85 million project was procured using the Construction Manager as Constructor (CMc) methodology, all team members worked diligently and collaborated to ensure it was delivered on time and within budget. The building topped out in October 2023.

Despite numerous structural challenges, as well as construction slowdowns caused by the COVID-19 pandemic, Fortville Elementary School is slated to open its doors to students, teachers, and staff in time for the 2025 school year. With a host of state-of-the-art amenities, the stunning finished product will be consistent with the pioneering vision of innovation that gave the building its inspiration.

RATIO Design

left: A rendering of the completed Fortville Elementary School Central Commons Connector.

below: The erected tree column.

O'Donnell & Naccarato

The architectural vision of an open commons area with a visibly appealing structure led the project team to choose the concept of a large learning tree as the school's central structure. RATIO needed a project partner with a proven history of providing solutions that are aligned with their goals. While O'Donnell & Naccarato has extensive experience working on unique and complex structures, it had not previously encountered a structural steel tree column in a design.

In lieu of a basic or traditional structural support system, the architect envisioned a "branched" element where students could gather, reminiscent of an old tree in the center of a park or town square where people share social and communal experiences.

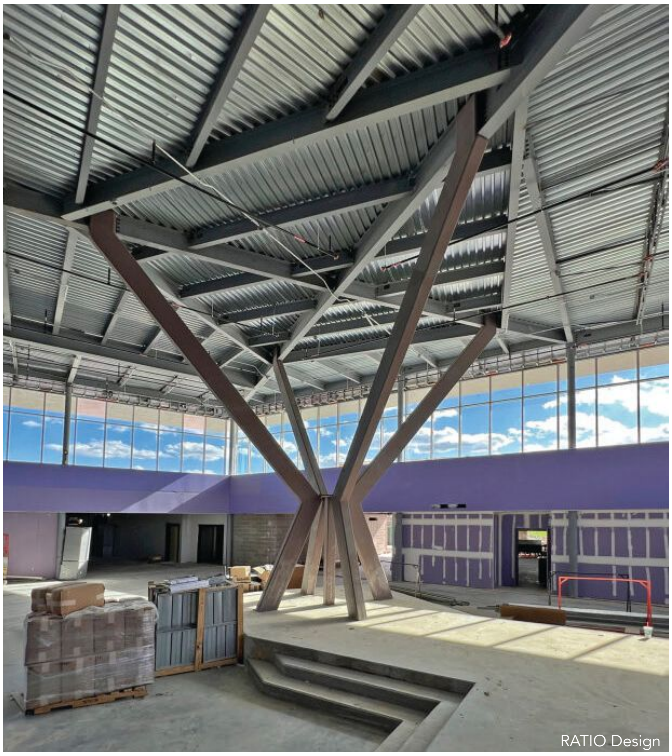
The Fortville Elementary School building utilizes a steel structural system, with moment frames and braced frames for lateral stability. The second-floor educational wings, meanwhile, employ composite steel framing, along with open-web steel roof joists to support the membrane roof system. The large open areas and long spans—along with the custom shape of the tree column—made steel the only viable option for the structure. Other materials would have required larger sections that would have made the space feel more confined.

Additionally, structural steel improved the speed of erection while also creating an open and inviting educational experience. Mark Beebe, AIA, principal in RATIO's Indianapolis office and the lead visionary and architectural principal for the project, best summed up the material choice: "The seamless and cost-effective ability of structural steel to blend the educational wings with the impactful central 'learning tree' design element helped make this an incredibly successful project."

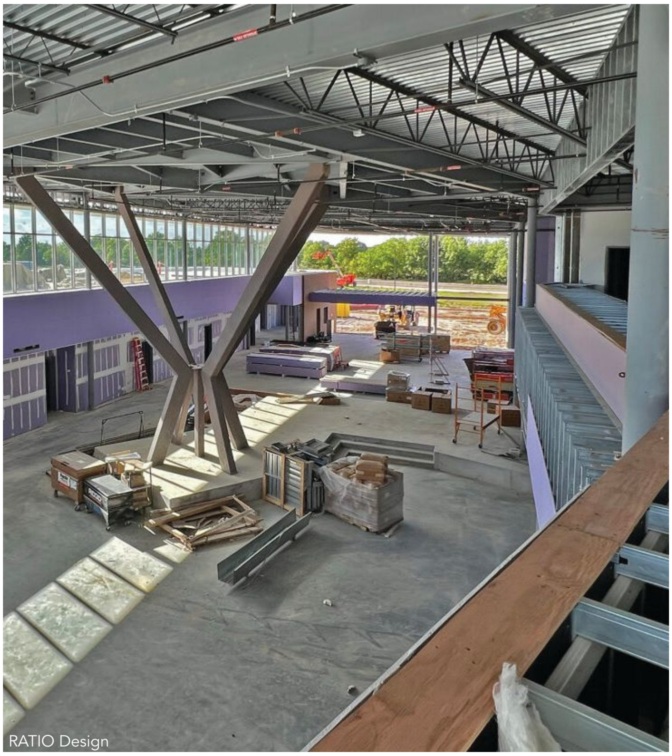
The unique geometry of the building and its challenges were compounded by pandemic-era construction and sourcing issues common to the entire construction industry at the time, emphasizing the need for close coordination among the project team. Early steel and foundation packages were provided to assist the contractor, allowing for early material procurement.

A rendering of the completed exterior.

RATIO Design



RATIO Design



RATIO Design

Aesthetically, O'Donnell & Naccarato strived to create a vertical support element with the look and feel of a tree—a broad base that separates into and branches that extend out as it rises upwards. A series of four bent columns with the lower portions tied to a central column was devised. However, the gravity loads from the roof combined with the sloping geometry of the bent columns created out-of-plane forces that worked to pull the individual elements apart.

The magnitude of the structure did not allow for a complete shop-fabricated element, but instead required individual pieces that were assembled in the field. The challenge was to keep all these members connected and working together with the final connections made in the field. All the columns were bolted to a common concrete base, and each bent column was connected to the center core column by bolting to single steel cap plate. Additional modifications were suggested by the fabricator in the


Individual tree column pieces were assembled in the field.
O'Donnell & Naccarato

shop drawing phase to simplify the connections to the roof framing members to the bent columns while maintaining the overall look.

The project team benefitted from numerous technological and process efficiencies using the design/bid/build delivery model. For example, the design team's use of Revit 3D modeling software, as well as the structural steel detailer's modeling tools, allowed for an economical detailing and erection process. Through this collaborative process, the tree column was seamlessly integrated with the roof framing, and connection configurations were continually refined during the submittal phase based on suggestions from the detailer.

The Central Commons Connector will be a cutting-edge learning hub and media center with operable glass classroom walls that open onto a flexible STEM lab, and a dual-purpose cafeteria that can host large-group instruction and regular dining. It's also a gateway to the rest of the school.

The school's design also includes a mode of transit that will excite elementary school-aged students. A two-story spiral slide runs from the second-floor learning area to the open commons space below—a fitting final touch on a transformational project. ■

Owner
Mt. Vernon Community School Corporation

Architect
RATIO Design

Structural Engineer
O'Donnell & Naccarato

General Contractor
AECOM Hunt

Steel Fabricator and Erector
Indiana Steel Fabricating, Inc. (AISC Certified Fabricator)

Tom Miltner is a principal with O'Donnell & Naccarato and regional director of the firm's Indianapolis Office.

Honing In On HSS

BY BRAD FLETCHER, SE

Ten reasons to incorporate HSS into your next design.

HSS beams support the ins and outs of the curtainwall at the top of One Vanderbilt in New York.

Max Touhey


HSS framing in One Vanderbilt's "snorkel" element near the top.
Severud

DESIGNERS HAVE SEVERAL OPTIONS for framing a steel building, and all of them have advantages. One major steel member type is hollow structural sections (HSS), which are a versatile, efficient, and economical choice for a steel structure. They're commonly used for structural grade applications such as load-bearing columns, but opportunities to employ them are plentiful. They're often exposed to view and used as curved steel—sometimes both at once—and are available in a variety of shapes, sizes, and specifications.

The list of reasons to use HSS members in a project is a lengthy. Here is a countdown of 10 important ones.

10 **Wide range of sizes and shapes.** There are 1,160 HSS sizes listed in the 16th Edition AISC *Steel Construction Manual.* HSS pieces come in square, rectangular, and round shapes. Squares range in size from ½ in. by ½ in. to 22 in. by 22 in.; rectangles from 2 in. by 1 in. to 34 in. by 10 in.; and round HSS range from 1⅔ in. outside diameter (OD) to 28 in. OD. Wall thicknesses up to 1 in. are now available.

9 **No webs.** No webs means no complicated web connections. Beam connections to HSS columns are simple and economical, and the recently published AISC Design Guide 24: *Hollow Structural Section Connections*, Second Edition includes expanded information and guidance on the topic. Welding is the most common way to make HSS connections, but there are also bolted connection options. Several products on the market work in blind connections, where both sides of the connection are not accessible, including the Lindapter Hollo Bolt, the Blindbolt, and Shuriken by Atlas Tube.

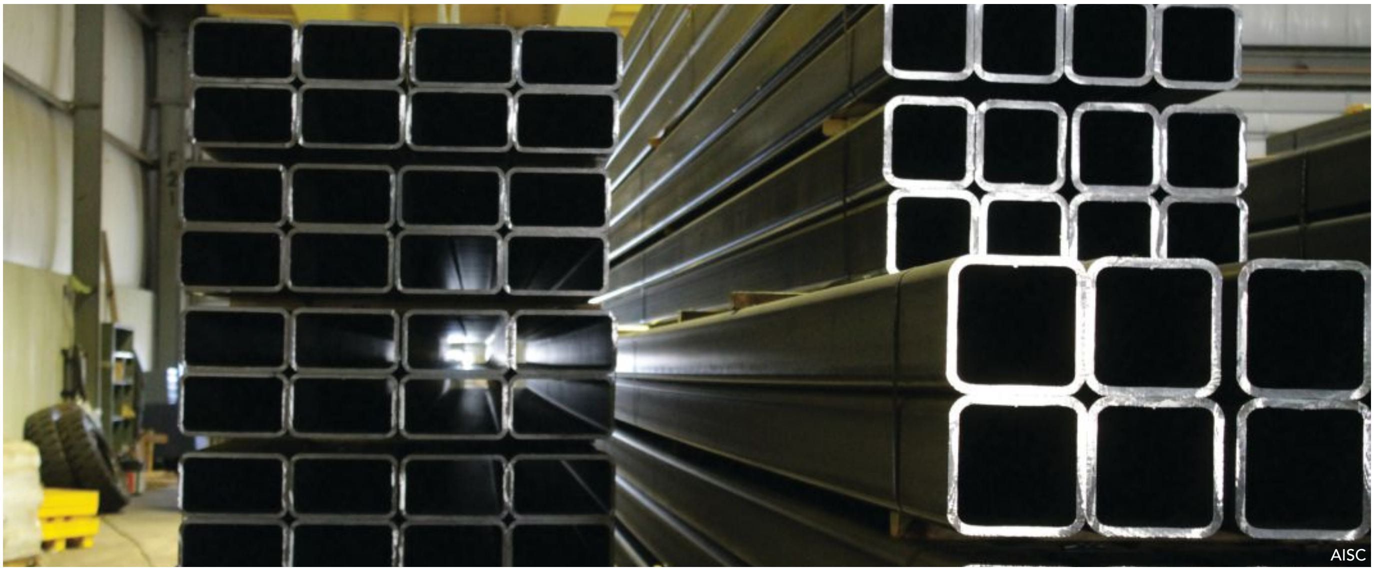
8 **Higher strength.** Because square HSS members don't have a weak axis, they have a high strength-to-weight ratio. For that reason, they're frequently used in column applications, especially those with long unbraced lengths, and will use less steel than open sections, such as wide-flange sections, to carry the same load. That approach is cost-effective and has the potential to reduce embodied carbon in the structure.

7 **Resisting combined loading.** HSS members efficiently resist biaxial bending because their closed shape puts material at the perimeter. That also enhances the strength in applications where unbraced length can control the design, including column and long-span applications where lateral torsional buckling is common.

6 **Ideal for resiliency and accidental loading.** The symmetry of round and square sections makes HSS ideal in applications that might be subjected to accidental or blast loads, because the direction from which the loads will come is not known. Also, composite columns (HSS filled with concrete) will further increase load capacity and resilience to harden and protect a structure.

5 **Torsion resistance.** One of the more obvious advantages of HSS is its high resistance to torsion. The torsional constant used to calculate a member's resistance to torsion can be 200 times greater for a closed section versus an open section. Any time a member is subjected to eccentric loads that induce torsion, an HSS member is the ideal choice. That includes whenever a steel beam is curved in plane, which means it will automatically need to resist torsion. Therefore, HSS members are often used in curved applications.

4 **Smaller footprint.** Because of the efficiency of its shape, HSS pieces used in a column application will often have a smaller footprint than a wide-flange member of equal axial loading capacity. This allows for more usable floor area within a building, helping to achieve the architect's vision for a more open and clean design.



AISC

Atlas Tube

The Tempe Town Lake pedestrian bridge in Tempe, Ariz., has four 225-ft tied arch spans made from 16-in.-diameter HSS.

3 **Less coating required.** HSS, compared to open sections of equal capacity, will have a smaller perimeter and surface area, meaning less material is needed to coat or paint the section, creating cost savings on coatings or fireproofing. HSS members lack the re-entrant corners that open sections have, so it is easier to apply coatings in places that are otherwise difficult to reach—improving the coatings' durability because of the consistent thickness that can be achieved at the corners.

2 **Availability.** HSS is stocked and widely available from service centers nationwide. And for big projects, fabricators and service centers can work with HSS producers to order custom lengths to minimize waste for a greener build.

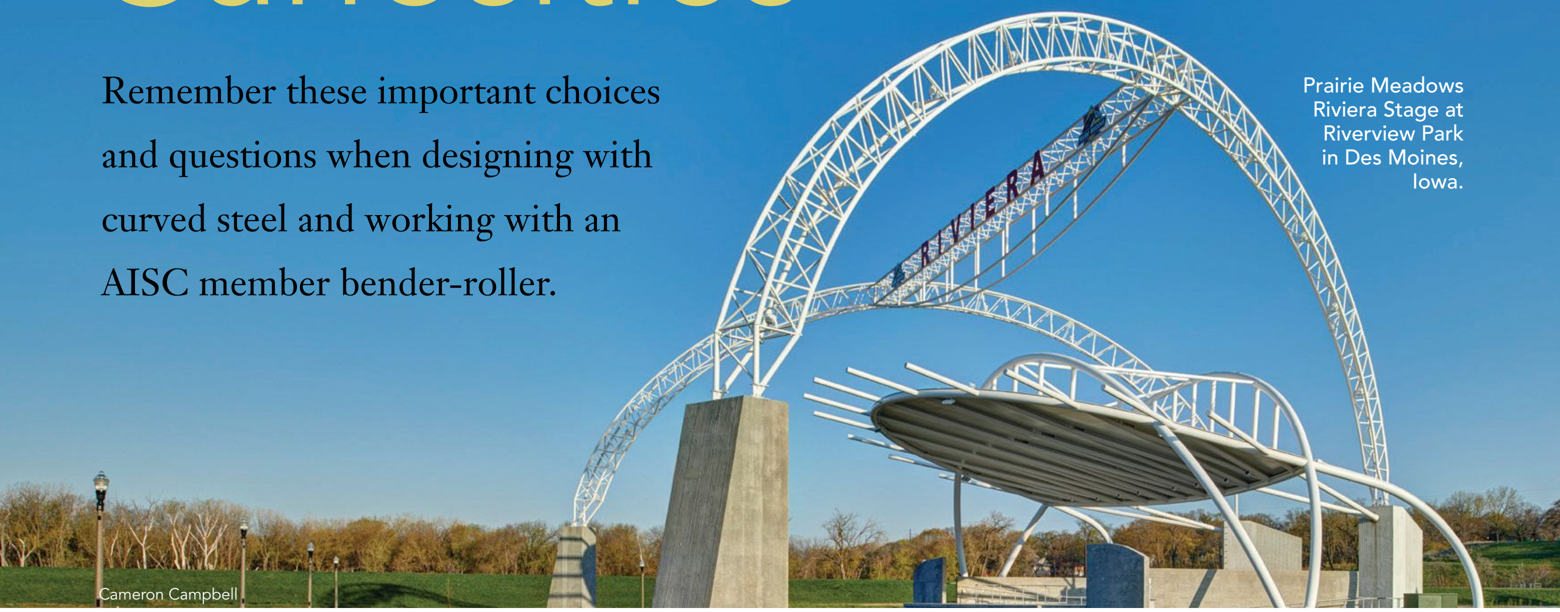
1 **Visual appeal.** Even with all the economic reasons that make HSS a good choice, HSS members are well liked because they're aesthetically appealing when used in exposed structures, especially those incorporating architecturally exposed structural steel (AESS). Many AISC award-winning structures in recent years have a common thread: the use of HSS in one of the many possible applications.

If you're looking for firsthand proof of HSS' effectiveness, you can enter a project's numbers in Atlas Tube's Axial Load Calculator (**atlastube.com/axial-load-calculator**), which is based on the *Specification for Structural Steel Buildings* (ANSI/AISC 360-22) as published in the 16th Edition *Steel Construction Manual*. The results might suggest HSS is an ideal choice for that project. ■

Brad Fletcher
(**bradlee.fletcher@atlastube.com**)
is a senior sales engineer at
Zekelman Industries.

Curved Steel Curiosities

Remember these important choices and questions when designing with curved steel and working with an AISC member bender-roller.



Prairie Meadows Riviera Stage at Riverview Park in Des Moines, Iowa.

Cameron Campbell

CURVED STEEL CAN ADD an eye-catching component to any structure. If a building has a curved element or assembly, it's often the most striking or memorable part of the project, especially when exposed to view. It's a way to add flair with signature shapes, whether small (like a canopy support) or large (like a curved roof)—and it maintains the structural efficiency that straight steel members provide.

If you're looking for guidance on implementing curved steel into a project, AISC Design Guide 33: *Curved Member Design* (available at **aisc.org/dg**) is one of the most comprehensive resources you can find. But for starters, read on for an overview of frequently asked questions and cost discussion when considering curved steel in a design.

Common Questions

Cost is the natural first inquiry when adding a fabrication step and another party to perform it. It matters, of course, but it's one of many curved steel questions that arise during the design process. Several bender-rollers provided some answers.

When should an architect involve a bender-roller?

As early as possible, and preferably during the preliminary design phase. The earlier a bender-roller is involved in project design, the better. Providing information as early as possible will help clarify the design possibilities, decrease the number of requests for more information, and control the costs. Sometimes, small changes in the size or members can significantly impact the project's outcome.

Does curving steel affect its strength and integrity?

Curving does not reduce the strength or structural integrity of the steel. When a shape has been curved successfully, the strains the member will experience under actual service conditions will be much smaller than those associated with the curving operation. Once curving is done, the member can be expected to perform as needed.

Is curving steel a better option than creating the appearance of a curve with multiple segments?

It's less costly to curve a length of material versus miter cutting and welding multiple segments to achieve the appearance of a curved assembly. In addition, a continuous curve facilitated by the bending process appears much smoother than a segmented assembly made from multiple sections. Bottom line, curved steel looks better than a faked curve.

What items will a bender-roller ask for when approached with a curved steel project?

These are the basics:

- The overall vision for what you want to bend
- Member shapes and sizes and material type to bend
- How the members will be oriented
- Correct nomenclature to match what is drawn (i.e., "inside radius")
- AESS requirements, if any, for the curved members

What details should designers include on curved steel documentation for bender-rollers?

A curved member's size and specified radius will determine how a bender-roller will approach the forming operation and determine the process and machine used to form that member. It's extremely important to convey as much detailed information as possible on curved members in the architectural and structural documents to get the most accurate cost for the curved and formed metals package.

Many construction projects release structural and architectural prints for the general contractors and subcontractors to bid on. Most of these prints containing rolled members do not have the necessary details to calculate an accurate cost of producing formed members. A properly detailed print containing rolled members should always detail radius and arc length, along with the proper section views to determine the orientation in which the member is rolled or formed.

Many times, a lack of information has forced subcontractors to speculate on the curved member's radius or to scale the rolled member from other members on the print and use that information to make a best guess at the radius. The result is that the original bid and quote are not what the design documents conveyed, causing major delays and cost increases for a project, especially when the mistake happens during fabrication or erection.

What's the best way to bend steel?

Several factors determine the best technique, including the overall member size, web and flange thickness or HSS wall thickness, radius requirement, and end application of the material. Also, varying amounts of extra material are required at one or both ends of the member, depending on the process used—you don't want to splice additional material to one or both ends. Talk to a bender-roller about the best options for your application and their capabilities.

Does AISC impose any tolerances on curved beams?

There are limited tolerances for curved members in the AISC *Code of Standard Practice for Steel Buildings and Bridges* (ANSI/AISC 303, download for free at **aisc.org/specifications**).

According to *Code* Section 6.4.2, "For curved structural members, the variation from the theoretical curvature shall be equal to or less than the variation in sweep that is specified for an equivalent straight member of the same length in ASTM A6/A6M." Other acceptable tolerances, such as any cross-sectional distortion, are not generally available because they are dependent on whether the member is AESS as well as any effect they may have on the member strength.

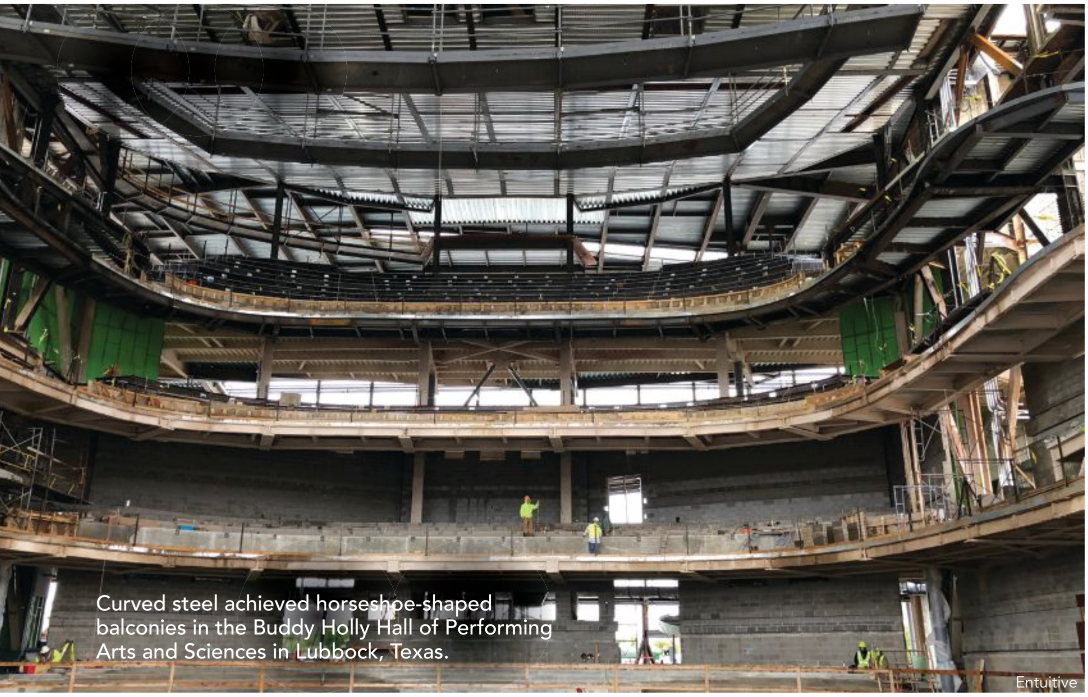
AESS tolerances are discussed in Section 10 of the *Code* (and briefly in the "Out in the Open" article on page 54). The actual geometric imperfections for rolled members are dependent on several factors, including:

- Cross-sectional shape of the beam
- Bending radius
- Bending axis
- Bending method used by the bender-roller
- Equipment limitations of the bender-roller

It's best to discuss the required tolerances with the bender-roller providing the service. Be sure to add the required tolerances to the contract documents to ensure the finished product is correct.

Iwan Baan Photography Studio

Curved AESS members add to the striking roof of the Jan Shrem and Maria Manetti Shrem Museum of Art in Davis, Calif.



Curved steel achieved horseshoe-shaped balconies in the Buddy Holly Hall of Performing Arts and Sciences in Lubbock, Texas.

Entuitive

Justin Barton

What are some considerations for members with multiple curves?

Compound or multi-radial members add a wow factor into an architect's design, but it also helps eliminate connections (especially if the shrinkage or growth of curved members and the specified connections of those members are a consideration). It's important to understand and grasp the idea and principle of tangential arcs. When a design calls for a single member with adjacent arcs of differing radii—commonly referred to as a compound or multi-radial member—it is extremely important to design the arcs tangent to one another.

If the arcs are not designed tangential to one another, then it is like having a miter cut at that point or bending the member at that point with a press brake, a three-point gag press, or a ram bending machine.

How do you know when arcs are tangential to one another? The answer is in the detailing or dimensioning of the arcs. When arc dimensions are pulled on each of the radiused portions of the curved member, one can tell if the arcs are tangential by looking at the leader lines of the arc dimensions. If adjacent dimensions' leader lines fall exactly over one another and cannot be distinguished from one arc to the next, then the adjacent arcs or lines are tangential.

If the two leader lines of adjacent arcs form an angle and are completely distinguishable, then the two arcs or radii in question are not tangent. They would need to be pressed or kinked at that point to achieve the desired geometry or be miter cut and have a connection placed between the adjacent arcs. Designing with tangential arcs or radii simplifies the curving process and is necessary to achieve the desired geometry when using bending-rolling methods without pressing or kinking.

Is it possible to put a 90° bend in a pipe?

Yes. The key factors are the radius and the bending method used. Contact a bender-roller or a fabricator to discuss the limits, options, and costs.

When are reverse curves necessary?

It is sometimes necessary to design reverse curves with a small amount of straight or tangent in between opposing radii due to the necessary bending moment needed to induce the second curve, which is required due to machine limitations. Most members can be redesigned to achieve this mid-tangent. In some cases, and with special machinery, it's possible to eliminate or drastically reduce the straight needed in between opposing curves.

What is the maximum geometric camber that I can specify for, say, a W27 rolled beam?

The capabilities of bender-rollers and fabricators vary, as do the equipment used and the cost. A tighter radius can often be obtained using a more sophisticated and costly process. It is best to speak with a bender-roller and a fabricator to get their opinions.

Is there a minimum radius for bending?

Minimum radius is merely a concept. Each bender-roller has its own practices, machinery, and developed technologies that, when applied to specific rolling jobs, can produce varying results.

AISC Member Bender-Rollers

- A-1 Roll Co.
- Albina Co., Inc.
- Bendco
- Chicago Metal Rolled Products Co.
- Greiner Industries, Inc.
- Hodgson Custom Rolling, Inc.
- Holloway Company, Inc.
- Max Weiss Company
- Midwest Metal Products
- Shaped Steel, Inc.
- Trilogy Machinery, Inc.

Curved HSS "driver pipes" at Allianz Field in St. Paul, Minn., create a sleek appearance.

How do you address cross-sectional distortion with curved members?

Regardless of whether you can eliminate wrinkles and concavity (the most common type of undesirable distortion), shrinkage and growth can severely limit the ability to make connections, and they can cause major delays and have cost implications to a project.

Welded connections, especially full-penetration, require good fit up to achieve the desired results. Cross-sectional distortion in the form of shrinkage and or growth can drastically limit the ability of the fabricator to make welded connections.

When a curved member is connected to a straight member, or if two curved members of differing radii will be connected with a welded joint, it's always best to keep in mind the possibilities of cross-sectional distortion and how that may negatively affect the fabricator's ability to make a connection. Bender-rollers do their best to limit this type of distortion, often called shrinkage and or growth (some companies have established up to and including 5% as in-house tolerances). But there is not an established AISC tolerance on the amount of acceptable cross-sectional distortion of a curved member, and architects should design with that in mind.

Cost Considerations

Here are some considerations and tips to ensure curving steel adds no significant costs and that there are no cost surprises late in a project.

Get involved early with a bender-roller. As with a steel fabricator, engage a bender-roller early to discuss materials that can be bent to specific configurations. An AISC member bender-roller will provide quality information during the design stage and before a project is budgeted.

The feature stair in the Buddy Holly Hall uses curved steel and HSS members.

Entuitive

Jacob Teats

Curving a Feather-Inspired Roof Design

The design team for the American Indian Hall at Montana State University in Bozeman, Mont., wanted a striking element that pays tribute to the state's current and past Native American inhabitants. They settled on an eagle feather-inspired roof—and chose curved steel as the material for it.

The large, sweeping curves of the entry under the bottom of the feather-shaped roof were integral to the vision the designers had for the building. Albina Co., Inc. rolled the material for the roof, and that process required several different complex rolls on different types of materials:

- Seven pieces of 6 in. by 6 in. by 5⁄16 in. ANGLE A36 rolled leg out to a 92-ft radius.
- Two pieces of 4 in. by 4 in. by ½ in. ANGLE A36 rolled leg out to a 107-ft, 3-in. radius.
- Two pieces of tube steel 14 in. by 4 in. by 3⁄8 in. WALL A500 GR B rolled the easy way to a 27-ft, 8-in. radius.

Albina also rolled the materials for the spiral staircase in the building. Those came in two main parts:

1. 2 in. by 2 in. by ¼ in. ANGLE A36:
   - 1 piece rolled leg out to 67 ft, 5 in. radius.
   - 1 piece rolled leg in to a 67 ft, 10 in. radius.
2. MC12 X 10.6# A36:
   - Five pieces rolled flanges out to a 67-ft radius.
   - Four pieces spiral rolled flanges out to a 67-ft radius.
   - Five pieces rolled flanges in to radii ranging from 57-ft, 5-in. to a 67-ft, 5-in. radius.
   - Four pieces spiral rolled flanges in to a 63-ft radius.

The American Indian Hall is the university's department home for Native American Studies and American Indian and Alaskan Native Student Services. The Hall also features a drum room, a ceremonial space, and an external site with an interpretive garden for education on native plants and their uses. WMK was the project's steel fabricator, and the erector was Western States Steel Erectors. ThinkOne Construction Management designed the roof.

—Jaime Smith, Marketing Director, Albina Co., Inc.

Jacob Teats

Curving steel is more economical than faking a curve. It is less expensive to curve a length of steel than to separate a span into small sections and miter cut and weld each section to create the appearance of a curve.

Time is money, but curved steel doesn't add time. Curved steel is like any other component. If planned for early in the design phase and obtained promptly, it will not add time to a project's schedule.

Different bending methods will result in different cost structures. The material size, material thickness, bend radius, and architecturally exposed structural steel (AESS) level dictate the various bending methods. A bender-roller can offer the best process for your specific project.

Tolerances will be a cost factor. Bender-rollers perform their work to the *Code* tolerances for bending, unless alternative tolerances are agreed upon. If tighter tolerances are required, then costs will increase.

Increasing wall thickness can lower costs in the long term. Although increasing wall thickness of material to be curved may increase the up-front cost, it may reduce the labor costs of the bender-roller and reduce costs by simplifying fabrication and erection due to less cross-sectional distortion.

Designing curves with uncommon material sizes and thicknesses can increase bending-rolling costs. Odd-sized materials and wall thicknesses can be difficult to curve, due to the tooling each bender-roller has in its shop. Bender-rollers will only make a small investment into tooling they may only use once or twice to accommodate such materials, so designing with common, readily available materials is the economical choice.

AESS level is a major determining factor for curved steel costs. Significant cost differences exist when comparing standard structural steel versus AESS 4 (close-to-view) showcase elements. (Read more about AESS 4 and the other AESS categories in "Out in the Open" on page 54). Identifying the proper level of AESS early in the design process will help define the bending costs. If the product will not be highly visible, do not request a high level of AESS.

Also, when working with HSS members, specifying the location of the weld seam in relation to the bend is critical when the bent material needs to adhere to AESS standards. The weld seam can cause greater distortion during the bending process, and if the material needs to meet AESS standards, the preference would be to have the weld seam on the least visible side.

Curved Steel Soars

Eastern Iowa Airport is small and regional like its name suggests, but it's a critical jumping-off point to the rest of the world for residents in the agrarian state's eastern half.

The airport, located in Cedar Rapids, services one-third of Iowa's commercial passenger traffic and welcomed a record 1.4 million travelers in 2023 amid an ongoing modernization project—one where curved steel had a vital supporting role.

Fully modernized airports make all aspects of travel more comfortable, from checking bags to security screening to boarding and departing planes to finding something to eat or drink. Eastern Iowa Airport embarked on a 10-year, $120 million upgrade in 2014, with work scheduled in four phases. The fourth, started in March 2023 and priced at $68 million, was the biggest yet.

The last phase is scheduled for completion in spring 2025 and will expand concourse space by 32,000 sq. ft. Six gates and their surrounding areas are set for remodeling. Four jet boarding bridges will be added, and the patio common area for passengers is being enlarged. New passenger amenities will include a sensory room for people to decompress from travel stress and a pet relief area.

Why curved steel for an airport? Its dramatic aesthetic effect is obvious and its structural efficiency makes for a powerful pairing often chosen by architects and engineers. Passengers now enter a well-lit open space with an efficient and stirring architectural design. The terminal is crafted with regional building materials and elements. Its front façade, anchored by an undulating 453-ft canopy, mimics the rolling hills near Cedar Rapids.

Mead & Hunt, Inc. was the project architect. Tipton Structural Fabrication supplied structural steel components for the airport work, and it hired Milwaukee, Wisc., bender-roller Max Weiss Company to form nearly 190 pieces. Ninety-two of those were column wraps, and the remainder were a mix of angle-rolled steel and square and rectangular tube sections. All the pieces accommodated a variety of architectural elements in the transformed airport.

The column wraps—made of plate steel—posed a challenge for the rollers. Their end function was protective barriers around structural columns and vital mechanical elements, warding off damage from collision, fire, or water.

They were formed in a brake press and plate roller, and then galvanized in 834° zinc. Hot zinc can ruin bends, opening and distorting the previously precise forms. Max Weiss Company's solution was to weld temporary whalers into the column wraps to preserve the bends. The extra step aided the fabricator and avoided costly do-overs.

The remaining pieces—just under 100 total—were an amalgamation of shapes and sizes:

- **24** 4 in. by 4 in. by ¼ in. A36 angle-rolled leg out, ends rough trimmed. Lengths ranged from 1 ft, 10$\frac{1}{16}$ in. to 11 ft, 4$\frac{15}{16}$ in.; inside radius was 31 ft, 9 in.
- **6** 6 in. by 6 in. by ¼ in. wall square A500 Gr. B tube formed, ends rough trimmed. Lengths were 24 ft, 10½ in. to 28 ft, $\frac{15}{16}$ in.
- **40** 6 in. by 6 in. by ⅜ in. wall square A500 Gr. B tube formed, ends rough trimmed. Lengths were 16 ft, 1$\frac{13}{16}$ in. to 24 ft, 11¼ in.
- **12** 6 in. by 2 in. by ¼ in. wall rectangular tube A500 Gr. B tube formed hard way, ends rough trimmed. Lengths were 16 ft, 1$\frac{3}{16}$ in. to 24 ft, 11¼ in.
- **6** 3 in. by 3 in. by ¼ in. A36 angle-rolled leg out, ends rough trimmed. Lengths 24 ft, 11¼ in., inside radius 31 ft, 9 in.
- **6** 3 in. by 3 in. by ¼ in. A36 angle-rolled leg in, ends rough trimmed. Lengths of 24 ft, 3½ in. to 29 ft, $\frac{15}{16}$ in.

These varied pieces had no benchmarking of radii, but all were within the capabilities of Max Weiss Company's talent and equipment. A proprietary forming method maintained the original shape of the tubing. Often, a mismatch between HSS members can challenge even the most experienced fabricators. The bending process maintained integrity of material and prototype.

Other pieces were put through a proprietary forming machine and incrementally bent. Common structural rolling equipment was used on some pieces. All finished products were delivered on time. Four weeks elapsed between quoting, order entry, production, and leaving the shop.

Few travelers will consider how metal bending, forming, and rolling contributed to the picture. But they were a significant piece and foundational to keeping the airport flying high.

—Al Sanders, President, Max Weiss Company

Cedar Valley Steel Erectors

Eastern Iowa Airport

Out In the Open

A refresher on understanding and specifying architecturally exposed structural steel in building projects.

STEEL IS MORE than just a material for constructing building. The right presentation can make it a compelling and aesthetically appealing part of the design.

Architects frequently lean into steel's beauty and structural advantages in their designs, and to do so, they may desire that the steel structure be held to a higher aesthetic standard than its typical unfinished appearance.

That's where architecturally exposed structural steel (AESS) requirements aid engineers, fabricators, detailers, and erectors. The *Code of Standard Practice for Steel Buildings and Bridges* (ANSI/AISC 303-22) has a standardized approach to specifying AESS in contract documents that will help ensure the architect's desired look is achieved.

Here's an overview of what to know when considering and specifying AESS, adapted from the November 2017 article "Maximum Exposure" (found at **aisc.org/modernsteel**) and updated based on the 2022 edition of the *Code*.

Exposure Basics

Per the *Code*, all AESS is identified by categories 1, 2, 3, 4, or C. The category system may be selectively applied to fabricated structural steel such as the following items listed in Section 2.1 of the *Code*: anchor rods, base plates, beams, bracing, canopy framing, columns, connection materials, crane stops, girders, lintels, posts, shear stud connectors, trusses, among others. Unfinished, reused, galvanized, or weathering steel may all be fabricated with AESS requirements.

AESS categories are used to designate practices implemented for aesthetic effects that go beyond standard structural steel fabrication and erection. During fabrication, shipment, and erection, extra care is taken to avoid blemishes, marks, paint damage, and unwanted surface appearance from handling the steel and removing temporary braces or fixtures. Special care must also be taken to avoid bending, twisting, or distorting the members.

Additionally, all backing and runoff tabs are removed, and welds are finished in accordance with their designated AESS category. Unpainted surfaces are required to meet requirements specified in the contract documents and coated surfaces are prepared as required by the contract and the specified paint or coating system.

Per the *Code*, there are "other steel, iron, or metal items" that are not typically specified under AESS, though there may be exceptions depending on project requirements. Among them are cables, castings, catwalks, chutes, cold-formed steel products, corner guards, flagpole support, grating, handrail, ladders, ornamental metal, stacks, stairs, steel deck, open-web steel joists, joist girders. Reference Section 2.2 of the *Code* for the full list, available for free download at **aisc.org/specifications**.

When architecturally exposing the structure as an integral part of the design intent, coordination is paramount. While the architect chooses the locations of AESS in a project, the structural engineer should document it. Fabricators and detailers typically look to the structural design documents in the contract documents as the primary source of information for structural steel, including AESS. References to AESS should be consolidated there as much as possible to save time and costs during construction.

Context Conscious

Many factors influence the level of finish and detailing on an exposed member, so it's important to understand the context surrounding the exposed steel before choosing an AESS category.

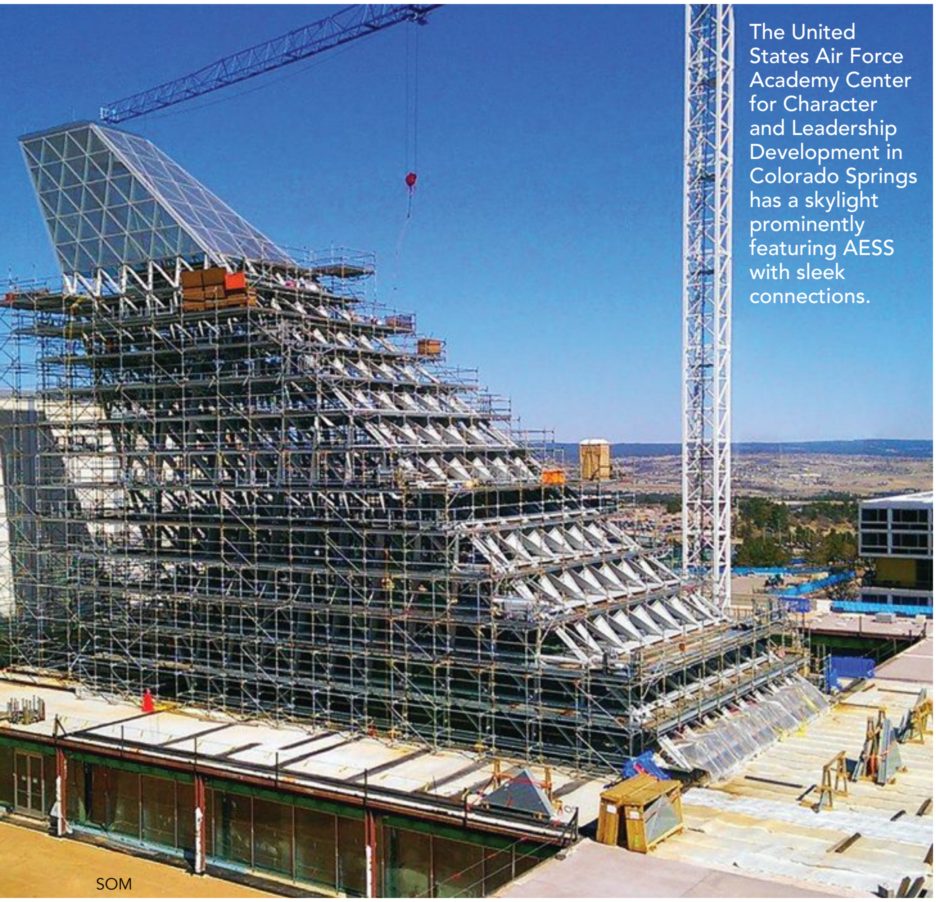
Member Visibility: If a member is not readily visible, there is no need to identify it as AESS. There are often conditions where one side of an exposed steel column or braced frame may be blocked from view by a wall or other component. It is possible to only note a specific AESS category on the side of an exposed member that is visible to view. Specifying AESS incurs more time and care during design, fabrication, and erection. It should only be spent on portions of the project that are visible and prominent.

Viewing Distance: Details tend to disappear from the naked eye the further away they are. When an object is beyond 20 ft, distinctions between components become less visible and clear than when they are within reach. The AESS category system recognizes that viewing distance is critical to the level of fabrication and erection required. The 20-ft distance separates AESS 2 from AESS 3.

Location: If placed on the exterior of a building, the exposed steel must withstand more corrosive or harsh climate conditions. Additional surface preparation and protective coatings are often implemented to promote long-lasting AESS. Methods of detailing at joints or connections must also take special care to keep water out to avoid rusting of steel members.

Ashley Murphy

The interior tree columns in the Freyer-Newman Center at Denver Botanic Gardens are exposed to view.


The United States Air Force Academy Center for Character and Leadership Development in Colorado Springs has a skylight prominently featuring AESS with sleek connections.

SOM


Hunt+Danis

Lighting: Lighting typically has the greatest impact on interior AESS, whereas sight lines are the most important for AESS located on the exterior. Details are not as visible in high ceilings with low lighting, but when elements are brightly lit, they may tend to expose more texture and blemishes on the surface. The location and type of lighting in relation to AESS components should be determined prior to specifying the appropriate category.

Coatings: The selection of a coating, whether it be paint or intumescent fire protection, should be coordinated with the location and lighting intent for an AESS member. Glossy coats often show a member's imperfection and surface variation, so a glossy coat combined with bright accent lighting within a close view range requires greater care and surface preparation for AESS. A thicker intumescent coating or matte finish tends to cover surface marks and blemishes, reducing the need for certain characteristics of surface preparation to the steel.

Style: Two basic styles govern the design intent with AESS: tectonic and plastic. A tectonic look is more expressive of the details that showcase the steel assembly and tends to emphasize bolted construction. A plastic aesthetic is uniform and smooth, using more welded or cast connections for a near-seamless appearance.

Adjacency: Structural steel is an ideal material for achieving tight tolerances because it's fabricated with precision. The *Code* distinguishes between standard tolerances and tighter tolerances with different AESS categories. Depending on the composition of the structure, tighter tolerances may or may not be necessary.

Category Choices

There are five AESS categories:

- AESS 1: Basic Elements
- AESS 2: Feature Elements not in Close View
- AESS 3: Feature Elements in Close View
- AESS 4: Showcase Elements
- AESS C: Custom Elements

More requirements and correspondingly greater costs are inherent as the category number increases. AESS C could require fewer levels of finish than AESS 1 or go even further beyond what is needed for AESS 4. When choosing AESS C, more information should be included in the drawings and specifications to clarify the intent. One or more of the categories must be annotated in the contract documents when the *Code* is referenced as a standard.

Here is an overview of AESS requirements for these categories. These requirements are detailed in the body of Section 10 of the *Code* and summarized in the AESS matrix included in Table 10.1.

AESS 1: Basic Elements. AESS 1 is the minimum treatment beyond standard fabrication. It's typically the lowest-cost category and is a prerequisite for categories 2, 3, and 4. The tolerances required for AESS 1 are the same as for standard structural steel and are found in Section 11 of the *Code*.

The 2022 *Code* no longer mandates a surface cleaning level. Instead, it requires the surface to be prepared in accordance with the requirements in the contract documents and the specified paint or coating system. To complete surface preparation, weld spatter, slivers, and similar surface discontinuities must be removed and sharp corners from shearing, flame cutting, or grinding must be eased.

Daily's Place, a sports complex with an amphitheater and covered football practice field in Jacksonville, Fla., uses exposed V-columns as vertical load-bearing members.

The main canopy of the Ambulatory Care Center at the Omaha VA Medical Center is designated as AESS Category 3.

LEO A DALY

Consistency of appearance between components is also important when specifying AESS. The AESS 1 Category requires that bolt heads be consistently located on the same side of a member as well as on adjacent steel members. The goal is to provide a uniform appearance beyond the standard requirements of structural steel.

When steel components are welded together, there may not always be a need for a continuous weld for structural purposes. Visually, however, the appearance of a continuous weld is more desirable than intermittent welds. AESS 1 requires all welds appear continuous and can be caulked, filled, or additionally welded to achieve this look. The projection of welds can be no higher than 1⁄16 in. above the surface.

AESS 2: Feature Elements not in Close View. AESS 2 serves a level of fabrication and erection specific to feature structural steel elements viewed from a distance greater than 20 ft. Because AESS 2 includes all requirements from AESS 1 and adds to them, it typically comes with a higher cost range.

AESS 2 is more refined than AESS 1. It mandates fabrication tolerances for straightness be half that of standard requirements. This is especially important when adjacent materials and components must closely integrate with steel members in a design.

During fabrication and erection, steel members are marked for inventory and tracking purposes. These numbers are visible on the steel, even through certain coatings. If AESS 2 or a higher category is specified, such marks must not be visible except for special cases such as when reused, weathering, galvanized or other steel intended to appear unfinished is used. The marks can either be ground out, filled, or turned away from view.

AESS 3: Feature Elements in Close View. AESS 3 is for feature components with a viewing distance less than 20 ft. It includes all the requirements for AESS 1 and 2, along with a more specific attention to detail because exposed elements are visibly closer.

A mock-up is required for AESS 3, and its nature and extent are to be specified in the contract documents. Acceptance is based upon the mock-up's approved conditions. Generally, a mock-up is produced and approved in the shop and then placed in the field. Alternatively, if a mock-up is not practical, the first piece of an element or connection can be used to determine acceptability.

Steel is marked with slightly raised characters called mill marks when it is delivered to a fabricator from the mill. Mill marks identify the steel mill from which the component was produced. These marks are required to be removed from view in AESS 3, typically by grinding them out or filling any depressions. Similarly, butt and plug welds for AESS 3 are required to be ground smooth or filled.

A weld seam is typically apparent when steel is joined together by welding. Hollow structural sections (HSS) often include weld seams arising from typical manufacturing processes. For AESS 3, HSS are to be oriented as shown in the contract documents. A designer may opt to orient them away from view or align them in a consistent manner across all members.

When two cross sections of AESS 3 steel are spliced together, it is critical the sections align when in close view range. The mock-up is used to establish acceptance criteria for this alignment. Lighting showcasing an AESS component can expose misaligned surfaces in an obvious and undesirable manner. Misalignments are not acceptable and require greater care in fabrication and erection to avoid these issues at cross-sectional surfaces that abut one another.

As with AESS 2, the tolerance for straightness in AESS 3 must be tighter than the standard level. Tolerance requirements in

Fisher Studios

An office with exposed steel beams and connections in the SteelRidge Center in Birmingham, Ala.

Falgun Surani, SEA

The steel canopy of the ONEOK Boathouse at The Gathering Place of Tulsa.

The St. Pete Pier market canopy in St. Petersburg, Fla., chose steel tubes for their aesthetic appeal and structural efficiency.

Randy Van Duinen

AESS 3 go further to minimize the gaps between the components. Greater precision during fabrication and erection is required so these gaps are no larger than ⅛ in. and uniform among all adjacent components. If the contract shows the surfaces to be in contact, the contact is to be uniform within $1/16$ in.

AESS 4: Showcase Elements. The sculptural nature of steel is meant to be the focus when specifying AESS 4. This category draws inspiration from the expression of form as the featured aesthetic in a project. Making material connections appear seamless in a project can be the most challenging to design and construct. The latter is also true of structure, especially when architecturally exposed structural steel is to have a very smooth and sleek finished appearance.

AESS 4 components come with the highest premium over the previous categories, not only due to the desired glove smooth finish, but more often due to the complexity of structural geometry. The design approach should be discussed between the architect and structural engineer in advance of selecting the AESS category.

The characteristics of the previous categories are all included or furthered with the selection of AESS 4. In AESS 3, reducing the visibility of HSS weld seams is acceptable. The glove smooth finish desired for show-case elements in AESS 4 necessitates grinding, filling, and sanding so that weld seams meet the acceptance criteria established by the mock-up. Certain structural steel shapes and sections, such as pipes or some types of HSS, lend themselves to fewer or no seams. If possible, turn the seam away from view for the most cost-effective strategy.

The smooth and contoured appearance of welds enhances the style of the more plastic look of AESS 4 components. Most steel designs in this category focus less on bolted connections and implement more welded connections for a seamless aesthetic. Therefore, welds are required to be contoured and blended for AESS 4.

There are cases where welds may show through the back face of an exposed steel element, a function of weld size and material thickness. Weld show-through is to be addressed by meeting the acceptance criteria established by the mock-up. Open holes placed in the steel members, often for the welding process, are to be closed off and smoothed out for a clean, finished surface.

More labor and time are often necessary during fabrication and erection to achieve AESS 4 quality compared to the previous categories. Surfaces in view range should be free of imperfections. Surfaces are filled and sanded to meet the acceptance criteria established by the mock-up.

AESS C: Custom Elements. Any deviation from the requirements of AESS 1, 2, 3, and 4 falls under AESS C. Occasionally, there are situations when sharp corners do not need to be eased or fabrication and erection marks are not required to be removed from view. Allowing this flexibility in choosing characteristics provides designers with greater freedom, but also notifies steel fabricators and erectors of a noteworthy difference from the typical category requirements. Custom elements are to be clearly defined in the contract documents with AESS C located as needed.

The matrix in Table 10.1 of the *Code* serves as a checklist for architects and structural engineers to specify customized AESS requirements in the contract documents.

Put It Together

The last portion of the AESS process, erecting the steel, is just as critical as a well-coordinated design phase. The *Code* addresses requirements for erection of AESS in Section 10. The higher-quality finish and treatment of AESS necessitates extra care and handling during transit and placement. The timeline for erection may be slightly longer when AESS is specified on a project. Erectors are tasked with assembling the steel with careful planning and methods to avoid damage to the finished product. ■


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 2025 IDEAS² award! Entries are due September 30, 2024.
aisc.org/ideas2
2024 IDEAS² Excellence in Engineering
Nashville International Airport Terminal Lobby and International Arrivals Facility Addition
Nashville, Tenn. | Photo: Jordan Powers
1-7
Pick-Up Zone
8-15
NO UNATTENDED VEHICLES
LOW OVERHEAD CLEARANCE
AMERICAN INSTITUTE OF STEEL CONSTRUCTION
AISC
FOUNDED 1921
2025
IDEAS²
AWARDS
Innovative Design in Engineering and Architecture with Structural Steel

This month's new products section features a threaded fastener coating, a coating order management system, and a new connection design software.

DÖRKEN Topcoat

DÖRKEN's coating solutions have achieved strong corrosion protection results for decades. They include coatings for threaded fasteners, which allow for a defined coefficient of friction. DÖRKEN's DELTA-PROTEKT TC 502 GZ is a new topcoat specially developed for threaded fasteners that enables a particularly narrow coefficient of friction window to be achieved.

Through a partnership with a German supplier of fasteners for wind turbines and steel construction, several million sets of galvanized bolts, nuts, and washers have been supplied with the new PFAS-Free DELTA-PROTEKT TC 502 GZ applied as a topcoat. The combination of HDG and topcoat achieves the required resistances to environmental fluctuations and mechanical loads. The friction values are kept stable regardless of weather conditions. HRC fittings are usually hot-dip galvanized and, in this case, optimized with an additional topcoat to ensure stable and secure bolting even in various weather conditions. Visit **www.dorken.com** for more information.

Valmont Coatings VCC Max

Valmont Coatings is revolutionizing the entire coatings process with VCC Max, our newly enhanced Valmont Coatings Connector. This innovative system optimizes efficiency and provides seamless connectivity at every stage of your order process. With VCC Max, you gain unprecedented visibility and confidence in your projects.

Real-time order tracking keeps you informed via automatic email and text notifications, eliminating uncertainty. Easily manage action items, request deliveries or trucks, and attach photos directly to your orders. You can view, download, and print essential documents on demand, including certifications, shipping forms, and invoices. Additionally, VCC Max allows you to pre-schedule future orders, ensuring a smooth workflow.

No other coatings provider offers the same level of service, technology, and visibility as Valmont Coatings. Stay connected and in control and experience the difference in efficiency and reliability with VCC Max. Learn more at **www.valmontcoatings.com/vcc-max**.

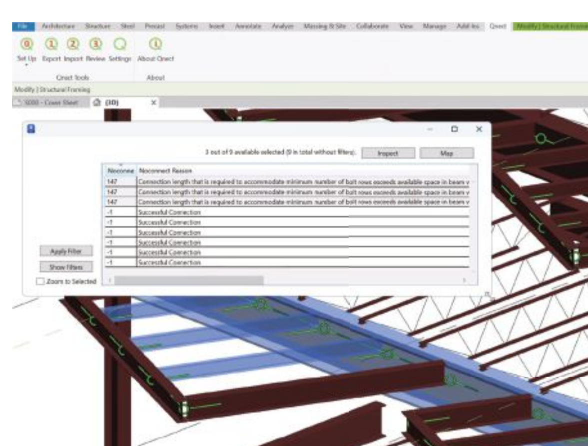
Qnect for Revit

Qnect for Revit automates the identification and resolution of steel framing issues within Revit, allowing users to visualize, coordinate, and address problems early in the design process. This proactive approach ensures more constructible designs, reducing RFIs and boosting profitability during construction administration.

Some of its key benefits include:

- Early Issue Resolution: Detect and solve constructability issues early, ensuring smoother coordination with other disciplines.
- Enhanced Learning: Young engineers gain insights into interdisciplinary coordination, constructability, and erectability.
- Increased Efficiency: Automation of repetitive checks frees up time for engineers to focus on complex challenges, improving overall design quality.

Interested in learning more? Visit **www.qnect.com/qnect-for-revit**.



IN MEMORIAM

Renowned Bridge Engineer Arthur Hedgren, Jr. Passes Away At 84

One of the nation's leading bridge designers, Arthur W. Hedgren, Jr., PhD, died on May 31. He was 84.

Hedgren, who received an AISC Lifetime Achievement Award in 2005, was the longtime lead designer for Richardson, Gordon, and Associates (RG&A) and, after its purchase, the Pittsburgh office of HDR. Hedgren was best known for his expertise in steel arch bridge design and, in the late 1990s, was even featured on a program about bridge design on WQED (the Pittsburgh PBS affiliate).

Among his many significant projects were:

- The Sewickley Truss Bridge over the Ohio River (a 1982 AISC/NSBA Long Span Prize Bridge Award winner)
- The I-579 Veteran's Steel Plate Girder Bridge over the Allegheny River
- The I-79 Ohio River Tied Arch Bridge
- The Double-Deck Steel Rigid Frame North Approaches to the Fort Duquesne Bridge
- The I-470 Tied Arch over the Ohio River (a 1984 AISC/NSBA Long Span Prize Bridge Award winner)
- The Chelyan Truss Bridge over the Kanawha River (a 1998 AISC/NSBA Long Span Merit Award winner)
- The Clifford Hollow Steel Plate Girder Bridge, whose piers towered nearly 300 ft above a mountainous valley (a 2005 AISC/NSBA Long Span Prize Bridge Award winner).

"Art was easily one of the most intelligent and practical bridge engineers and an incredible leader in our bridge community," said AISC Vice President of Bridges Brandon Chavel, PE, PhD, a former bridge engineer at HDR. "His influence on the bridge practice of HDR in Pittsburgh and beyond is immeasurable. His legacy will live on with those lucky enough to have had the opportunity to learn from him."

In addition to his giant portfolio of significant bridge projects, Hedgren was widely recognized as an author and lecturer. He wrote the arch bridges chapter in the second and third editions of the *Structural Steel Designer's Handbook*. A graduate of Princeton University, he was recognized as the ASCE Young Civil Engineer of the Year in 1977 and later as the Civil Engineer of the Year in 1998. He served for many years on the executive committee of the International Bridge Conference (IBC) and as its general chair in 1995.

PUBLIC REVIEW

Prequalified Moment Connection Standard Available for Public Review

The AISC standard *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* (AISC 358-27) is available for public review from Sept. 9 until Oct. 21, 2024.

The standard is available for download on the AISC website at **aisc.org/publicreview**, along with the review form. Copies are also available (for a $35 nominal charge) by contacting Martin Downs at **downs@aisc.org**. Please submit comments using the forms provided online by Oct. 21 for consideration.

People & Companies

The **Canadian Institute of Steel Construction (CISC)** named **Keanin Loomis** President and CEO. Loomis, a former lawyer in Washington, D.C., and the President and CEO of the Hamilton Chamber of Commerce for nine years, currently chairs the HR and Governance Committee for the Hamilton-Oshawa Port Authority Board. He replaces Ed Whalen, who is stepping down after more than 15 years as CISC President.

Each year, the **American Welding Society (AWS) Foundation** provides grant funding of up to $25,000 per location to secondary, post-secondary, and welder training facilities to enhance and expand welding education programs. Grant funding may be used on facility improvements, investing in welding or metalworking equipment, and upgrading computer-based training systems.
Fourteen schools will receive grants this year:

- Bristol Technical Education Center, Bristol, Conn.
- Capital Area Career Center, Springfield, Ill.
- Carrollton Area Career Center, Carrollton, Mo.
- Central Arizona College, Coolidge, Ariz.
- El Capitan High School, Merced, Calif.
- Indiana County Technology Center, Indiana, Penn.
- Lawrence-Nelson Community Schools, Nelson, Neb.
- Maple Mountain High School, Spanish Fork, Utah
- Milton High School, Milton, Wis.
- Rimrock Jr./Sr. High School, Bruneau, Idaho
- Santa Fe Independent School District, Santa Fe, Texas
- The MILL National Training Center, Colorado Springs, Colo.
- Tidioute Community Charter School, Tidioute, Penn.
- Tourtellotte Memorial High School, North Grosvenordale, Conn.

FELLOWSHIPS

AISC Awards Five Ernest J. McCartney/B&B Welding Company, Inc. Undergraduate Research Fellowships

AISC has awarded the 2024 Ernest J. McCartney/B&B Welding Company, Inc. Undergraduate Research Fellowship to five students. The fellowship provides funding to research structural steel design and construction topics under the guidance of a faculty sponsor for a full academic year or one term. This year's recipients will receive funding to conduct their respective proposed research projects during the 2024–2025 academic year.

Feasibility Study Of Composite Floor System With Cold-Formed Z-Sections
Student Name: Israel Barreto
Faculty Sponsor: Michael Seek
Institute: Old Dominion University

This project examines the use of Z-shaped cold-formed steel sections in composite floor systems as an alternative to traditional W-shaped beams. Z-sections, known for efficient fabrication and nesting, will be paired and braced to improve structural performance. The study aims to develop Z-sections with depths of 18 in. to 24 in. and thicknesses from 0.5 in. to 0.75 in., comparable to W18, W21, and W24 shapes. The project will involve designing composite floors using these Z-sections and comparing them with traditional systems, focusing on factors including weight, cost, and ease of assembly. The goal of this research is to assess whether Z-sections offer a cost-effective and efficient solution for composite floor systems.

Mechanical Behavior Of High Strength (Gr. 80) Steel
Student Name: Emily Lamos
Faculty Sponsor: Rachel Cross
Institute: University of Cincinnati

This project explores the properties and applications of high-strength structural steel (HS3), particularly ASTM A913 Gr. 80. With its higher yield (65+ ksi) and ultimate strengths, this type of steel lacks strain-hardening compared to traditional steel, posing challenges in its structural applications.

The project, part of a larger AISC-funded study, focuses on tensile and compression tests and residual stress measurements of HS3 to provide necessary data for structural design. The goal is to enhance the adoption of HS3 by offering critical performance data, thereby encouraging its use in building components like gravity columns and transfer girders. The results aim to support HS3's implementation in high-rise and seismic applications, promoting wider industry acceptance.

Additively Manufactured Steel Seismic Fuses
Student Name: Michael Moschella
Faculty Sponsor: Islam Mantawy
Institute: Rowan University

This project focuses on the development of novel seismic fuses using metal 3D printing techniques like Binder Jetting and Direct Metal Laser Sintering (DMLS). These fuses, designed for easy replacement, aim to concentrate seismic damage, protecting the structural integrity of bracing systems and reducing repair costs.

Three innovative fuse designs, including a Double Funnel Fuse and Honeycomb Fuse, are optimized for energy dissipation and resilience under cyclic loading. The project's goal is to enhance the functionality and sustainability of steel structures by creating fuses that efficiently handle seismic loads, preserving the structure's overall integrity and minimizing downtime. The research includes fuse optimization, 3D printing, and extensive testing to ensure performance.

Efficient HSS Seismic Moment Connections
Student Name: Paul Quinn
Faculty Sponsor: Jason McCormick
Institute: University of Michigan

This project aims to develop cost-effective, robust connections for hollow structural sections (HSS) in seismic moment frames. HSS, known for their strength and light weight, pose challenges in connections due to their geometry, necessitating complex welding or proprietary solutions. The project seeks to explore non-proprietary connections that meet intermediate and special moment frame requirements. Using previous research on collar connections, the project will test various configurations to understand failure conditions and optimize design parameters.

The research includes experimental testing and finite element analysis to ensure that the connections effectively transfer seismic loads and adhere to seismic standards, ultimately aiming for practical, affordable solutions for HSS connections in seismic applications.

The Ultrasonic Characterization Of CR50 Stainless Steel Welds
Student Name: Ryan Turnbull
Faculty Sponsor: Glenn Washer
Institute: University of Missouri, Columbia

The aim of this project is to improve non-destructive evaluation (NDE) methods for detecting defects in CR50 stainless steel welds, which are increasingly used in construction due to their corrosion resistance and cost-effectiveness. Traditional ultrasonic testing faces challenges with stainless steel's coarse grain structure, which causes high attenuation, wave scattering, and beam skewing, complicating flaw detection.

This study seeks to address these issues by collecting detailed velocity profiles of ultrasonic waves through CR50 welds, understanding how these velocities affect wave refraction angles according to Snell's Law, and characterizing wave behavior across different orientations of the welds. This will enhance the accuracy of ultrasonic inspections and support the broader use of CR50 stainless steel in construction.

ASTM STANDARDS

AISC Releases Digital Version of *Selected ASTM Standards*

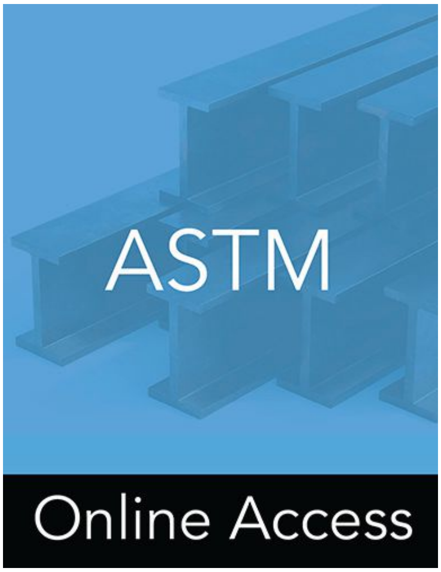
AISC has released the online replacement for its popular ASTM standards collection, *Selected ASTM Standards for Structural Steel Fabrication, including Structural Stainless Steel.*

AISC partnered with ASTM International to create an online subscription that will ensure that users always have the latest standards (including downloadable PDFs) at their fingertips.

"We've had requests for an all-digital version for quite a while," said AISC Vice President of Membership and Certification Todd Alwood, "and we're delighted to move to an online format. The new version is an invaluable tool for designers as well as the AISC-Certified fabricators and erectors they count on for reliable, high-quality work."

The subscription also includes access to past versions of ASTM standards for easy reference.

Annual subscriptions cost just $225 for members and $450 for non-members. Subscribers receive access within 24 hours—no waiting for a book to ship.



SEAA AWARDS

Two Steel Erector Leaders Honored with 2024 SEAA Awards

The Steel Erectors Association of America (SEAA) recognized two board members for their years of dedicated service with annual awards. David Deem, Founder and President of Deem Structural Services, LLC, received the William Davis Service Award. Chris Legnon, Vice President of Technology at Cooper Steel, was named SEAA's Person of the Year.

The William Davis Service Award is SEAA's highest honor and recognizes Deem for his lifelong dedication to service in the steel construction industry. A member of SEAA for more than 20 years, Deem served as SEAA President twice, from 2004 to 2006 and again from 2022 to 2024. Throughout his tenure, Deem actively contributed to committees and initiatives aimed at improving industry standards and safety.

"David has always been an innovator within the industry, even from his days as an ironworker," said Drew Heron, Vice President of Field Operations at Deem Structural Services. "His focus on safety, quality, and integrity has set a high standard, reflecting the values celebrated by the William Davis Service Award. It's an honor to work alongside David at Deem Structural Services and on SEAA's Board of Directors. I strive to uphold his high standards daily. David is not just a mentor and colleague, but also a friend."

Deem's impact extends beyond SEAA and his company, as he has contributed to technical publications on steel detailing and safety practices. His dedication to mentorship has helped shape the next generation of industry professionals, ensuring ongoing growth and advancement.

Legnon's recognition as SEAA's 2024 Person of the Year underscores his exceptional leadership and contributions to the industry. A dedicated SEAA member for 15 years and board member since 2015, Legnon has shown proactive leadership, notably as chairman of SEAA's Marketing Committee, enhancing outreach and engagement for the association.

At Cooper Steel, Legnon has driven initiatives that improve safety, training, and industry standards, pioneering advancements in steel fabrication techniques for greater efficiency and sustainability. His leadership ensures a lasting impact on the steel erection industry.

"Chris has been a huge asset to SEAA over the years," said Glen Pisani, SEAA Strategic Planning Committee chair. "His calming and positive influence and analytical way of thinking has made such a difference when working on projects for the association. He looks at things from all angles to help find the right solution to a problem. That skill paired with this passion for the industry makes him invaluable."

Corrections

In the "Dynamic Design" article in the July issue, we inadvertently left out the bender-roller in the team list. Chicago Metal Rolled Products rolled the curved steel for the project.

In the 2024 Prize Bridge Awards feature in the same issue, we inadvertently left out the steel detailer for the SR 32 Bridge over Stony Creek. Weaver Bridge Corporation was the detailer.

The "Four in a Row" article in the August issue should have designated the University of Florida as the 2024 Student Steel Bridge Competition John M. Parucki National Champion. The SSBC champion became a named award in 2022 upon John Parucki's retirement from 27 years of volunteering as the competition's national head judge.

advertiser index

Randall Schieber

Columbus Crossing

THE LIVELY ARENA DISTRICT neighborhood in downtown Columbus, Ohio, rose from an industrial corridor.

Three stadiums and countless restaurants now stand where warehouses and smokestacks once did, and the area has become more accessible to walkers and bikers traveling along the Olentangy Greenway Trail, located across the Olentangy River from the Arena District. And a new steel bridge that links the trail to downtown also honors the area's past.

One primary design goal of the Olentangy Trail-Arena District Connector was to create a nod to the steel truss structures—one railway and one vehicle bridge—that once crossed the river in the same spot it does and served the area's industrial needs. The City of Columbus Recreation and Parks Department chose a custom truss design instead of a prefabricated short-span bridge to achieve the desired industrial look.

The aesthetic highlight is an inclined Vierendeel truss constructed with round tube members. Structural engineer Burgess & Niple, Inc., designed it, and AISC member Ohio Structures, Inc., fabricated the steel members.

The structure depth below the bridge deck had to be small so it would not trigger a hydraulic impact, because the river's 100-year floodplain elevation was within a few feet of the bike trail's elevation. The design team and owners thought steel was best suited to eradicate flood risks.

The Olentangy Trail-Arena District Connector is one of several bridge projects that will be featured in the October issue. ■