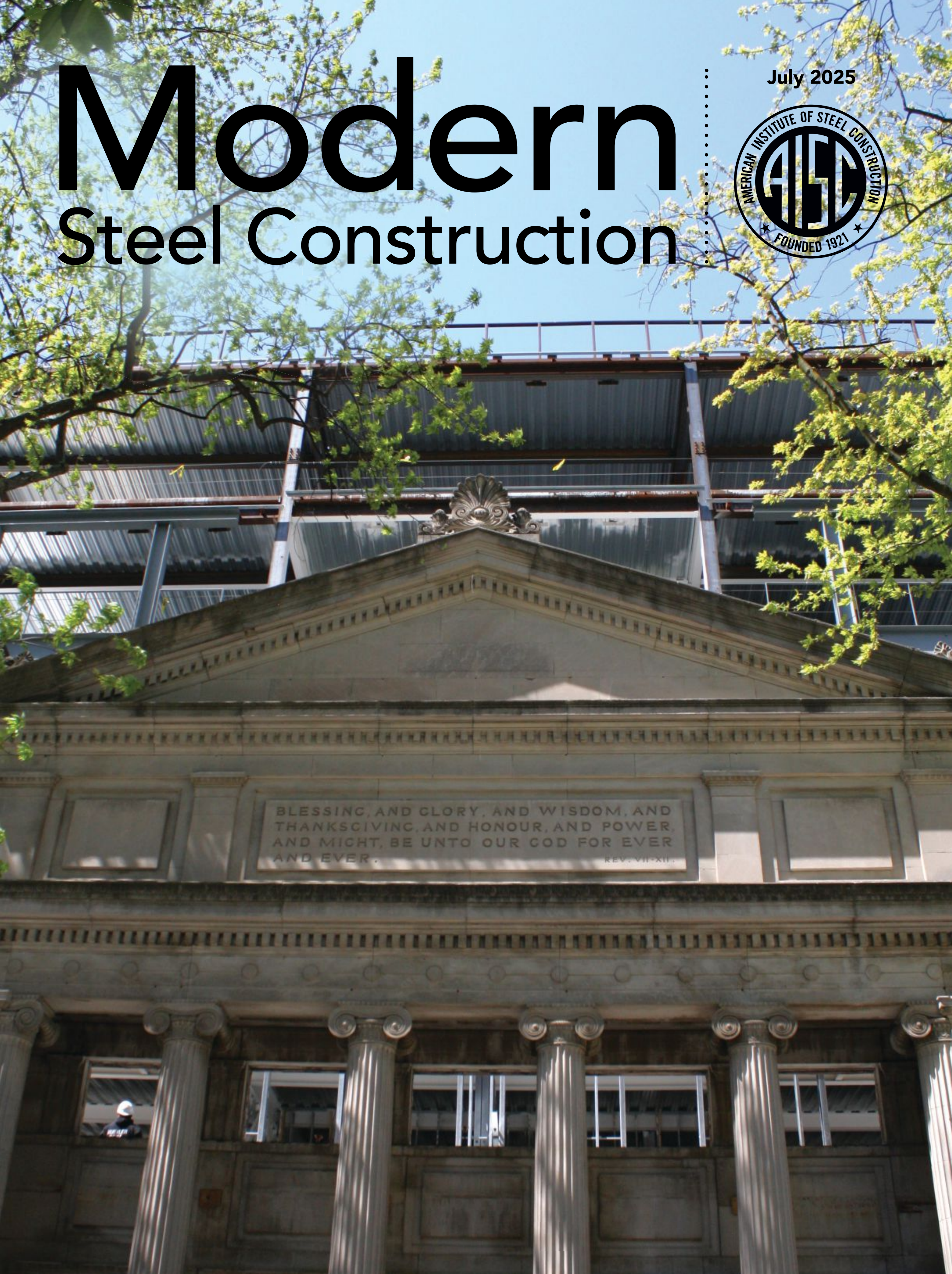
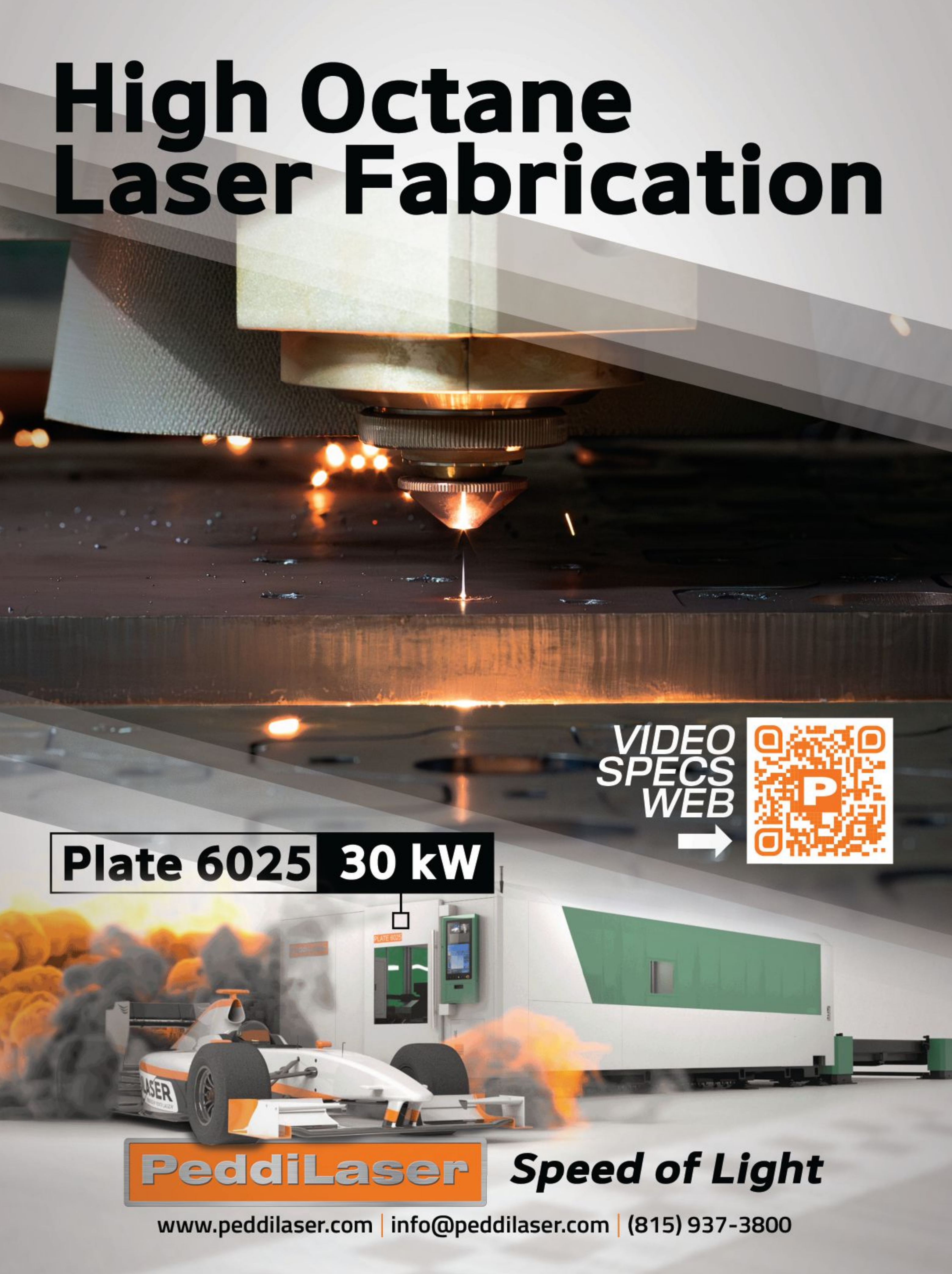
Modern Steel Construction

July 2025

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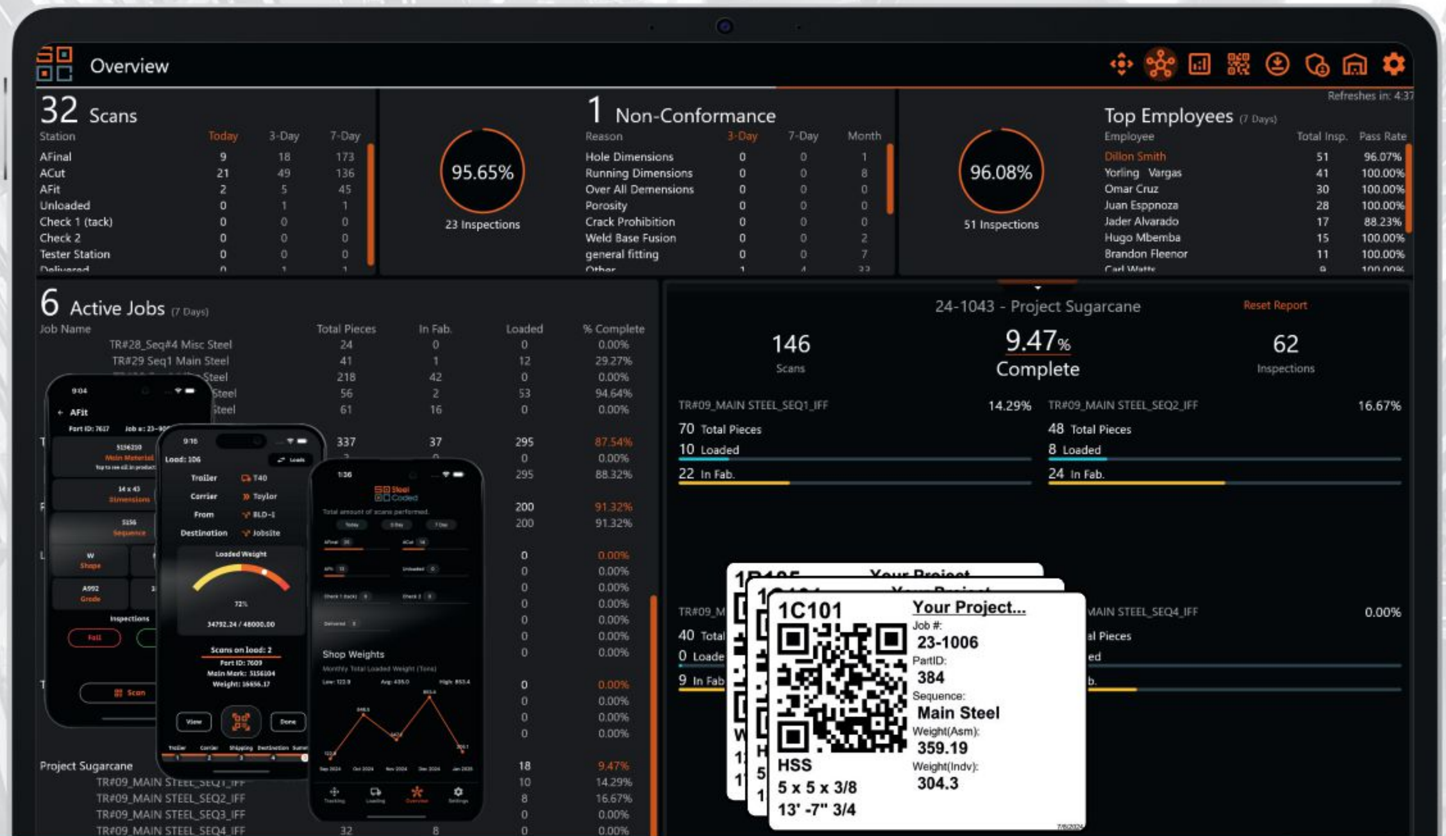

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ON THE COVER: A 120-year-old church exterior will fit in with a new steel apartment building and worship space, p. 24 (Image: AISC)

MODERN STEEL CONSTRUCTION (Volume 65, Number 7) 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.

Back in late March, we took a trip to the Pacific Northwest during our son's spring break from school. I love that part of the country.

It's lush, there are mountains and plenty of water, and it has a laid-back feel—at least to me—though I will say that the traffic is… pretty bad.

We stayed with friends outside of Corvallis, Ore., and in Tacoma, Wash. We took plenty of day trips from both locations, saw the ocean, visited a couple of college campuses (Go Beavs and Huskies!), caught up with longtime friends we hadn't seen in a while, hiked, meandered around Seattle (lots of steel bridges, one with a troll under it!), hit some cool breweries and coffee shops, wandered through Pike Place Market and the Museum of Pop Culture, made a pilgrimage to the original Voodoo Doughnut in Portland, peeked at Mt. Hood, Mt. St. Helens, and Mt. Rainier as we were flying past along Interstate 5, and generally had a great time.

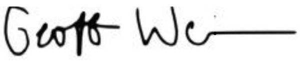
Besides seeing old friends, one of my favorite parts was a hike we took between Corvallis and the Pacific Coast. The trees and vegetation were astounding, and like so many hikes I've taken, this one culminated in an impressive waterfall. Every magic trick needs its "Ta-da!" moment.

The hike, with its copious amount of verdancy, was a reminder of how the concepts of sustainability and conservation have taken deeper root in some areas than others; if you are surrounded by natural beauty, you tend to want to keep it that way. It was also a reminder of the misconception that wood is the only sustainable building material, since the Pacific Northwest is basically the epicenter of the structural wood industry.

Of course, we know that every material has its sustainable attributes. In fact, an independent life-cycle assessment (LCA) report, which showcases newly refined and even more accurate methods to calculate the steel industry's impact, indicates an 11% reduction in the embodied carbon of structural steel as compared to a 2021 industry-wide environmental product declaration (EPD). The three main reasons are less use of ore-based metallics (OBMs), a greener U.S. electrical grid, and more onsite renewable energy generation. You can download the report at **aisc.org/11-percent**. You can also read more about steel's overall environmental footprint at **aisc.org/sustainability/leed-v4**.

This is great news for building teams in general, but if you're looking for more practical information on steel and sustainability, I have even better news! AISC has recently released a couple of sustainability-related publications, and this issue previews them. For a look at sustainable design strategies and general guidance, check out "Sustainability Strategies" on page 45, which is a copy of AISC's new *Sustainable Steel Design Strategies and Rules of Thumb* resource. Meanwhile, "Start at the Top" on page 56, focuses on AISC's new *Owner Sustainability Toolkit* document, which empowers owners to make data-driven decisions to reduce embodied carbon and enhance sustainability and includes a curated Sustainability Steel Academy course, case studies, and myth-busting FAQs.

There are plenty of benefits that come with structural steel; it's a matter of leveraging each of them. And these resources can help you best leverage steel's sustainable attributes.



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steel interchange

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**.

Site-Specific Erection Plan and Job Hazard Analysis

We are required to provide site-specific plans for steel erection and rigging as well as a job hazard analysis. What guidance is available that can assist us in this effort?

OSHA 1926, Appendix A to Subpart R is titled, "Guidelines for Establishing the Components of a Site-Specific Erection Plan." This appendix includes general information, information related to the development of the site-specific erection plan, components of a site-specific erection plan, and other information.

A job hazard analysis lists all operations on the jobsite, such as unloading trucks, hoisting steel, welding, using a manlift, etc. For each operation, it is best to meet with the employees involved in the operation and develop a list of operations on the jobsite. For each operation, answer the following questions:

- What can go wrong?
- What are the consequences?
- How could it happen?
- What are the other contributing factors?
- How likely is it that the hazard will occur?

In most cases, one can list typical activities involved in steel erection. It is not unusual for the job hazard analysis to be altered on the jobsite; activities and site conditions change. To learn more, read OSHA *Job Hazard Analysis* at **aisc.org/OSHAjobhazard**.

Larry Kruth, PE

HSS Longitudinal Seams

For ASTM A1085 shapes being purchased by a fabricator, do the requirements for ultrasonic testing (UT) included in Section N5.5b of the *Specification for Structural Steel Buildings* (ANSI/AISC 360-22) apply to the longitudinal seams on rectangular HSS shapes made using the electric-resistance-welding (ERW) process? If so, is it mandatory that the fabricator perform the UT as part of their quality control?

No, the requirements in *Specification* Section N5.5b do not apply. Section N5.5b applies to fabrication. The fabricator is not fabricating the HSS shapes. The fabricator is purchasing the HSS shapes, which are manufactured to meet the requirements in the ASTM A1085 standard. Any additional testing requirements that exceed those addressed in the ASTM standard would need to be agreed upon by the buyer and the manufacturer prior to production if the manufacturer is being assigned this responsibility.

Therefore, there are no quality control (QC) requirements that would require the fabricator to perform UT on the longitudinal seam. *Specification* Section A3.1 states, "Material test reports or reports of tests made by the fabricator or a testing laboratory shall constitute sufficient evidence of conformity with one of the standard designations listed in Table A3.1…"

Speaking more generally on the topic of quality assurance (QA) and QC requirements, authorities having jurisdiction (AHJ), applicable building codes, purchasers, owners, or engineers of record (EOR) sometimes require additional quality assurance (QA) in the contract documents. QA is typically performed by third-party inspectors hired by the owner. "Such inspections shall be timely, in-sequence, and performed in such a manner as will not disrupt fabrication operations…" as described in Section 8.5.2 of the *Code of Standard Practice for Structural Steel Buildings and Bridges* (ANSI/AISC 303-22).

Larry Muir, PE

Double Angle Flexural-Torsional Buckling Check

When designing a double-angle section in compression, does the adjusted slenderness determined in AISC *Specification for Structural Steel Buildings* section E6 (equation E6-1) need to be incorporated when checking the flexural torsional buckling strength per Section E4?

$$\left(\frac{L_c}{r}\right)_m = \sqrt{\left(\frac{L_c}{r}\right)_o^2 + \left(\frac{a}{r_i}\right)^2} \qquad \text{(E6-1)}$$

Yes. You can see how the check is intended to be applied in Design Example E.6 in AISC's *Manual Companion Volume 1: Design Examples* Version 16.0 (available at **aisc.org/designexamples**). The adjusted slenderness determined in AISC *Specification* section E6 is incorporated into the calculation of F_{ey}, which is then used when calculating the flexural torsional buckling strength.

Larry Muir, PE

Spliced Beam Sweep Tolerances

What is the sweep tolerance for a beam that has a moment splice within the span of the beam?

There are mill tolerances, fabrication tolerances, and erection tolerances that are applicable. Table 1-22 in the 16th Edition AISC *Steel Construction Manual*, which replicates the tolerance requirements in ASTM A6, provides mill tolerances that address the sweep of each individual member that makes up the overall member after it has been spliced together. The *Code of Standard Practice for Structural Steel Buildings and Bridges* also includes fabrication and erection tolerances. Fabrication tolerances can be used to evaluate members that are spliced in the shop. Section 11.2.2.1 in the *Code* states, "For straight structural members, the variation in straightness shall be equal to or less than that specified for structural shapes in the applicable ASTM standards except when a smaller variation is specified in the contract documents.

For splices made in the field during erection, Section 11.3.1.2(d) applies and states, "For a member that consists of an individual, straight shipping piece and that is a segment of a field assembled unit containing field splices between points of support, the plumbness, elevation, and alignment shall be acceptable if the angular variation, vertically and horizontally, of the working line from a straight line between points of support is equal to or less than $1/500$ of the distance between working points."

Section 7.12 in the *Code* addresses the accumulation of mill and fabrication tolerances and states, "The accumulation of mill tolerances and fabrication tolerances shall not cause the erection tolerances to be exceeded." The commentary further clarifies, "It is recognized in the current provision in this Section that accumulations of mill tolerances and fabrication tolerances generally occur between the locations at which erection tolerances are applied, and not at the same locations."

Carlo Lini, SE, PE

Carlo Lini (lini@aisc.org) is the director of the AISC Steel Solution Center. **Larry Kruth** is AISC's former vice president of engineering and research, and a consultant to AISC. **Larry Muir** is also a consultant to AISC.

steel quiz

This month's quiz is all about the newly released 2024 edition of the AISC *Specification for Safety-Related Steel Structures for Nuclear Facilities* (ANSI/AISC N690-24). Download your free copy at **aisc.org/standards**.

1 **True or False:** The *Nuclear Specification* is compatible with the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360-22).

2 Which of the following is not considered an abnormal load case?
- **a.** P_a – maximum differential pressure load generated by the postulated accident
- **b.** Y_r – loads on the structure generated by the reaction of the broken high-energy pipe during the postulated accident
- **c.** E_s – loads generated by the safe shutdown earthquake (SSE) or design basis earthquake (DBE)
- **d.** Y_m – missile impact load, such as pipe whip generated by or during the postulated accident

3 Which of the following factors influence the minimum section thickness, t_{sc}, of exterior steel-plate composite structural elements?
- **a.** Material availability
- **b.** Minimum required penetration resistance for tornado missile impact
- **c.** Practical fabrication practices
- **d.** Both (b.) and (c.)
- **e.** Both (a.) and (c.)

4 **True or False:** When designing structural elements affected by impactive and impulsive loads, it is not permitted to consider strain-rate adjusted material strengths for structural steel, reinforcing steel, and concrete materials.

5 The *Nuclear Specification* requires that bolted connections for members subject to impactive or impulsive loads be configured such that which of the following limit states controls the connection design?
- **a.** Ductile
- **b.** Brittle

6 When applying heat or mechanical means locally to introduce or correct camber, curvature or straightness in ASTM A514/A514M and ASTM A709/A709 Grade 70 steels, the temperature of heated areas should not exceed:
- **a.** 1,200 °F
- **b.** 1,500 °F
- **c.** 1,100 °F
- **d.** 900 °F

7 Which of the following inspection tasks are required to be performed for steel elements of composite construction prior to concrete placement?
- **a.** Verify welds meet visual acceptance criteria
- **b.** Verify repair activities of steel headed stud anchors, if applicable
- **c.** Document acceptance or rejection of steel elements
- **d.** All of the above

TURN TO PAGE 12 FOR ANSWERS

The answers to this quiz are based on the AISC *Specification for Safety-Related Steel Structures for Nuclear Facilities* (ANSI/AISC N690-24); make sure to download your copy for free at **aisc.org/standards**.

1 **True.** The *Nuclear Specification* is compatible with the AISC *Specification for Structural Steel Buildings*. Provisions of the AISC *Specification* are applicable unless stated otherwise. Only those sections that differ from the AISC *Specification* provisions are indicated in the *Nuclear Specification*.

2 **c.** E_s is an extreme environmental load defined as the loads generated by the safe shutdown earthquake (SSE) or design basis earthquake (DBE). Extreme environmental loads are loads that are highly improbable but are used as a design basis, whereas abnormal loads are those loads generated by a postulated high-energy pipe break accident. The different loads and load combinations are presented in Section NB2 of the *Nuclear Specification*.

3 **d.** Both (b.) and (c.). The minimum section thickness, t_{sc}, for exterior steel-plate composite (SC) structural elements is based on both practical fabrication practices and the minimum required penetration resistance for tornado missile impact as described in the Commentary. The minimum thickness for exterior SC structural elements is given as 15 in., and this value can be found in Section N9.1 of the updated Appendix 9.

4 **False.** It is permitted to consider strain rate-adjusted material strengths for structural steel, reinforcing steel, and concrete materials per section N10.1.2 of the new Appendix N10, *Special Provisions for Impactive and Impulsive Loads*, which includes information on dynamic strength increase. Table A-N10.1.1 includes Dynamic Impact Factors (DIF) that reflect the fact that structural steels and concrete exhibit elevated strengths under high strain rate (such as due to impulsive or impactive loads), while the modulus of elasticity remains nearly constant.

5 **a.** Ductile. Bolted connections for members that are subject to impactive or impulsive loads are required to be configured such that a ductile limit state controls the connection design. Section NJ3 covers bolts, threaded parts, and bolted connections and includes a new Section 14 for connections for members subject to impactive or impulsive loads.

6 **c.** 1,100 °F. For ASTM A514/A514M and ASTM A709/A709M Grade 70 steels, the temperature of heated areas shall not exceed 1,100 °F (590°C). Section NM2 of the *Nuclear Specification* covers fabrication and Section NM2.1 is specific to cambering, curving, and straightening.

7 **d.** All of the above. Table NN6.1 in Chapter NN provides a list of the inspection tasks to perform during both QA and QC of the steel elements of composite construction prior to concrete placement. This includes, but is not limited to, verifying welds meet visual acceptance criteria, verifying repair activities of steel headed stud anchors, if applicable, and to document acceptance or rejection of steel elements.

STEEL SOLUTIONS CENTER

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

200 Park
San Jose, Calif.
2025 Award Winner

photo: Jason O'Rear

Seismic Updates

BY MICHAEL GANNON, SE, PE

The 4th Edition AISC *Seismic Design Manual* has made the go-to seismic resource bigger and better with updated discussions and new tables and examples.

THE ESSENTIAL RESOURCE for designing steel and composite seismic force-resisting systems (SFRS) has a new and improved version. AISC recently released the 4th Edition of the *Seismic Design Manual* to reflect the latest design standards and add enhanced technical discussions and new design examples—all tailored to guide engineers in the seismic design of steel and composite structures.

The manual includes detailed guidance on applying the latest standards, including the 2022 *Specification for Structural Steel Buildings* (ANSI/AISC 360-22), 2022 *Seismic Provisions for Structural Steel Buildings* (ANSI/AISC 341-22), 2022 *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* (ANSI/AISC 358-22), *Minimum Design Loads for Buildings and Other Structures* (ASCE/SEI 7-22), and the 16th Edition AISC *Steel Construction Manual*.

With nearly 70 in-depth examples and more than 100 pages of design tables, the manual illustrates how to design critical members and connections for commonly used SFRS. These examples don't stop at seismic-specific checks. Instead, they feature complete member and connection designs, limit state by limit state, making this edition an indispensable resource for understanding and implementing structural steel design for seismic applications.

The overall organization of the *Seismic Design Manual* has not changed from the 3rd Edition and has nine chapters, organized as follows:

- Part 1: General Design Considerations
- Part 2: Analysis
- Part 3: Systems Not Specifically Detailed for Seismic Resistance
- Part 4: Moment Frames
- Part 5: Braced Frames
- Part 6: Composite Moment Frames
- Part 7: Composite Braced Frames and Shear Walls
- Part 8: Diaphragms, Collectors, and Chords
- Part 9: Provisions and Standards

One of the manual's most helpful features is in the opening pages. The Scope section clarifies when the *Seismic Provisions* do or do not apply, using the criteria in ASCE/SEI 7. It also offers a roadmap of how the manual is organized.

Part 1: General Design Considerations

The first section overviews key seismic design concepts. It covers topics such as performance goals, expected system behavior during seismic events, seismic drift, quality control and assurance, design documentation requirements, and referenced standards.

The section on load effects and combinations explains how vertical and horizontal seismic loads, E_v, and E_h, are integrated into the ASCE/SEI 7 basic load combinations, which are referenced throughout the design examples in later sections of the *Manual*. In the design of specific elements or connections, some sections within the *Seismic Provisions* allow the use of either overstrength or capacity-limited seismic loads, while others mandate the use of capacity-limited seismic loads. This part identifies each provision and its corresponding loading requirement.

The section comparing key differences between wind and seismic design offers guidance on evaluating governing loading conditions, particularly for regions, building types, or even individual elements where it is not evident if wind or seismic forces will control.

Part 1 also reviews the symbols and terminology from ASCE/SEI 7 relevant to steel seismic design. It provides detailed explanations of key seismic performance factors, including the response modification coefficient (R), deflection amplification factor (C_d), overstrength factor (Ω_0), and redundancy factor (ρ).

The *Seismic Provisions* require that structural design documents include designation of the SFRS and its associated members and identification of protected zones and demand critical welds, among other items. Part 1 includes a sample plan and fully developed connection detail to provide an example of how engineers can clearly communicate this information to other members of the construction team.

Part 1 also features a collection of practical design aid tables. Table 1-1 provides 16 options for weld access hole dimensions that satisfy the alternate geometry for seismic applications found in AWS D1.8/D1.8M. Table 1-2 offers a quick-reference guide for identifying member ductility requirements for each SFRS defined in the *Seismic Provisions*. Tables 1-3 through 1-7 list the steel member sizes that satisfy ductility requirements for W-Shapes, angles, rectangular and square HSS, and round HSS. Each of these tables is updated to reflect changes to these requirements in the *Seismic Provisions*, and they are also updated to include the many new shapes added to the AISC shapes database—six new W-shapes and 210 new HSS shapes. The W-shape tables are also updated to reflect how ductility requirements are now different depending on if the member is used in a moment frame or in a braced frame.

One of the 4th Edition highlights is the new Table 1-10, a comprehensive roadmap for navigating the systems chapters of the *Seismic Provisions*. For each SFRS, the table lists the seismic design coefficients and factors from ASCE/SEI 7. It then outlines the requirements for steel yield strength, analysis, member ductility, capacity-limited design, connection detailing, protected zones, and demand critical welds, among other considerations. While this table does not delve into the full details of each provision, it allows the user to quickly locate the pertinent sections of the *Seismic Provisions* and enables quick comparison across the different SFRS.

Part 2: Analysis

A core principle of seismic analysis is certain components of the SFRS are intentionally designed to yield in a controlled, ductile manner to dissipate earthquake energy. Part 2 explains how the *Seismic Provisions* define ductile behavior for each system and how capacity-based design is used to protect the remaining members and connections from inelastic response—by designing them to resist forces based on the expected strength of the ductile elements.

Part 2 also presents an overview of the structural analysis procedures outlined in ASCE/SEI 7, the *Specification*, and the *Seismic Provisions*. The *Specification* includes three stability design approaches: the direct analysis method, effective length method, and first-order method. ASCE/SEI 7 specifies four seismic analysis methods, which are the equivalent lateral force method, modal response spectrum analysis, linear response history analysis, and nonlinear response history analysis. Part 2 offers guidance on applying either the equivalent lateral force method or modal response spectrum analysis in conjunction with the direct analysis method.

The 4th Edition added Table 2-1 (see Figure 1) for determining B_2, the multiplier to account for P-Δ effects as defined in *Specification* Appendix 8. The values in the table are calculated for various drift limits based on the total vertical load supported by the story (P_{story}), the total story shear (H), the story height (L), and the deflection amplification factor (C_d). This table enables a quick preliminary check that second-order drifts will not exceed drift limits before continuing with a detailed design and analysis.

Recommended modeling techniques are provided for steel and composite member stiffness, connection panel zones with rigid offsets, diaphragms, column bases, and foundations.

Part 3: R = 3 Systems

Part 3 is a standalone chapter for systems not specifically detailed for seismic resistance, where the requirements of the *Seismic Provisions* are not applicable. A common misconception when designing these R = 3 systems is that no additional seismic requirements apply beyond those in the *Specification*. While the *Seismic Provisions* are not used, other seismic-related provisions from the applicable building codes still apply. For example, requirements in ASCE/SEI 7 include horizontal and vertical irregularities, seismic load combinations, collector design, and foundation design. Part 3 features design examples for the member and connection design for typical R = 3 moment and braced frame lateral systems. It's a valuable reference for engineers working in seismic and nonseismic regions, offering a framework for two of the most widely used connections in lateral force-resisting systems.

Parts 4 and 5: Steel Systems

The next two parts of the 4th Edition correspond to the chapters in the *Seismic Provisions* that address steel moment frames and braced frames.

Part 4 covers the expected ductile behavior and detailing requirements for ordinary, intermediate, and special moment frames (OMF, IMF, and SMF, respectively), as well as special truss moment frames (STMF). It includes a series of design examples for member connection configurations commonly used in OMF and SMF systems. Design examples for IMF systems are not included, as the requirements largely overlap with those for SMF systems.

The end plate moment connections used in OMF and STMF examples are updated based AISC Design Guide 39, *End-Plate Moment Connections* (download or order at **aisc.org/dg**). The SMF examples demonstrate two prequalified moment connections, reduced beam section (RBS) and bolted flange plate (BFP), using the step-by-step instructions found in *Prequalified Connections*.

Table 2-1
Second-Order Amplifier, B_2

$\alpha P_{story}/(C_d H)$		4	5	10	20	25	33	40	50	100	200	250	500
Δ_{all}/L	Δ_{all}	Values of B_2											
0.0010	L/ 1000	1.00	1.01	1.01	1.02	1.03	1.03	1.04	1.05	1.10	1.20	1.25	1.50
0.0020	L/ 500	1.01	1.01	1.02	1.04	1.05	1.07	1.08	1.10	1.20	1.40	1.50	2.00
0.0025	L/ 400	1.01	1.01	1.03	1.05	1.06	1.08	1.10	1.13	1.25	1.50	1.63	2.25
0.0050	L/ 200	1.02	1.03	1.05	1.10	1.13	1.17	1.20	1.25	1.50	2.00	2.25	
0.0100	L/ 100	1.04	1.05	1.10	1.20	1.25	1.33	1.40	1.50	2.00			
0.0150	L/ 66.7	1.06	1.08	1.15	1.30	1.38	1.50	1.60	1.75	2.50		B_2>2.5	
0.0200	L/ 50	1.08	1.10	1.20	1.40	1.50	1.66	1.80	2.00				
0.0250	L/ 40	1.10	1.13	1.25	1.50	1.63	1.83	2.00	2.25				

Fig. 1. Table 2-1: Second-order amplifier, B_2.

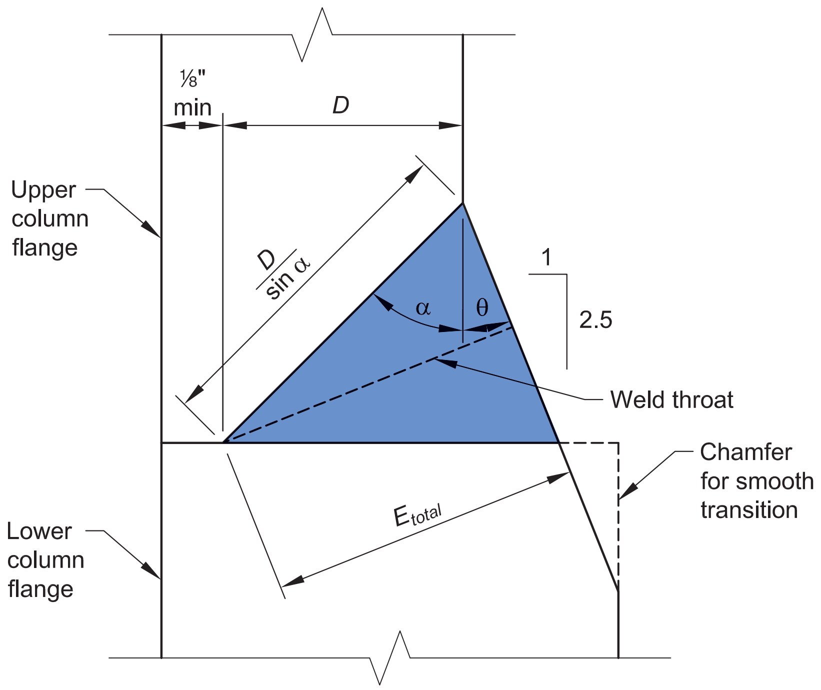


Fig. 2. PJP groove weld option for SMF column splice.

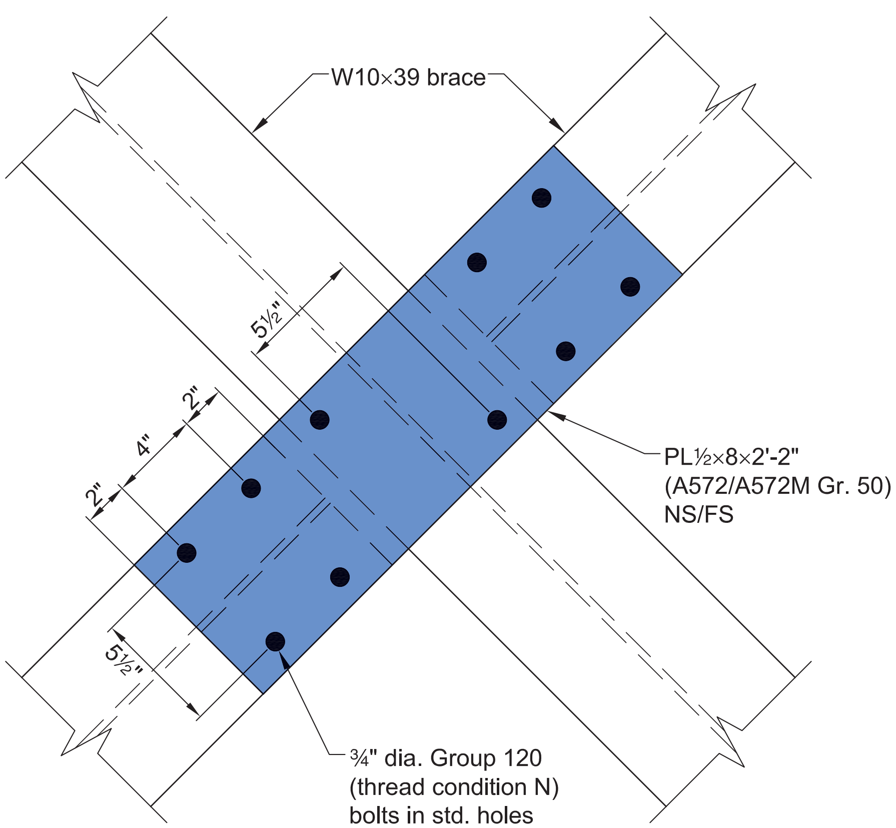


Fig. 3. OMF intersecting braces.

The strong-column weak-beam (SC/WB) requirement for SMF in the *Seismic Provisions* is intended to promote ductile behavior by concentrating inelastic deformation in the beams rather than the columns. The *Seismic Provisions* also permit exceptions to this requirement, allowing the designer to bypass satisfying SC/WB, and Part 4 includes a design example that meets the criteria for one such exception.

The SMF example for a column splice example is expanded to include an option for a partial-joint penetration (PJP) groove weld (see Figure 2). This option illustrates the additional detailing requirements, such as providing a smooth transition between the flanges of different thickness through the weld and chamfer of the thicker flange. Compared to a complete join penetration (CJP) groove weld, the PJP option can eliminate the need for a weld access hole, reduce weld material and preparation, and is not subject to the same inspection requirements.

Part 5 addresses system designs for ordinary concentrically braced frames (OCBF), special concentrically braced frames (SCFB), eccentrically braced frames (EBF), and buckling-restrained braced frames (BRBF).

A new design example has been introduced in the 4th Edition to address the connection of two intersecting braces in an OMF X-brace configuration (see Figure 3). This example includes a check for brace continuity, evaluated by comparing the moments of inertia of the interrupted brace with those of the connecting flange plates.

The SCBF brace-to-beam member and connection examples address the chevron effect at the brace-to-gusset interface, which can induce additional localized bending and shear forces in the supporting beam within the connection region. These forces may exceed those determined from member analysis and, in some cases, may surpass the available strength of the beam. The design examples offer a detailed discussion of the chevron effect, present a method for evaluating its impact on member design, and proceed with the design of localized web reinforcement where required.

Two new examples are included specific to design of SCBF columns. The first

Table 5-3
Summary of Load Cases for Column in Two Intersecting Frames

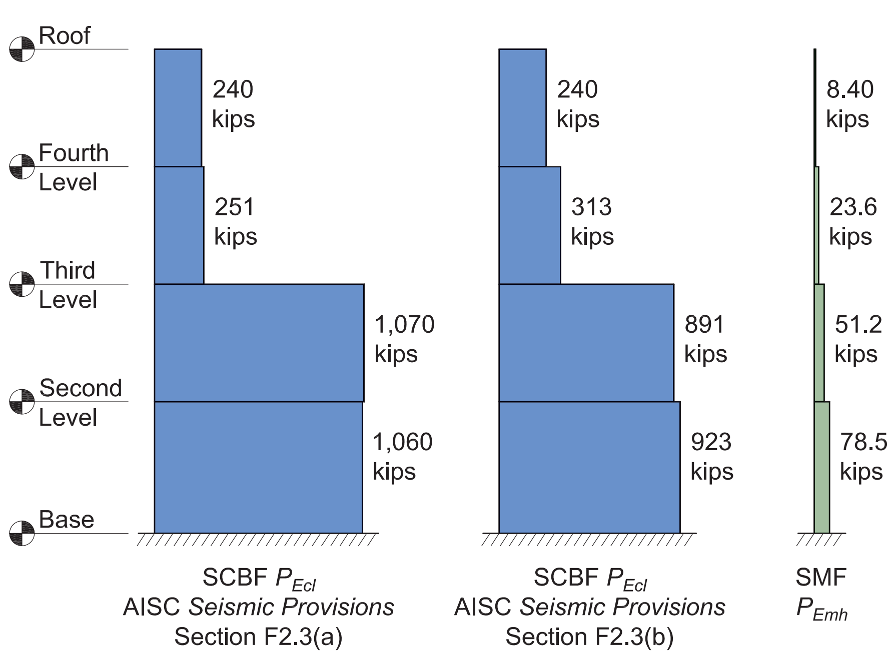
Load Case	SCBF Axial	SCBF Flexure	SMF Axial	SMF Flexure	Referenced Standards
Load Cases for Column Design					
1	$1.0E$	$1.0E$	$0.3E$	$0.3E$	ASCE/SEI 7, Section 12.5.1.2
2	$0.3E$	$0.3E$	$1.0E$	$1.0E$	
3	$1.0E_{mcl}$	0	$1.0E_m$	0	AISC *Seismic Provisions* Sections D1.4a, E3.4a, and F2.3
4	$0.3E_{mcl}$	0	$1.0E_m$	$1.0E_{mcl}$	AISC *Seismic Provisions* Sections E3.2 and F2.3, and ASCE/SEI 7, Section 12.5.1.2
5	$1.0E_{mcl}$	0	$0.3E_m$	$0.3E_{mcl}$	
Load Case for the Satisfying the Strong-Column/Weak-Beam Requirement					
6	$1.0E_{mcl}$	0	$1.0E_m$	$1.0E_{mcl}$	AISC *Seismic Provisions* Sections E3.4a and F2.3

addresses a common question regarding the required strength at the column base. The example illustrates the multiple code provisions that must be considered, with specific references to interconnected requirements in *Seismic Provisions* Chapter D and Section F2 (specific to SCBF). It provides guidance on how to navigate and interpret these sections collectively when determining the required strength at the column base.

The second of these new examples addresses the condition where a single column is shared between two intersecting SFRS—in this case, SMF and SCBF systems (see Figure 4). The applicable minimum design requirements from ASCE/SEI 7 and the *Seismic Provisions* are evaluated to determine the governing case. This includes simultaneous inelastic demands from both the SCBF and SMF systems. The required column strength is therefore determined by combining the forces from the SCBF expected brace strengths in both tension and compression, together with the effects of plastic hinge formation in the SMF beams.

(a) Load cases

Fig. 4. Column in intersecting frames.



(b) Required axial strength

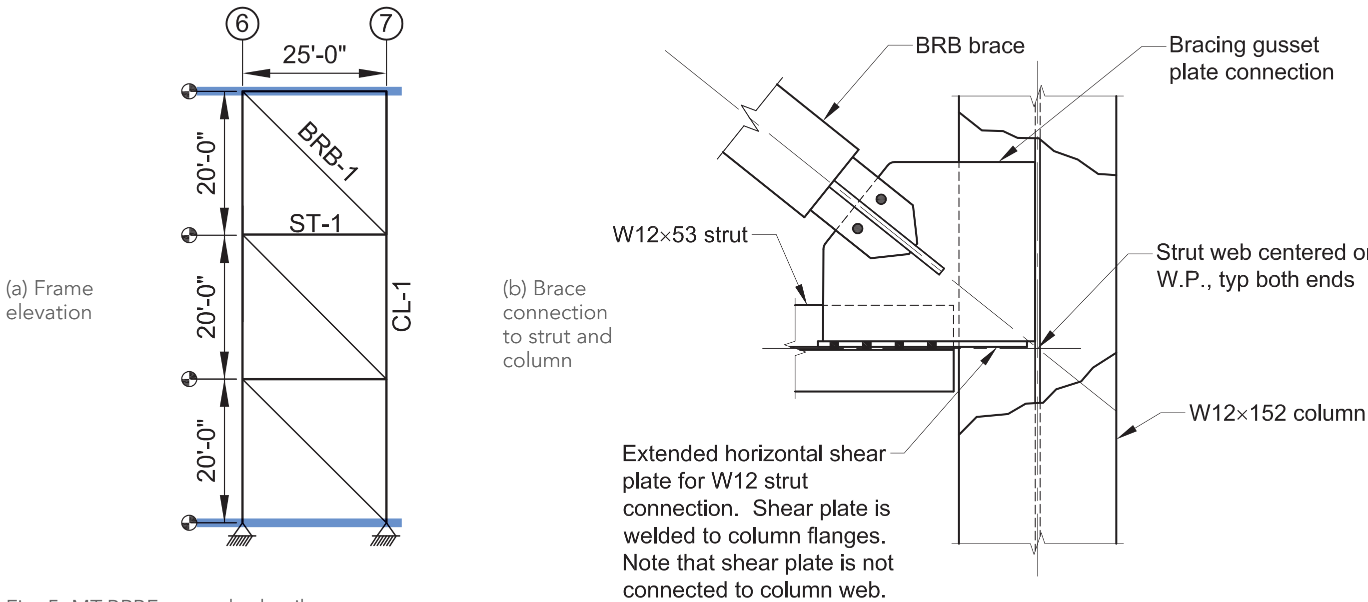


Fig. 5. MT-BRBF example details.

New to Part 5 is a suite of new design examples for a multi-tiered buckling-restrained braced frame (MT-BRBF) system (see Figure 5). In multi-tiered systems, the columns are not braced out-of-plane at intermediate tiers, so they must have sufficient strength and stiffness to support the unbalanced or notional loads at these levels. The new examples demonstrate how the *Seismic Provisions* requirements can be satisfied through appropriate member selection, configuration of the frame geometry, and connection detailing.

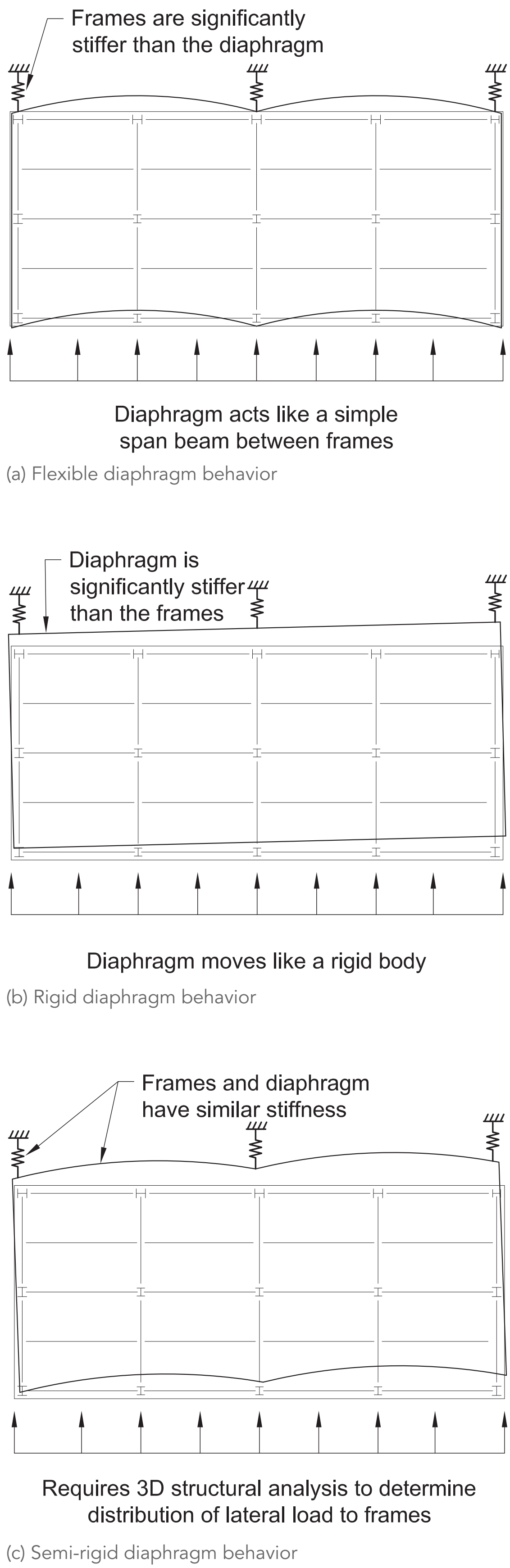


Fig. 6. Categories of diaphragm behavior.

Parts 6 and 7: Composite Systems

Parts 6 and 7 are the composite counterparts to Parts 4 and 5, addressing moment frames and composite braced frames and shear walls. Due to the complexity of these types of systems and the requirement for prequalification, the content in these sections is primarily limited to system-level discussions. They provide overview roadmaps that guide designers to the applicable requirements in the *Seismic Provisions* and ACI 318. Additionally, these parts discuss experimental tests that provide valuable background information on specific composite systems.

Part 8: Diaphragms, Collectors, and Chords

Part 8 discusses diaphragms, collectors, and chords—key components of the floor system responsible for transferring seismic forces to the SFRS. The discussion of diaphragm behavior, covering rigid, semi-rigid, and flexible diaphragm classifications, has been expanded to address the complexities in predicting force distribution in diaphragms and how this force is accumulated and transferred along lines of collector elements (see Figure 6). Axial member design, which is typical for these horizontal elements, accounts for varying restraint conditions influenced by member type and floor system configuration, with corresponding design checks. The concluding design example illustrates these principles by highlighting the bracing assumptions used in the design of a representative collector beam.

Part 9 and Additional Resources

Part 9 contains the two seismic standards' most recent versions: the *Seismic Provisions* and *Prequalified Connections*. These two, along with all other AISC standards, are available for free download at **aisc.org/standards**.

Additional seismic-specific resources are available on the AISC Technical Resources page at **aisc.org/technical-resources/seismic**. Designers can also access other useful resources that supplement the *Seismic Design Manual* and the *Steel Construction Manual* at **aisc.org/manualresources** and find archived NASCC: The Steel Conference proceedings—many of which focus on seismic design—at **aisc.org/learning**.

The 4th Edition *Seismic Design Manual* is a must-have resource for engineers who frequently design SFRS and a helpful tool for those who encounter them only occasionally. Order your copy today at **aisc.org/seismic**.

Michael Gannon (**gannon@aisc.org**) is a senior engineer at AISC.

Sustainability Savvy

INTERVIEW BY GEOFF WEISENBERGER

Fraser Reid did not envision becoming a sustainability champion when he began his structural engineering career, but he has flourished in that space and found an industry niche where he's comfortable.

ONE THREE-MONTH PROGRAM as an entry-level engineer put **Fraser Reid** on track to finding his passion within structural engineering. Reid, an associate principal at Buro Happold in New York, started in the firm's London office in 2007 after he graduated college and enrolled in a three-month secondment with its sustainability team. He picked the sustainability track mainly because it was a familiar topic from his classes.

It gave him much more than three months of knowledge. It helped him become a prominent sustainability voice in the industry. More importantly, it led him to a passion within the field that he says all engineers should strive to find. Reid has worked on several sustainability-focused projects and is involved in nationwide sustainability initiatives. It's not the career niche he envisioned when he started, but it's one he quickly embraced. Reid spoke with *Modern Steel Construction* about his career path, sustainability work, and more.

Where are you from and where did you grow up?

I'm from Edinburgh, Scotland. I've worked at Buro Happold for my whole career, starting in London. I moved from Scotland to England for college at Cambridge University, then was in London for about seven years and rose to a senior engineer level. I was transferred to New York and have been here for about a decade.

My engineering path started as a kid with my interest in math and physics. My parents guided me to stick with what I was good at, and I enjoyed problem-solving and had an analytical mind. As a kid, you don't necessarily know what's out there, and neither of my parents were engineers, but they helped me recognize my strengths and the career options for them. I thought the hard work was getting into Cambridge, but I quickly learned that the hard work was being there and studying engineering.

What pushed you into engineering, and was there a building or project that made an impression?

My parents took me to the Falkirk Wheel near Edinburgh, one of the first projects that grabbed my interest. It was the world's first rotating boat lift. Putting a floating object in a body of water displaces the same water weight as the object, so it's always perfectly balanced. It needs little energy to lift or lower something to meet the canal at the higher or lower elevation. I remember hearing lifting a boat takes the same energy as boiling 12 kettles. That was my "buildings are cool" moment.

What's one of your most memorable steel projects that you've worked on?

One of my most recent projects is one of my favorites. It was at the Minnesota Zoo, and it's the ultimate adaptive reuse project. We turned a disused monorail track into a treetop trail for the zoo that opened in 2023. As an industry, we're recognizing the importance of reusing existing buildings from a climate and historic preservation standpoint. This project resonated with the team, and we're really proud of the outcome.

We had experience on a similar project with the High Line in New York, and that got us the call for the Minnesota Zoo. We did all the engineering work on the High Line, and we have five or six active High Line projects—new stairs, new plazas, things like that. But the High Line and the zoo project couldn't be more different from an engineering standpoint. The High Line was designed for freight trains and can comfortably support the assembly and park loading.

The treetop trail was the opposite. One of the first things we highlighted was the limitation of the original design load, which was 1 kip per foot. That isn't a lot when you start putting live load on there. One early challenge was asking ourselves what's possible if we reuse the structure?

Describe your sustainability role at the firm and your involvement in SE 2050.

SE 2050 is a commitment program for structural engineering firms framed around achieving net zero in structures by 2050. The Structural Engineering Institute (SEI) started it in 2019. Right now, and most importantly, it's data reporting by structural engineering firms to provide open access to embodied carbon data for a range of firms and range of projects.

It's also a big community of people and firms, which is unique because in cross-industry collaboration, competing firms tend to stay in their lane or stay separated. But with climate action, we recognize that collaboration is key to addressing carbon reduction right now, because we're already behind with the climate crisis. We must be open about barriers to carbon reduction and share lessons learned.

My role is the embodied carbon champion for Buro Happold. Each SE 2050 firm has an embodied carbon champion responsible for managing that firm's data reporting, advocacy, education, and ensuring we're targeting real carbon reductions on our project portfolio.

What pushed you to get involved in sustainability efforts?

My degree at Cambridge was in civil, structural, and environmental engineering, so sustainability topics were part of my education. When I started with Buro Happold, the firm offered secondments for graduates, and I took a three-month secondment with our sustainability team. We were looking at embodied impacts of structures, which nobody wanted to hear about at the time. A lot of the focus in sustainability then, and rightfully so, was on the environmental performance of buildings and energy consumption of active buildings.

But it stuck with me that there was this real crossover between structures and sustainability. A decade or so later, around the pandemic, I did another track at Buro Happold called C:lab. It's a research and development program where you're given hours to take off project work. I was one of about 10 participants in the C:lab U.S. chapter. Overall, the program is global community of people interested in exploring themes around the built environment outside their day-to-day work.

I used that program to dig into embodied carbon as a business and industry question—where are we going with it and what's our company's role? I got into the weeds of where the industry stands, how embodied carbon is measured, and how we should tackle embodied carbon. I unwittingly became a source of sustainability knowledge for our structural team. That was around when SE 2050 was founded, and Buro Happold happily signed up for it.

What has finding that role and niche meant for you professionally?

It plays right into the advice I give people early in their careers: it can really help to find your "thing." In other words, what do you do that no one on your team or in your firm is doing? You don't have to define yourself by it, but if you can identify something that sets you apart, you find yourself in meetings you wouldn't otherwise be in or be asked to opine on decisions. It can be a catalyst for career growth. I encourage our younger engineers to figure out a passion. You don't have to commit to it for your whole career, but find a thing that will help stimulate your growth.

How did you get involved in other AISC initiatives and ventures?

My relationship with AISC started a few years ago over lunch with (vice president) Brian Raff and (structural steel specialist) Jonathan Tavarez, who are involved in the AISC sustainability efforts. We went to lunch and I remember asking them how AISC can help facilitate more steel reuse as an alternative to recycling. It's a circular economy question. We have lots of steel in buildings that is fit for reuse in another project when that building is demolished or deconstructed. What are the barriers in the industry there, and what's AISC's role?

I asked that question, and Brian's response was inviting me to join the AISC think tank. For the last two or three years, I've explored industry innovation and how AISC adapts to industry trends. The more people you know in the organization, the more invitations you get, like with the IDEAS^2 Awards. I've always been fond of steel as a structural material. I think it's the purest material in structural behavior and how shapes are made.

What was your IDEAS^2 Award judging experience like?

I really enjoyed it. It was a cool opportunity to see what's out there in steel across the industry. As a professional, you're sometimes in a bubble with your firm's projects. I liked the chance to be impartial and give a high-level assessment of what's going on and what's innovative. I was the engineer on the panel, and it was neat to have lots of perspectives agreeing on the best innovations, design work, and construction.

What have you enjoyed about New York since moving there?

When you get used to its energy, it's hard to replace. My wife and I moved out of New York during the pandemic. We love nature and we took the opportunity to live somewhere more rural. We thought it would stick, but three years after leaving, we were mulling our next move and chose to go back to New York.

We live in Brooklyn, which I like because I want to escape Manhattan at the end of the day. The most important criterion when moving back was proximity to Prospect Park in Brooklyn. It's my happy place in New York. I run a lot, and it has a lot of trails. You can feel like you're out in the sticks if you find the right trails.

When people visit New York, I point them to Prospect Park. You can be in the middle of it and not see other buildings around you because of how it's landscaped. I also always recommend getting on a boat and experiencing the city by water.

But another part of it was my relationship with work. If you're in structural engineering and live in New York, many big architects and engineers have offices here. There's a lot more in-person activity, meetings, and evening events. I think I'm team-oriented, and I come into a real office space and work with our structural team of about 20 people. We're a tight-knit team, and that matters a lot when you spend so much time in each other's company. ■

This interview was excerpted from my conversation with Fraser. To hear more, listen to the July 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.*

Pass It Down

BY BAILEY LACKEY

Unrecorded tribal knowledge has sustained fabricator training and growth, but formalizing it before it's lost is crucial for the industry to stay strong.

IN THE STEEL FABRICATION INDUSTRY, skill, experience, and expertise are often passed down through informal channels such as mentorships, on-the-job training, and shared stories. That unrecorded, experience-based proficiency is often referred to as tribal knowledge, a traditional method that has long sustained the industry. But it is becoming increasingly fragile in the face of a rapidly aging workforce.

As seasoned fabricators approach retirement, the risk of losing invaluable information grows. The fabrication industry must take proactive steps to capture and formalize tribal knowledge to ensure it lives on, because it's essential to continuity, quality, and operational efficiency. And those steps start with individual shops.

Tribal knowledge encompasses practical insights, tips, techniques, and workarounds that experienced workers developed over decades. In steel fabrication, it could include how to best position a beam for welding to avoid distortion, subtle tricks for operating older machinery, or effective problem-solving techniques that are not taught in training manuals. While these practices often lead to better productivity and fewer mistakes, they are seldom documented, and effective methods for achieving a good outcome often vary from shop to shop. As a result, tribal knowledge exists within individuals rather than within institutional systems.

When key personnel retire or leave the company, their expertise is at risk of going with them. If it does leave, it creates a knowledge vacuum that newer employees, even if technically trained, may struggle to fill.

I have learned through discussions within the industry that many fabrication company leaders expect a significant percentage of skilled tradespeople to retire in the next five to ten years. It's not just a feeling. Data show an aging workforce that does not have an inflow of younger workers to keep pace with the rate of retirement. Additionally, younger workers tend to be more technologically adept but may lack the hands-on experience of their predecessors.

The workforce shift creates a dual challenge. Not only is tribal knowledge at risk of being lost, but the new generation of workers may also be operating in a completely different paradigm—digital, automated, and more process-driven. Bridging this gap is not just a matter of preserving knowledge; it is about translating knowledge into a form that can be used effectively by modern workers and applied to a modern and futuristic shop floor.

Find a Formalized Format

Formalizing tribal knowledge means capturing it in a structured, accessible format, such as work instructions, training manuals, videos, or digital knowledge bases.

Standardized processes ensure that every fabricator, regardless of experience, follows the same proven methods to reduce variability and increase product quality. New hires can be onboarded more quickly when documented procedures or work instructions are available. Structured learning paths also build confidence and reduce dependence on senior staff acting as a reference for the new employee. Documented best practices help enforce safety protocols and reduce the likelihood of accidents due to improper techniques. When knowledge resides in systems rather than individuals, organizations are less vulnerable to disruption when experienced employees retire or leave.

Capturing tribal knowledge is not a one-size-fits-all-shops endeavor. It requires thoughtful planning, active participation from experienced workers, and often a cultural shift within the organization. The following strategies, though, will likely help your efforts:

Interviews and knowledge mapping. Conduct structured interviews with senior fabricators to document their expertise. These interviews should focus not just on how things are done, but also why they are done that way. Knowledge mapping tools can help identify critical areas where expertise resides and visualize interdependencies within the workflow or management systems.

Mentorship programs with documentation. Pairing seasoned workers with less-experienced employees can facilitate direct knowledge transfer. To make it sustainable, mentorship should be paired with documentation efforts, encouraging mentors and mentees to co-create process guides during training that can supplement or help update current work instructions used throughout the company.

Intentional and robust mentorship programs can help your shop in many ways beyond tribal knowledge transfer. Creating successful mentorship pairings requires thoughtful evaluation of mentees and mentors. For some guidance on how to foster a strong mentorship program, read the "Building Your Future Leaders" column in the December 2023 issue at **modernsteel.com/archives**.

Workshops and knowledge-sharing sessions. Host internal workshops where employees are encouraged to share best practices. These can be recorded or transcribed and integrated into training materials. Recognizing and rewarding participation can help build a culture that values knowledge sharing.

Digital knowledge management systems. Investing in software platforms where employees can contribute, search, and update documentation to make knowledge easily accessible and updatable over time.

AISC also has a resource to help standardize and convey tribal knowledge: The Fabricator Education Training Program, a series of self-paced online classes that launched last year. It's designed to shorten the time needed to make new employees productive and immediately show them a promising career path in the industry. The program is the closest thing in the industry to a standardized, tangible training manual for all shops, and several experienced fabricators were involved in its development.

The Fabricator Education Training Program is free for all AISC full members and is available at **aisc.org/fabricator-training**. The "Workforce Development Win" article in the October 2024 issue shares more about how it was developed.

Potential Challenges

Capturing and formalizing tribal knowledge can encounter resistance. Longtime employees may be skeptical of documentation efforts or reluctant to change how they have always worked. They may also worry that sharing their knowledge could make them replaceable. Managers who face these hurdles should communicate the value of knowledge-sharing not as a means of replacing people, but as a crucial step in preserving the industry's legacy and building future resilience. Recognizing and rewarding contributions to documentation efforts can also incentivize participation.

Another challenge is ensuring that formalized knowledge remains relevant. Processes, technologies, and materials evolve, so documentation must be regularly reviewed and updated. Assigning ownership of various process documents and scheduling recurring updates can help keep them current. Updating formal material helps keep your company ahead and helps the employees feel an ownership of their processes.

By capturing and standardizing tribal knowledge, steel fabrication and erection companies can transform a potential knowledge gap crisis into a strategic advantage. When knowledge is centralized and accessible, teams can build upon it, identify opportunities for improvement, and adapt more easily to new challenges and technologies.

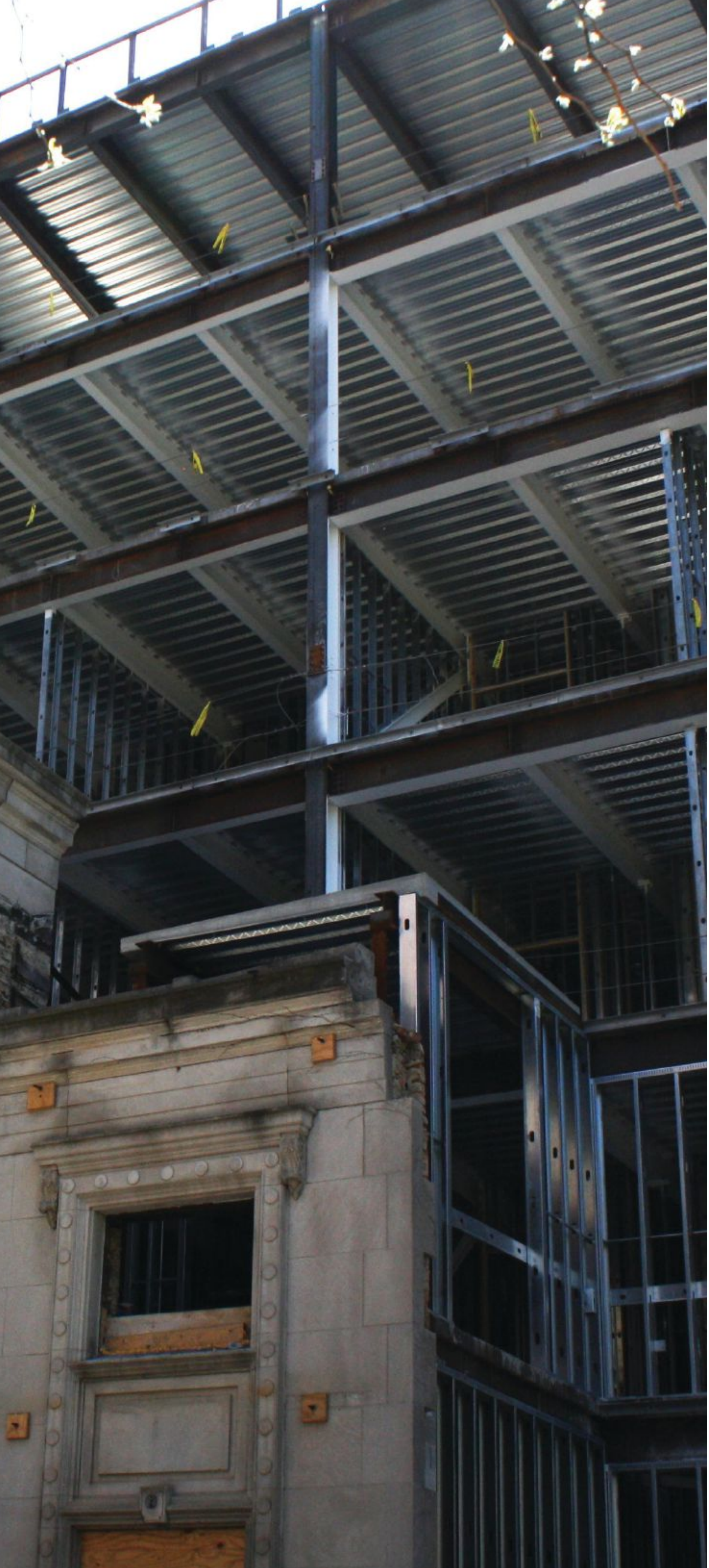
Most importantly, a deliberate knowledge-capturing effort tells older and younger generations in the workforce that every employee's knowledge is valued and that the company is committed to preserving and building upon the craftsmanship that defines the trade. Formalizing tribal knowledge is not about replacing people with manuals; it is about honoring decades of experience by making it accessible to the next generation.

Bailey Lackey (**bailey.lackey@trcfab.com**) is a quality assurance manager at TRC Fabrication.

Creative Conversion

BY MATT THOMAS, SE, PE,
JOE BURNS, SE, PE, FAIA,
AND EMMA BROWN

Steel provided a structural solution for the large forces and tricky load paths that came with converting a church into a residential building while preserving its historic exterior.



CREATIVITY THRIVES on constraints.

The most imaginative solutions often result from challenging situations where the usual methods won't work. In Chicago's Lincoln Park neighborhood, a much-needed housing stock expansion faces limitations from a lack of available land and the desire to maintain the area's historic fabric that makes it one of the city's most desirable residential locations.

One recent project in the neighborhood brought new apartments to the site of a 120-year-old church while providing a new worship space and keeping the church's original exterior. The unusual idea mandated creative bracing usage and created significant transfer and seismic forces—and steel delivered the most practical and cost-efficient solutions.

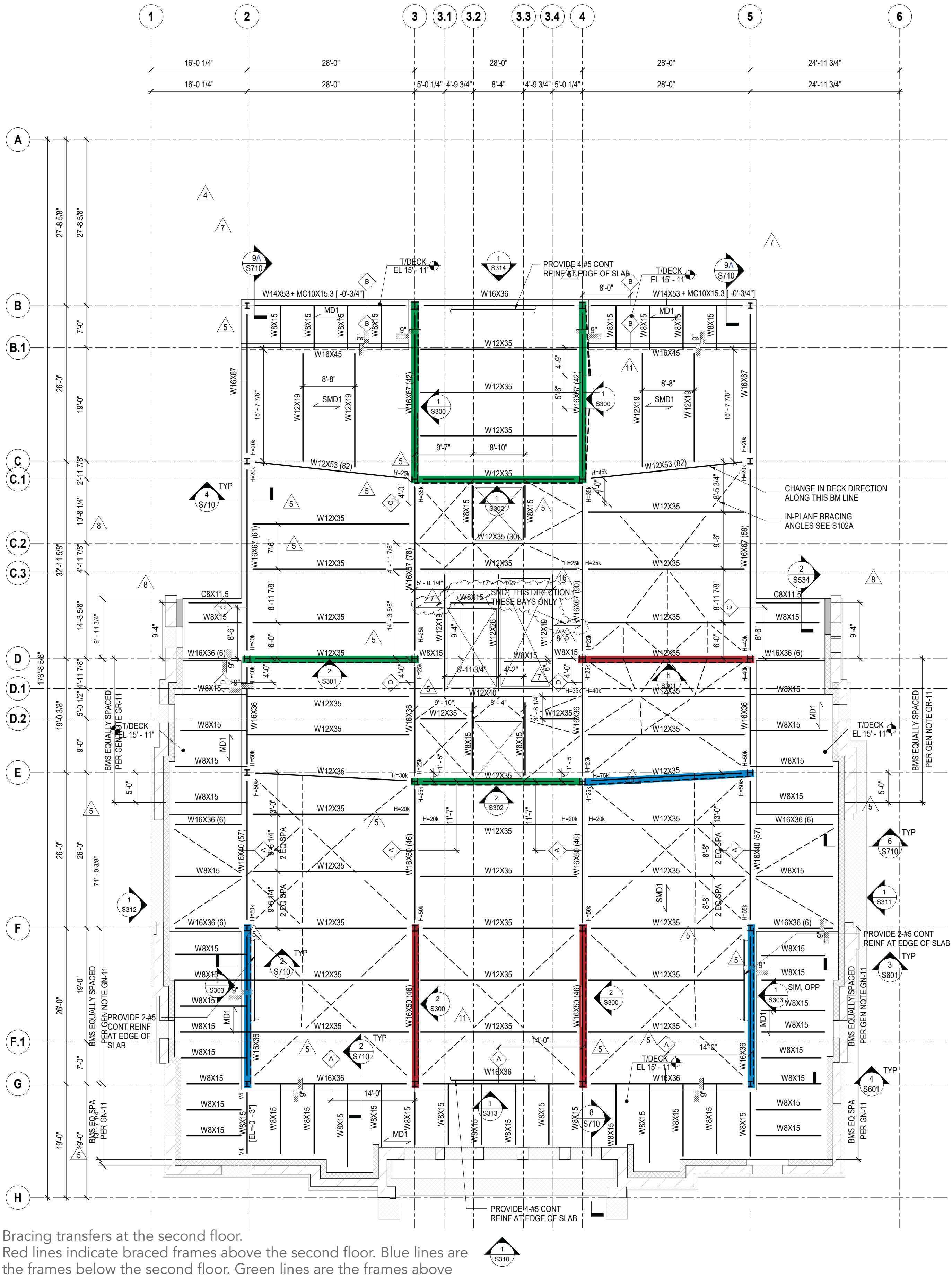
A Long History

The Second Church of Christ, Scientist, a stone's throw from Lake Michigan and the Lincoln Park Zoo, was built in 1901 and designed by Solon S. Beman in the Neoclassical style. Beman was a renowned architect who also designed Chicago's Grand Central Station, the Pullman railroad community in Chicago, and at least a dozen other Christian Science churches around the U.S.

When the church was constructed, it neighbored the mansions of Chicago's elite, including brewing magnates and department store owners, and served the community's needs for over 100 years. By the early 2020s, though, the congregation had dwindled. Its few dozen remaining members were facing substantial difficulties maintaining the aging building and were interested in selling to capitalize on the value of the land while maintaining worship space. Local preservation organizations worked to save the building but were unable to obtain public funding to purchase and restore it.

In came developer Ogden Partners and Booth Hansen Architects, who came up with a plan that would, at a stroke, keep three of the church's four limestone and granite exterior walls, provide a 4,700-sq.-ft modern worship space for the congregation, and create 22 new housing units spread across six floors. Thornton Tomasetti was brought in after the schematic design phase to provide a flexible structural design that could accommodate the numerous site and programmatic challenges.

The 120-year-old church exterior will surround 4,700 sq. ft of new worship space and 22 new apartments.



Bracing transfers at the second floor.
Red lines indicate braced frames above the second floor. Blue lines are the frames below the second floor. Green lines are the frames above and below. Dashed lines represent in-plane bracing.

Structural Challenges

The building's layout, with separate elevator and stair cores, would typically lend itself to concrete masonry unit (CMU) shear wall cores for the full building height. However, several issues pushed the team toward a hybrid steel-and-CMU system.

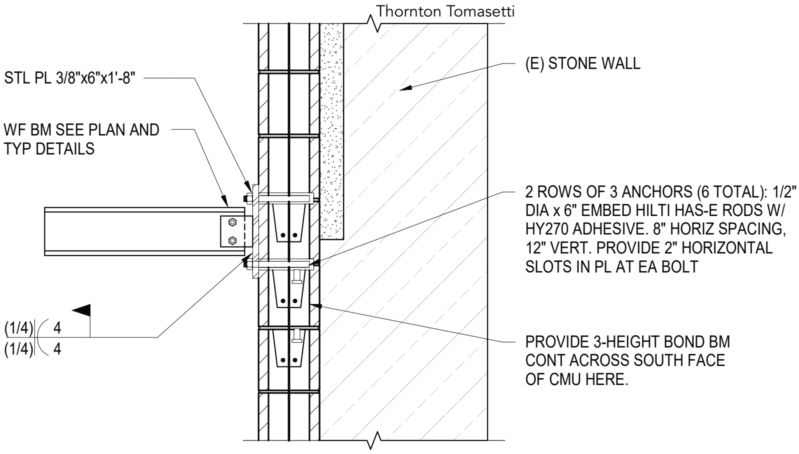
The congregation's need for worship space on the ground floor meant that few of the braces from the upper levels could continue all the way down to the foundation. Thornton Tomasetti developed steel concentric braced frame layouts for the upper residential floors, which were generally aligned with common walls between units. On the first floor, most of the bracing lines were shifted to respond to the different programming needs of the worship space.

Shifting the bracing resulted in substantial transfer forces within the second floor. Thornton Tomasetti ran analyses in two different structural analysis programs, along with hand checks, to ascertain proper distribution for lateral forces. Complicating matters, large seismic forces occur on the second floor due to the church's existing 17-in.-thick stone walls. Chicago's 2019 building code revision introduced a requirement for seismic forces for the first time in the city's history. While substantial seismic events are rare in the area, structures with heavier dead loads, such as this church's thick walls, will often have seismic forces govern their lateral design.

While the slab on metal deck diaphragm had substantial capacity, its strength was exceeded in several locations. The engineering team used in-plane bracing

The original church building.

The Newberry Library



above: Second-floor connection to the CMU wall allowing slip (in and out of page).

below: Elevation view of bracing.

Thornton Tomasetti

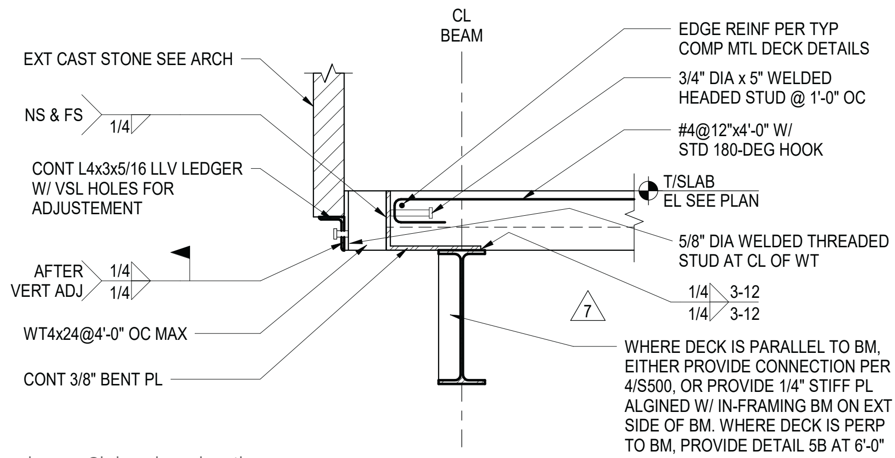
with steel angles just below the bottom of the slab on metal deck to directly transfer forces. The team ran several models in RISA-2D to optimize the bracing layout to minimize the forces on any one brace, simplifying connections. In addition, the team developed a detail which allowed the diaphragm to “slip” at the CMU wall along the south side of the floor; this was done to prevent a mismatch in stiffness between the CMU wall and the bracing attracting a disproportionate amount of force.

Gravity and lateral issues complicated confounded the design for the first-floor framing. Economic needs dictated the presence of a basement garage. The desire to avoid underpinning the existing foundation, coupled with a need to keep the first-floor elevation as low as possible, meant the structure needed to be relatively shallow, especially above drive aisles. On the upper floors, the framing grid followed a simple rectilinear layout, with 28-ft typical column bays in each direction, with a 2-in. composite metal deck topped by 3¼ in. of lightweight concrete.

The slab on metal deck spanned a maximum of 10 ft between W12×35 beams (A992 grade, typical for all WF shapes), which were framed to girders ranging from W16×36 to W16×100, the heavier sizes being utilized on the exterior to maintain strict masonry deflection requirements. The 16-in. girders were generally kept buried in interior or exterior walls, allowing the 12-in. beams to provide greater ceiling heights in the living spaces. All told, the project had 400 tons of steel.

At the first floor, however, the heavier live and superimposed dead loads associated with the worship space complicated the framing strategy. Using the same framing would result in a deeper system than desired for the garage space below. A previous design had considered using a cast-in-place, two-way concrete slab with drop panels, but mixing steel and concrete systems was determined to be inefficient from a cost standpoint.

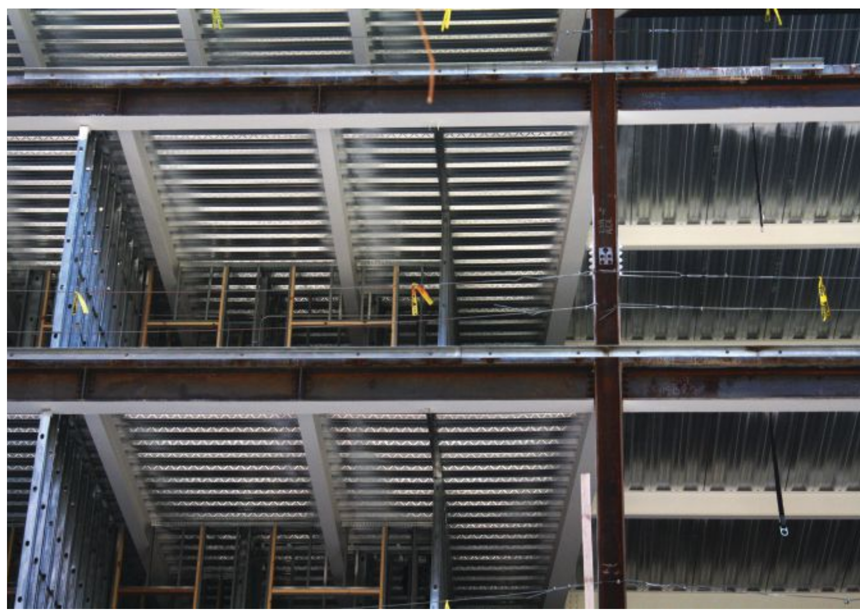
A deep deck system solved the problem. The COMSLAB 8-in. composite deck with a 4½-in. topping could span the full 28-ft bay width while supporting the applied loads. Beams parallel to the deck span, required for column bracing and lateral load distribution, were limited to 12 in. deep and recessed into the deck, creating a system with a total depth of 16½ in. On column lines supporting the deck, 16-in. beams were used because they were mostly buried in walls or over portions of parking spaces that could accommodate lower head heights.

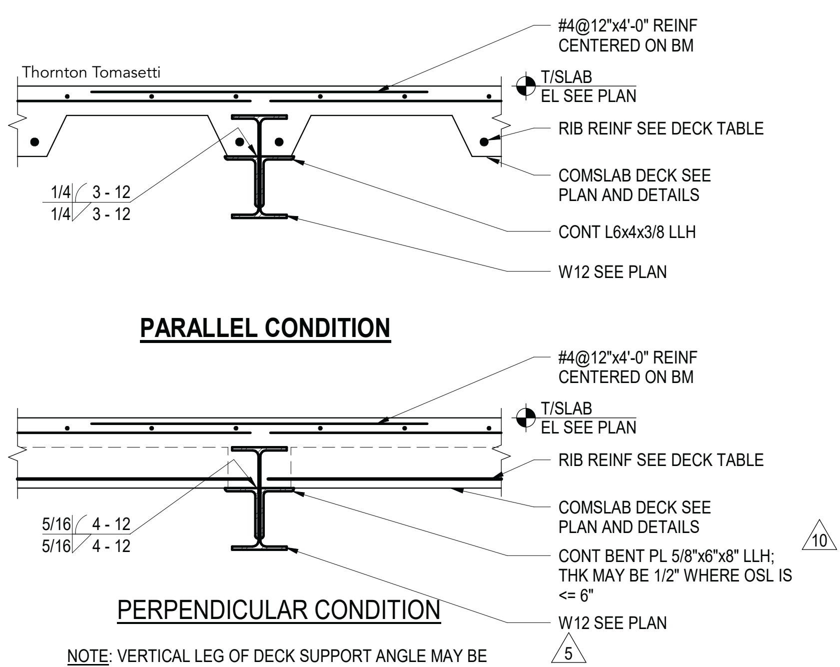


above: Slab edge detail.

below: Upper floors have 28-ft column bays in each direction.

Thornton Tomasetti





First-floor COMSLAB detail for the 28-ft span.

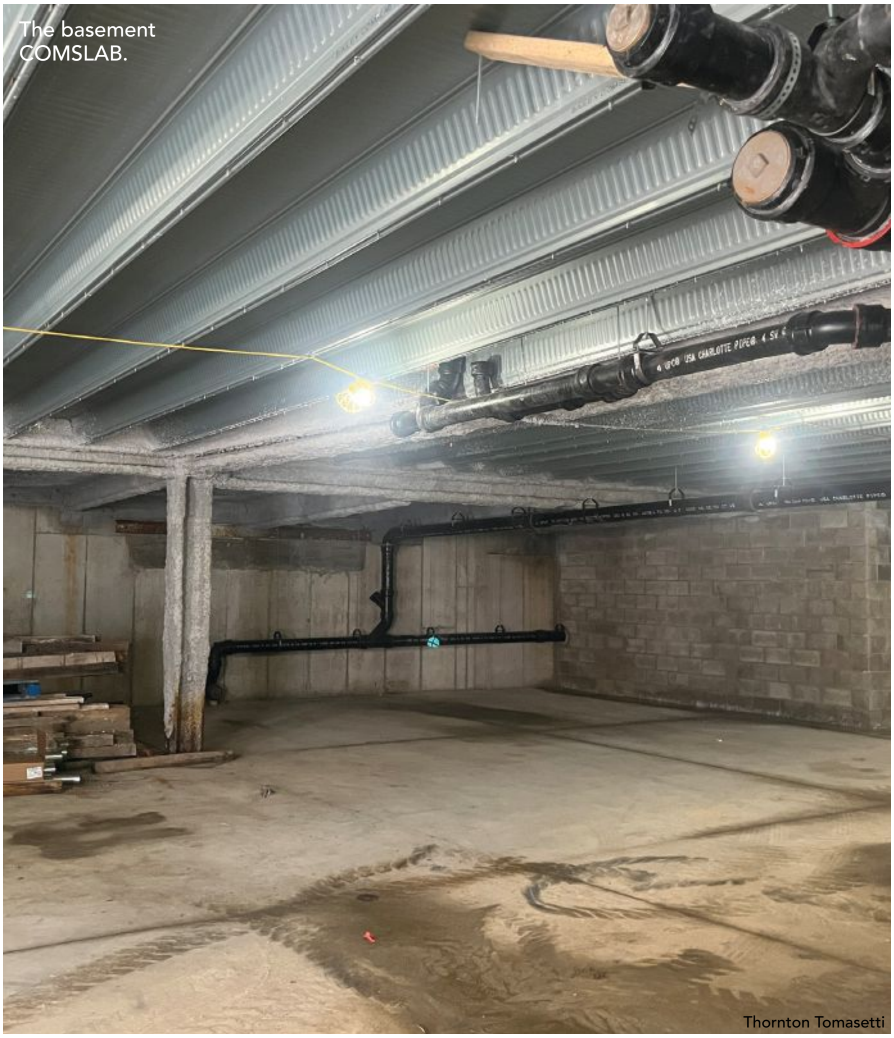
The in-plane bracing at the second floor.

Thornton Tomasetti

Three of the church's limestone and granite exterior walls are intact.

As with the second-floor framing, lateral transfers were required on the first floor. In this instance, only one braced frame continued to the foundation, and the remainder of the lateral load was handled by CMU walls, which occur around the perimeter of the building and were used as backup for the existing stone wall. Due to the thicker topping slab above the COMSLAB deck, the concrete slab could serve as the lateral load transfer mechanism and did not require in-plane bracing.

The exterior cladding consists of a stone system relieved at each floor. Increased energy requirements in the modern code required continuous insulation approximately 4 in. thick outside the slab. To accommodate the insulation, Thornton Tomasetti developed a detail using a WT4×24 section welded at intervals to the deck edge plate with a welded, threaded stud sticking out. The stud allowed for vertical adjustment of the shelf angle, which was later welded to the WT for the permanent condition.



The basement COMSLAB.

Thornton Tomasetti

A rendering of the completed building.

Booth Hansen Architects

A Neighborhood Boost

Work on the project began in summer 2023, and completion is expected later in 2025. The new building will include below-grade parking, a fitness center, a rooftop deck, and bike storage facilities.

Worship-to-residential conversions are a small part of the overall construction market and are not without their challenges. But they're a creative way to add housing while giving new life to neighborhood landmarks—and in larger cities like Chicago with an abundance of historic building stock, they are sure to become more common in the years to come. ■

Owner
Ogden Partners

Architect
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New and Improved

BY RICH SCHOEDEL, PE, AND KEITH YODER, PE

The emergency replacement of a damaged northwest Pennsylvania steel bridge resulted in a safer and sleeker crossing that better fits the area's needs.

A STEEL DESIGN provided the necessary quick fix to a damaged bridge over an interstate highway in northwest Pennsylvania, creating a more efficient crossing and improving adjacent roads.

The State Route 318 bridge over I-376 near West Middlesex, Pa., carries approximately 3,000 vehicles daily and is ½ mi south of the I-376 and I-80 interchange in Mercer County. It has adjacent on- and off-ramps for I-376 and is the main interstate access point for a major trucking company's distribution center. The crucial bridge and interchange closed when an over-height truck boom struck the span over eastbound I-376 on December 7, 2023 and inflicted substantial damage.

The Pennsylvania Department of Transportation (PennDOT) opted to replace the entire bridge, and a cohesive emergency response delivered a new and improved bridge that opened to traffic in September 2024. The new steel bridge wasn't just a replacement. It also brought safer clearances to avoid over-height collisions, material that's reparable if one occurs, a widened road, and new on and off ramps better equipped to handle the frequent truck traffic in the area.

Right to Work

An inspection shortly after the crash revealed damage to three beams and a hole in the bridge deck, and for under-bridge traffic safety, the damaged span needed to be removed, forcing I-376 to close temporarily. Damaged span removal began almost immediately, and I-376 was reopened less than 33 hours after the strike.

Early alternative assessments concluded that complete structure replacement was prudent to correct the structure's substandard vertical clearance. PennDOT contacted bridge engineer Michael Baker International the same day as the incident to begin designing the replacement.

Expedited design is an important early piece of emergency bridge repairs and replacements. By the time the formal project planning scoping field view and bridge Pro-Team meetings occurred on December 21, 2023, numerous vertical profiles had already been analyzed and coordinated with the emerging structure design. Five bridge alternatives were prepared and evaluated for relative cost, schedule, right-of-way, environmental, and utility impacts. The design criteria submission; preliminary type, size, and location plans; and a decision matrix summarizing impacts and costs were prepared for on-site consideration. Because of that preparedness, the team selected a preferred bridge type on the spot.

The choice was a two-span steel structure with seven Grade 50 steel girders totaling 248 tons. Each span is 102 ft long, and the two-span structure halved the number of spans in the prior bridge.

Delivering the bridge was a testament to the power of collaboration and engineering excellence. That effort included collaboration with internal services from PennDOT for surveying, borings, and environmental permitting, as well as prioritizing timely reviews. Special project and safety review meetings were held on-demand to accelerate decision-making, eliminate surprises, and minimize comments when formal submissions were made.

"It took an immense amount of collaboration from our PennDOT staff and our consultant team to deliver the design in less than three months," said PennDOT district executive Brian McNulty, PE. "That partnership approach continued into the construction phase, allowing us to open the bridge a month earlier than expected, just over nine months after the crash."

Michael Baker provided bridge engineering, roadway design, and construction consultation services, with Markosky Engineering Group providing drainage design, traffic control, signing and pavement marking, and erosion and sedimentation control plans.

The new 248-ton State Route 318 steel bridge reopened to traffic nine months after an over-height truck idamaged its predecessor.

PennDOT

The damaged concrete girders before their removal.

PennDOT

A committed team of dedicated engineers with accelerated project delivery experience was instrumental.

Michael Baker and PennDOT engaged fabricator High Steel Structures early in the process, and High Steel suggested material specifications, sizes, details, and coatings with the shortest lead time. Michael Baker integrated the suggestions into its design in real time. Shop drawing production, review, and approval were done collaboratively with Michael Baker in a few days, not weeks.

"Michael Baker's willingness to ask fabrication and material-related questions during their design effort was paramount, said Tom Wandzilak, High Steel business development manager. "And fortunately, MBI knew exactly what questions to ask."

Mekis Construction Corporation won the construction contract on March 14, 2024, and notice to proceed with construction was issued April 9. The bridge and roadways reopened to traffic by September 20. All original contract work was completed by November 4. The project was funded through 20% state and 80% federal funds, most of which were federal emergency relief funds.

Steel Selection

The design team's top priority was reopening the bridge by fall 2024. A prestressed concrete bridge is often considered in short turnaround projects, but in this instance, it would have required deeper beams and a raised profile grade. Those items would have increased roadway reconstruction and caused greater impacts, particularly to right-of-way which would significantly delay the project. The existing structure consisted of 33-in.-deep concrete box beams, an 8-in. deck, and a 3-in. wearing surface. With haunch, this resulted in an approximately 48-in.-deep superstructure.

The steel replacement structure was only 36 in. deep, minimizing the overall profile grade adjustment. Further impacts to the profile grade would have meant costly impacts to right-of-way, wetlands, and utilities, plus extending the schedule. The steel design minimized the number of plate sizes and transitions; only two different thicknesses were used for the entire bridge to expedite fabrication. The design also had rolled sections for the diaphragms, allowing for accelerated procurement approval of shop drawings and steel fabrication.

Meeting a tight construction schedule began with a straightforward bridge design involving a girder with no flange transitions and in-stock material sizes to expedite procurement of fabricated steel. The integral abutments were designed with identical geometry, expediting the detailing of abutment reinforcing.

The engineer's bid estimate was \$5.39 million, which was within 5% of Mekis Construction's \$5.145 million projection. The total project—including emergency demolition, design, construction, and construction engineering—was approximately \$6.5 million, consistent with the initial programming estimates.

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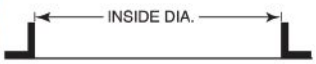
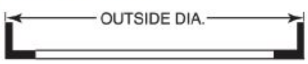


10" x 10" x 1" Angle

2 Angle Leg In

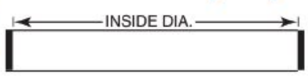


10" x 10" x 1" Angle

3 Flat Bar The Hard Way

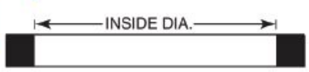
24" x 12" Flat

4 Flat Bar The Easy Way



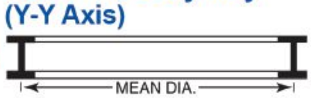
36" x 12" Flat

5 Square Bar



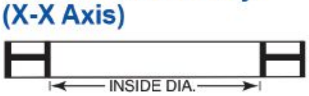
18" Square

6 Beam The Easy Way (Y-Y Axis)



44" x 335#, 36" x 925#

7 Beam The Hard Way (X-X Axis)



44" x 285#

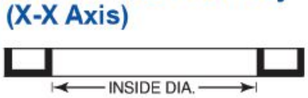
8 Channel Flanges In

All Sizes

9 Channel Flanges Out

All Sizes

10 Channel The Hard Way (X-X Axis)



All Sizes

11 Tee Stem In

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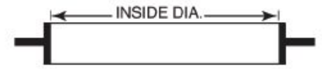
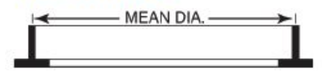
12 Tee Stem Out



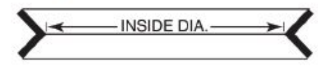
22" x 142 1/2# Tee

13 Tee Stem Up



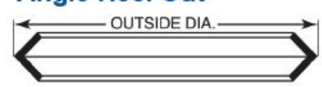
22" x 142 1/2# Tee

14 Angle Heel In



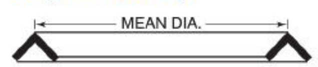
8" x 8" x 1" Angle

15 Angle Heel Out



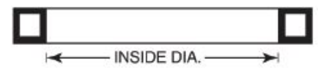
8" x 8" x 1" Angle

16 Angle Heel Up



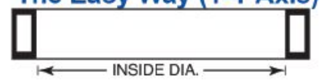
8" x 8"x1" Angle

17 Square Tube



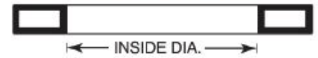
24" x 1/2" Tube

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



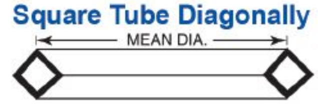
20" x 12" x 5/8" Tube

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



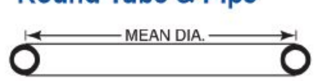
20" x 12" x 5/8" Tube

20 Square Tube Diagonally



12" x 5/8" Square Tube

21 Round Tube & Pipe



24" Sched. 80 Pipe

22 Round Bar

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The new steel bridge is 36 in. deep, 12 in. less than the prior bridge.

Michael Baker

Each bridge span is 102 ft long.

The slender two-span structure created an open view for motorists traveling on I-376. The original beam span-to-depth ratio was approximately 18, compared to 34 for the replacement.

Several sustainable features were incorporated into the replacement structure, including:

Fewer bridge expansion joints. Traditional expansion joints tend to fail and leak onto the ends of beams, causing maintenance issues and deterioration. The team opted to use only two joints located off the bridge at the ends of the approach slabs, reduced from five in the original structure.

The right material. Steel structures are resilient and easily accommodate future rehabilitation. As a premium green material, structural steel plate produced in the U.S. consists of recycled steel content above 80% on average and is 100% recyclable. At the end of a structure's life, 98% of all structural steel is recycled into new products. Structural steel is multi-cycled and can be recycled or reused many times over.

Integral abutments. Integral abutments are the default abutment choice in the region and the state. These abutments eliminate on-structure joints and bearings, which are significant maintenance problem areas. Owing to their flexibility, integral abutments accommodate the movement of the superstructure and have an excellent record of performance, requiring little or no maintenance.

Rock armored slopes. The embankments leading up to the integral abutments were armored against the possibility of erosion by constructing stone slopes. In places where bridges obscure light, promoting vegetation growth may be impractical and lead to erosion and drainage problems. Rock slopes protect against erosion and contribute to the site's finished look.

Reinforced cement concrete pavement. The choice of reinforced cement concrete pavement base minimizes cracking, increases longevity, and reduces maintenance. At the end of the roadway's life, the concrete can be excavated, crushed, and repurposed as aggregate. The reinforcing steel is also recyclable.

The old spans over I-376 exhibited sub-standard vertical clearance with a history of bridge strikes. After the accident, PennDOT increased the vertical clearance to meet the required 16-ft, 6-in. vertical clearance for interstate structures. The final vertical clearances were 16 ft, 10 in. over the westbound lanes and 17 ft, 1 in. over the eastbound lanes. If another strike occurs, the continuous steel structure is repairable even after the most severe collisions.

The existing structure had three piers within the clear zone of I-376, two of which were within a few feet of the shoulder edge and had sub-standard concrete barriers. The replacement structure eliminated the two end piers, reducing the number of fixed objects within the clear zone and improving safety on the interstate. The replacement pier in the median is also narrower, contributing to the bridge's openness. Unobstructed views improve safety as motorists can more easily spot hazards and merging traffic.

The bridge has an integral abutment, which eliminated on-structure joints and bearings.


Michael Baker

Construction Complexities

Successful project completion required abiding by several constraints, increasing the vertical clearance, widening the SR 318 shoulders to achieve safety requirements, avoiding impacts to right-of-way, minimizing utility impacts, protecting environmentally sensitive features, and employing streamlined design procedures to meet the schedule.

The bridge's construction could not disturb the nearby bioretention facility and had to maximize the availability of a nearby PennDOT Park and Ride lot. The ramps are the main highway access point for major stakeholder Estes Express Lines trucking, meaning maintained access to the I-376 ramps through phasing and traffic control was crucial. A mild winter helped field surveying, drilling, and environmental wetland delineation be completed quickly.

During construction, partial-season six-day work weeks ensured the eastbound on- and off-ramps were opened before the new school year to accommodate a nearby school district's bus routes. A phased roadway reconstruction approach on the western approach allowed trucks to cross the new bridge while the westbound on-ramp was reconstructed.

The design and construction team united to meet a tight emergency repair deadline, but it did more than simply replace a bridge. It created a new highway overpass and ramps that better serve the area and should stand strong for decades.

Owner
Pennsylvania Department of Transportation

General Contractor
Mekis Construction

Bridge Engineer
Michael Baker International

Fabricator and Detailer
High Steel Structures AISC CERTIFIED FABRICATOR

Rich Schoedel (rschoedel@mbakerintl.com) is an associate vice president and Great Lakes regional technical manager, and **Keith Yoder** (kyoder@mbakerintl.com) is a senior bridge engineer and project manager, both at Michael Baker International.

These nine reasons made a galvanized steel truss bridge the best solution for a rural Ohio creek crossing, and they're likely applicable for your next local road project.

Go for Galvanized Trusses

BY PAUL HUELSKAMP, PE

A GALVANIZED STEEL TRUSS BRIDGE is a forward-thinking solution for local road infrastructure, especially in non-urban areas. Its combination of durability, cost-effectiveness, and adaptability makes it an ideal choice for communities seeking reliable and long-lasting bridges—qualities that drove its selection to replace a bridge in Miami County, Ohio, over Greenville Creek, a designated State Scenic River. Galvanized steel's protective properties ensure bridges can withstand changing weather conditions and heavy traffic, and its aesthetic appeal and sustainability contribute to the overall quality of life.

The bridge in Miami County near Bradford, Ohio, carries Croft Mill Road over the creek and replaced a 107-ft single-span steel structure originally built in 1928. The new 100-ton single-span bridge is 121 ft, 6 in. long and 28 ft wide, nearly double its predecessor's 15-ft, 6-in. width. The truss members are W14s made of ASTM A572 Grade 50 steel, and the bridge also uses W10×45 stringers and W27×146 floor beams. AISC full member U.S. Bridge fabricated the steel.

A concrete bridge with prestressed box beams was considered, but manufacturing limits at the time of construction eliminated that option. The depth of concrete beams required for a single-span bridge would have affected the structure's waterway adequacy. The steel truss solution allowed for a single-span crossing that maintained the existing waterway opening, and the galvanized members gave the bridge corrosion protection that can last up to 100 years.

As local governments and municipalities look to improve transportation networks, galvanized steel truss bridges offer a practical and efficient way to enhance connectivity and accessibility. By investing in these bridges, communities can create infrastructure that not only meets present-day needs, but also prepares for future

A new 121-ft, 6-in. galvanized steel truss bridge improved a State Scenic River crossing in rural Ohio.

All photos courtesy of Miami County

demands. The following galvanized steel truss benefits were part of Miami County's decision and explain why a galvanized steel truss bridge is often appealing for other local road projects.

1 Aesthetic Appeal

While functionality is paramount in bridge design, aesthetics also play a role in enhancing the visual appeal of local road networks. The existing 1928 steel truss bridge carrying Croft Mill Road sported a similar profile and look to the chosen replacement, and the desire to maintain the overall travel and scenic experience of the site was considered in the selection. Galvanized steel truss bridges offer a sleek and interesting appearance that complements various settings. Their clean lines and geometric patterns add an element of quaintness to the landscape, whether in rural areas or urban environments. The silver finish of galvanized steel enhances the aesthetic value, contributing to the overall charm of the community.

2 Corrosion Resistance

One of the most significant benefits of using galvanized steel is its superior resistance to corrosion. Galvanization involves coating steel with a layer of zinc, which protects it from the effects of moisture, oxygen, and other environmental factors that cause rust. Durability is particularly important for bridges in four-season climates like Ohio that are exposed to varying environmental conditions, including rain, snow, humidity and deicing agents. The galvanization process extends the lifespan of steel truss bridges by preventing rust and degradation, making them an excellent choice for local roads that need long-lasting infrastructure.


The old crossing over Greenville Creek.


Galvanized steel trusses are often an aesthetics boost or complement.


Low maintenance requirements are helpful for rural bridges that are crucial traffic routes.

3 Low Maintenance Requirements

Galvanized steel truss bridges require minimal maintenance compared to other bridge types. The protective zinc coating ensures the steel remains intact without frequent repairs or repainting, reducing maintenance costs over time and freeing up resources for other infrastructure projects. The Croft Mill site also benefits from the low upkeep requirements by increasing the time between maintenance events and allowing the natural features to dominate the area—plus minimizing the need to introduce potentially hazardous maintenance materials to the site.

4 Cost-Effectiveness

For local road projects operating within tight budgets, galvanized steel truss bridges provide a cost-effective solution that balances upfront costs with long-term savings. While the initial investment in galvanized steel truss bridges may be higher than in other materials, the long-term cost savings are substantial. Their durability and low maintenance requirements contribute to reduced life cycle costs. Truss designs' inherent structural efficiency also helped minimize construction costs.

5 Strength and Stability

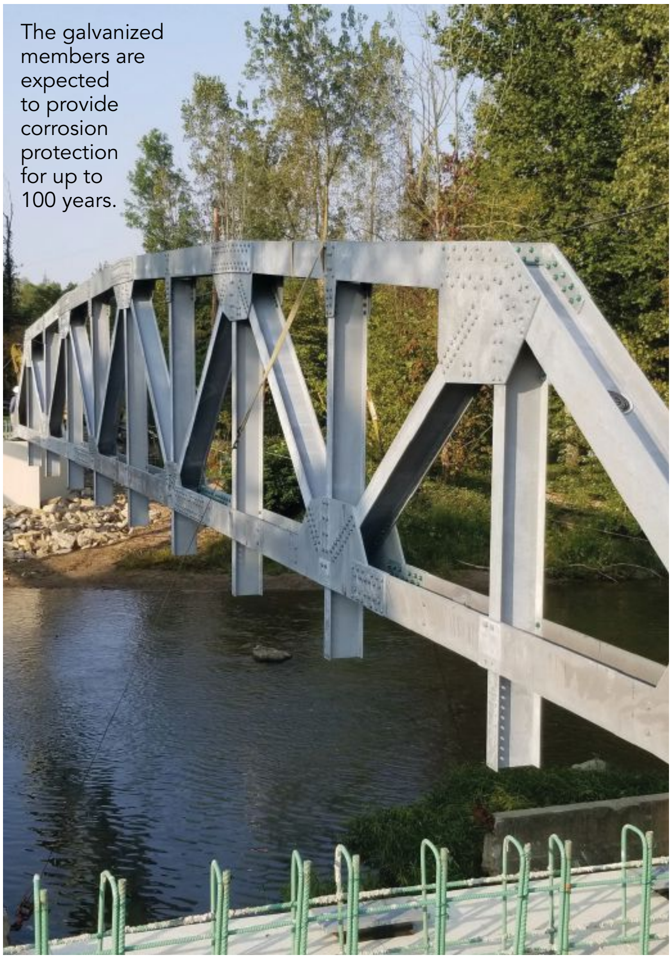
Steel truss bridges are inherently strong due to their triangular geometry, which evenly distributes weight and forces across the structure. When combined with galvanized steel, this strength is further enhanced. These bridges can support heavy loads, including vehicles and trucks commonly found on local roads, without compromising safety. Their ability to handle dynamic loads makes them suitable for varying traffic conditions, ensuring reliable performance over time.

6 Adaptability to Local Environments

Local roads often traverse through diverse terrains and environments, requiring bridges that can be adapted to different conditions. Galvanized steel truss bridges are highly versatile and can be customized to fit specific requirements. Because Greenville Creek is designated as a State Scenic River, it was important to design a crossing without piers while maintaining sufficient waterway opening.

Other alternatives that were explored reduced the waterway opening by extending significantly below the highway surface or required installation of a pier to reduce member depth. The truss bridge design allowed the Greenville Creek crossing to be made in a single span without decreasing the waterway cross section, ensuring it would seamlessly integrate into the local road network.

Galvanized steel adds to the trusses' strength.



The galvanized members are expected to provide corrosion protection for up to 100 years.

7 Sustainability and Environmental Benefits

Sustainability is becoming a key consideration in infrastructure development, and galvanized steel truss bridges align with it. Steel is a recyclable material, and the galvanization process does not diminish its recyclability. At the end of their lifespan, these bridges can be dismantled and repurposed, reducing waste and conserving resources. Additionally, the long lifespan of galvanized steel truss bridges minimizes the environmental impact associated with frequent replacements, making them a sustainable choice for local roads.

8 Ease of Construction and Installation

The modular nature of truss design simplified the construction process, allowing for prefabrication and on-site assembly. Galvanized steel components were manufactured off-site and transported to the construction location, reducing disruptions to the surrounding area. This method accelerated the building process, ensuring that the bridge was completed efficiently. For the Croft Mill project, efficiency meant faster implementation and less inconvenience for residents and commuters. Construction in the field took about four months, and the trusses were fabricated in eight weeks.

above: Galvanized trusses are long enough to avoid piers in smaller rivers.

left: The Croft Mill Road bridge truss members are W14s made of ASTM A572 Grade 50 steel.

9 Safety and Reliability

Safety is a top priority in bridge design, and galvanized steel truss bridges excel in it. Their robust construction ensures they can withstand natural disasters such as floods and earthquakes. The galvanized steel coating further enhances their reliability by preventing structural weaknesses caused by corrosion. Regular inspections and maintenance programs can ensure that these bridges continue to provide safe passage for vehicles and pedestrians, promoting confidence in local infrastructure.

Widely Applicable

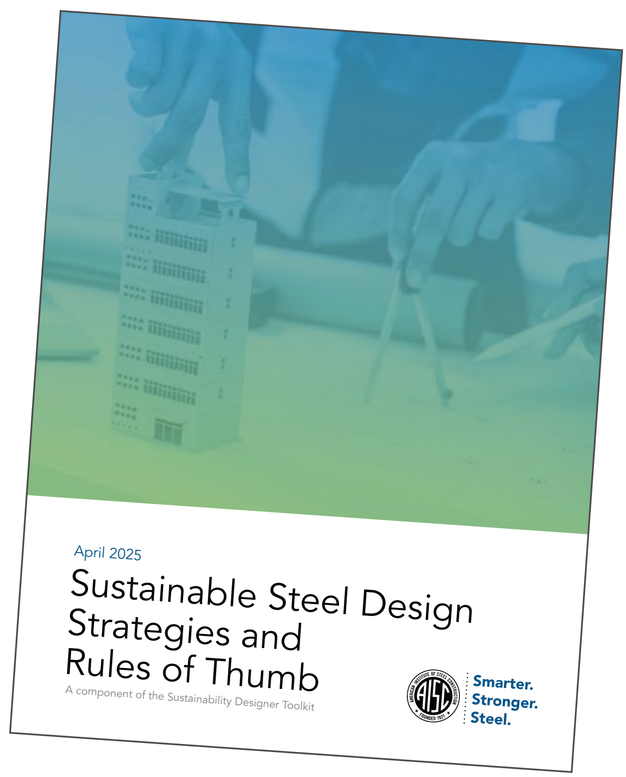
Local road networks and the bridges that carry them form the backbone of transportation infrastructure, connecting communities and enabling the movement of people and goods. Overcoming natural obstacles, providing adequate waterway openings, and minimizing environmental impacts all come into play when designing and constructing bridges for local roads, and a galvanized steel bridge solution will usually align with those considerations. ■

above and left: Construction in the field for the Croft Mill Road bridge took about four months, and trusses were fabricated in eight weeks.

Paul Huelskamp (**phuelskamp@miamicountyohio.gov**) is the county engineer for Miami County, Ohio.

Sustainability Strategies

Optimize the sustainability performance of a structure by following these design strategies and rules of thumb.



SUSTAINABLE STEEL DESIGN is a broad concept with many considerations. AISC's newest sustainability resource, *Sustainable Steel Design Strategies and Rules of Thumb*, walks designers through many important ones. It was developed in accordance with the Structural Engineering Institute's SE 2050 Design Guidance for Reducing Embodied Carbon in Structural Systems and is one component of the AISC Sustainability Designer Toolkit.

Along with other toolkit components, this document provides practical information to leverage structural steel for reducing embodied carbon. All toolkit components are available at **aisc.org/sustainability-toolbox**.

These strategies are presented from the perspective of optimizing a structure's sustainability performance. Many other factors not included affect a building's design. Additionally, different strategies will or will not be applicable depending on project goals (i.e. standardized shapes for future deconstruction and reuse vs. material reduction and optimization).

In partnership with AEC industry leaders, AISC expects to publish a sustainability design guide in early 2026. The strategies presented here will complement the information in the design guide. Read on for the full *Sustainable Steel Design Strategies and Rules of Thumb* contents.

The First Question: Do You Really Need a New Structure?

The greenest building is the one you don't have to build at all.

Designers can have an instinctive tendency to demolish and build anew when a structure's program changes, but that may not actually be necessary.

- Evaluate the project goals and engage in an open dialogue about the structure's capabilities with respect to the proposed design program. Be sure to look for opportunities to minimize the size of any new building addition where appropriate.
- Use the Carbon Avoided Retrofit Estimator (CARE) Tool (found at **www.caretool.org**) to compare the total carbon impacts of renovating an existing building vs. replacing it with a new one.
- If time and budget permit, use material probing to discover the real in-situ material ASTM grades. The more you know about an existing building's structural materials, the more efficiently you can work with them. For instance, designers may opt to assume that an existing structure has 36-ksi material to avoid running tests to confirm 50-ksi material—but they may end up adding more new material as a result.
- Note that the *International Existing Building Code* requires more significant retrofits beyond certain thresholds. Strategic programming can minimize this.

Structural steel lends itself particularly well to adaptive reuse because designers don't have to work around load-bearing walls. AISC has several additional resources for existing and historic steel, including:

- Design Guide 15: *Rehabilitation and Retrofit* (**aisc.org/dg**)
- Design Guide 16: *Assessment and Repair of Structural Steel in Existing Buildings* (**aisc.org/dg**)
- Appendix 5 in the AISC *Specification for Structural Steel Buildings* (AISC 360) (**aisc.org/specifications**).

Your Secret Weapon: Early Fabricator Involvement

Think of steel fabricators as the ultimate efficiency consultants. They can help you reduce material—and ensure that you're working with steel products they can readily source.

Bringing a local steel fabricator to the table early (immediately after bidding, if not during) will save you time and money while helping you cut the carbon footprint of your structural system.

Here's an example: Your design may use 42-ft bay spacing. A fabricator may immediately realize that the members you're using have a standard length of 40 ft. They can work with you to optimize your design and reduce waste.

Or perhaps you've designed with lighter members to reduce embodied carbon—but that will require more time- and labor-intensive stiffening and connections. A fabricator can help you make an informed decision.

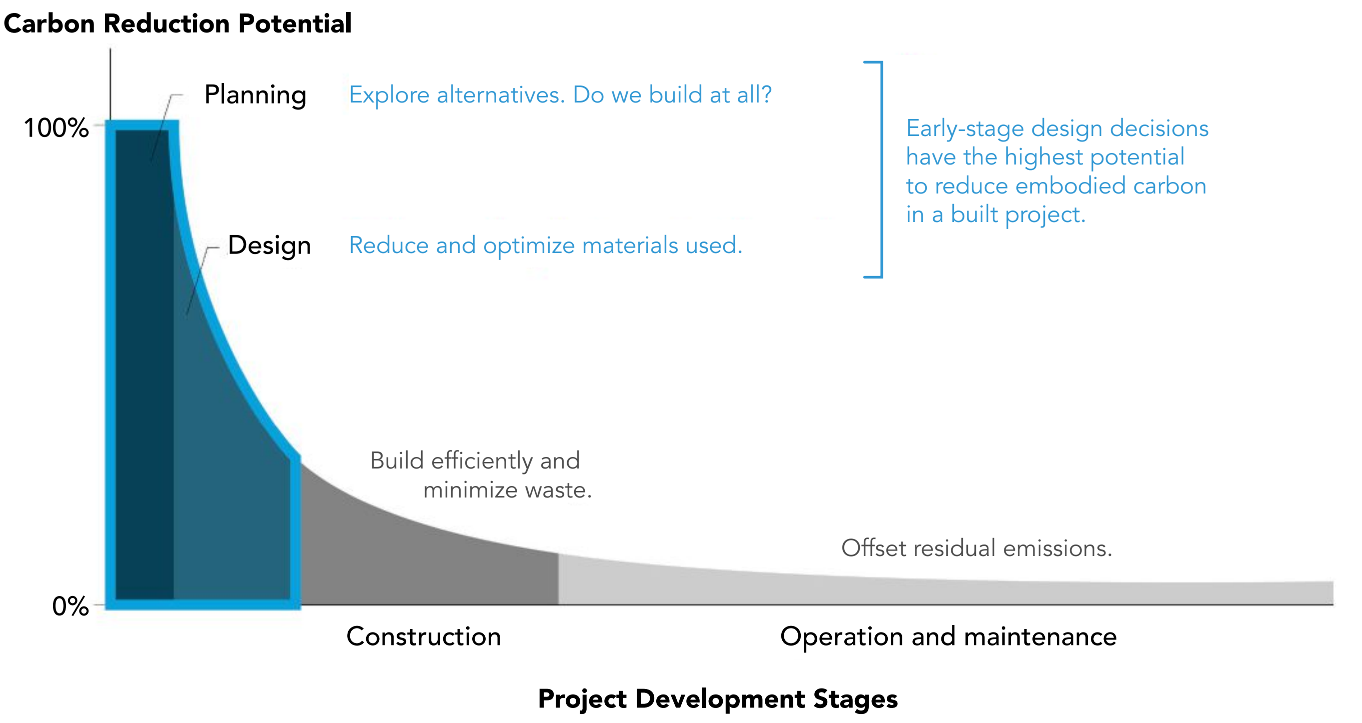
Some fabricators may already have extra material on hand that they can use instead of ordering new material from a mill.

AISC's online steel shape reference (available at **aisc.org/steelavailability**) will help you identify readily available shapes that could allow you to take advantage of uniformity and repeatability in fabrication, which cuts down on environmental impacts from fabrication and erection. Learn more about the benefits of early fabricator involvement at **aisc.org/fabricator-collaboration**.

It is critical to evaluate and address structural embodied carbon during the early stages of design, where the most significant opportunity for reduction exists.

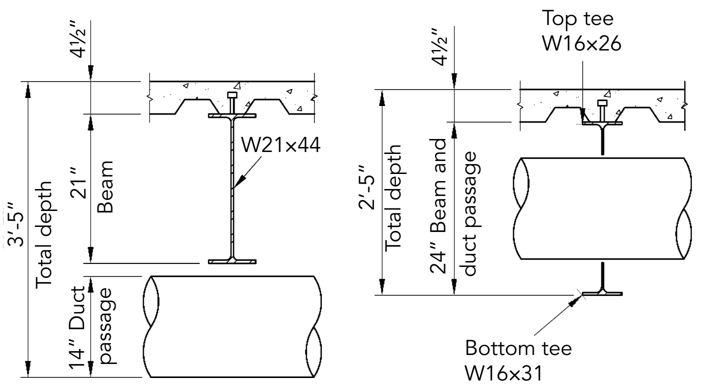
courtesy of the SE 2050 Commitment Program

Adapted from: Bringing embodied carbon upfront, World Green Building Council 2019.



above: The use of castellated beams in the Watershed Building helped it meet programming and sustainability goals. Learn more at **aisc.org/watershed-2021**.

below: Open web structures can reduce height per floor by several inches, an excerpt from Design Guide 31: *Castellated and Cellular Beam Design*.



High-Strength Material

Simply put: You can use less material to achieve the same performance if you choose a higher-strength steel. This is ideal for strength-controlled members like columns.

Reducing the amount of material in your structure offers compounding benefits; for instance, a lighter structure requires a more streamlined foundation, which itself uses reduced materials. A913 Grade 65 (65 ksi) is widely produced domestically and is particularly well-suited to large columns and belt trusses. Steel grade has a negligible impact on the GWP for structural steel.

The AISC online steel shape reference can help you find a high-strength steel supplier.

Castellated or Cellular Beams For Long Spans

A fabricator can add substantial value to a traditional steel beam by simply splitting it into two halves and staggering the two halves before welding it back together. Beams with hexagonal holes are referred to as castellated beams, and beams with circular holes are referred to as cellular beams.

The resulting castellated or cellular beam is approximately 40% stronger due to the increased depth, but has the same weight per foot as the original un-split section. The beam's signature web openings (and the related 50% increase in depth) provide easy access for MEP systems to run through the beams instead of below them.

Castellation was patented until 2009; any fabricator can now offer castellated beams. For more, see Design Guide 31: *Castellated and Cellular Beam Design* (available at **aisc.org/dg**).

Design Load-Optimized Members

About 90% of the total embodied carbon from a structural steel system comes from raw steel production, not fabrication—and that 10% leaves some wiggle room for clever design and efficient fabrication to work hand-in-hand.

Substantial material savings (for instance, from high-strength steel or optimized member sizes and shapes) can often outweigh the carbon impacts of fabrication, but intricate fabrication can also cut into the environmental benefits of material reduction.

The more a piece is cut, welded, or handled, the more energy is consumed in its fabrication. Complex shapes require more welding consumables and may lead to more waste. So there's a delicate balance.

This is another place where a fabricator can be your secret weapon. They know what their own shop does most efficiently, and they can gauge the amount of welding and cutting a piece will need as well as the waste that will be left over.

For example, you may consider optimizing a transfer beam design to add reinforcing only where concentrated loads occur instead of upsizing the whole member. A steel fabricator can help you weigh the benefits of the reduced steel tonnage against the environmental impacts and cost implications of additional fabrication.

In many situations, web-tapered members can provide maximum strength and stiffness while minimizing weight. For more information, see Design Guide 25, *Frame Design Using Nonprismatic Members*. Substituting optimized trusses for plate girders in long-span framing can also reduce tonnage while facilitating MEP coordination. See section 4.5.2 of Design Guide 23: *Constructability of Structural Steel Buildings* for further information on long-span truss framing. Both are available for download at **aisc.org/dg**.

Consider Cambering

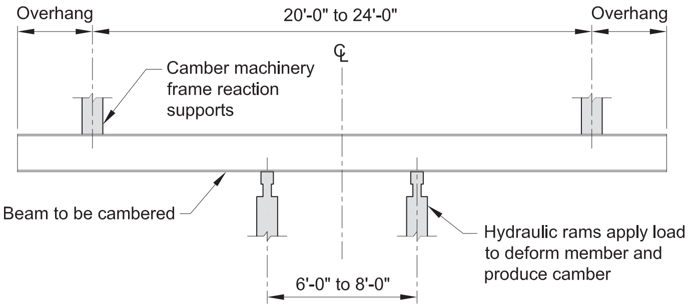
If you have a beam that's longer than 24 ft and could benefit from a camber of ½ in. or more, cambering might be an attractive option. It's a cost-effective way to reduce material weight—and it can be used on a large number of beams in the same project. In some cases, cambering beams can cut weight and embodied carbon by as much as 25%.

A steel fabricator can advise on schedule and cost tradeoffs of cambering. Consider other solutions if you require cambering of less than ½-in. More information is available in Design Guide 36: *Design Considerations for Camber*. Note: Lighter beams may require additional vibration consideration. See Design Guide 11: *Vibrations of Steel-Framed Structural Systems Due to Human Activity* for additional guidance. Both are available for download at **aisc.org/dg**.

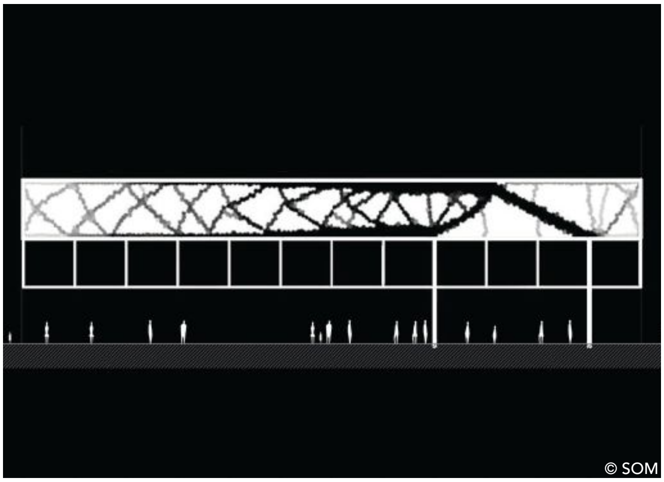
Implement Structural Optimization

Generally speaking, there are three ways to optimize a structural design. All can help you reduce the amount of structural material and associated embodied carbon in a project:

- **Size optimization.** Based on the engineer's design criteria (section depth, deflection criteria, vibration performance, maximum utilization ratio, etc.), individual framing members can be sized to the lightest, most efficient section possible.
- **Shape optimization.** Structural components may be fabricated to use material where it is most needed, such as optimizing the depth of bending elements.
- **Topology optimization.** Determine the most efficient arrangement of material of a minimum-volume structure under given loading, support, and serviceability conditions.



above: Cambered beams are curved with hydraulic rams, an excerpt from Design Guide 36: *Design Considerations for Camber*.



© SOM

above and below: This pedestrian bridge at the Winship Cancer Institute at Emory Midtown is the result of an iterative process to strip away all excess material—an excellent real-world example of topology optimization.

Dave Burk © SOM

Pay Attention to Connection Details

Designing connections based on beam capacity (for instance, based on uniform dead load) is very conservative and may lead to unnecessary connection material and labor.

Instead, consider designing based on resisted loads. Additional factors may come into play if you're designing for adaptability or reuse, or in an area with seismic activity. You can start with a typical detail design, but ensure to further customize it for your particular needs so as not to use excess material.

In some instances, you may want to opt for dry and mechanical fasteners such as bolts and screws, but these are not required when designing for deconstruction. You may want to designate standardized cuts for all connections to facilitate the deconstruction process.

The AISC *Steel Construction Manual* contains essential guidance for detailers, as does AISC's *Detailing for Steel Construction*. Visit **aisc.org/detailing-resources** for more.

Minimize Beam Penetrations

Early collaboration with the MEP trades can reduce beam penetrations and avoid costly, carbon-intensive field work.

The additional fabrication and material involved in making beam penetrations may increase a project's embodied carbon. As an example, a W24 that is lighter than a W18 but needs a penetration could be more carbon-intensive than a W18 without a penetration. A fabricator can help you balance the impacts of additional fabrication versus weight reduction.

Apply Seismic Design Strategies

Replacing concrete with a steel plate shear wall is one way to reduce embodied carbon. See AISC Design Guide 20: *Steel Plate Shear Walls* (available at **aisc.org/dg**) for further information.

A lot of steel's sustainable advantage lies in its ability to be deconstructed and reused, which means it must weather a seismic event undamaged. Steel rocking wall systems can reduce the risk of structural damage, as can bolted lateral systems like bolted buckling-restrained braces.

Modular proprietary fuse systems (like SidePlate and Dura-Fuse) ensure that beams and columns remain elastic after an earthquake. They are also easier to deconstruct and are therefore worth consideration if a seismic force-resisting system relies on moment frames for inelastic performance.

Base isolation uses bearing-like structures to form a sliding buffer between the foundation and the building. It can reduce the risk of structural damage, though it has not been widely adopted in the U.S. The Loma Linda University Medical Center in California uses a base isolation system.

The base isolation used in the Loma Linda University Medical Center separates dangerous seismic ground motion from the critical structure above.

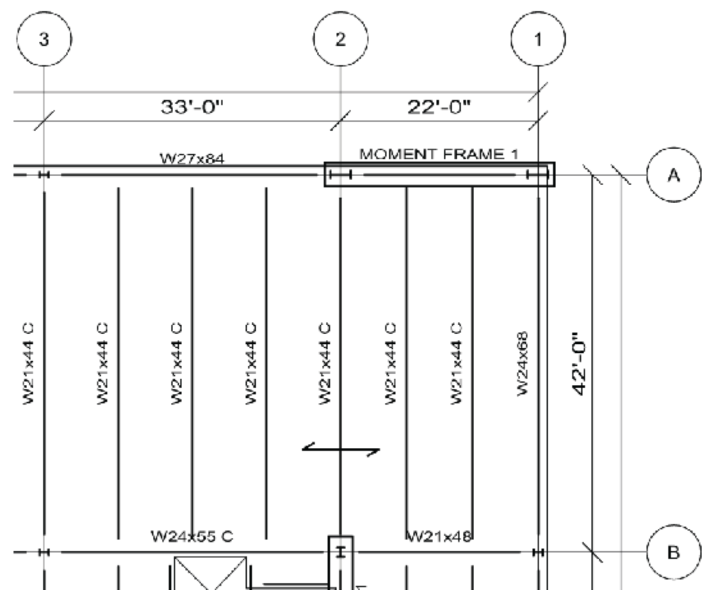
Select Bay Sizes Thoughtfully

Bay framing decisions can significantly affect the embodied carbon of a superstructure, and therefore bay studies during conceptual design are essential to understanding the embodied carbon implications (not to mention the cost and efficiency) of different structural materials and layouts. Use parametric modeling and/or optimization to determine optimal framing for each system.

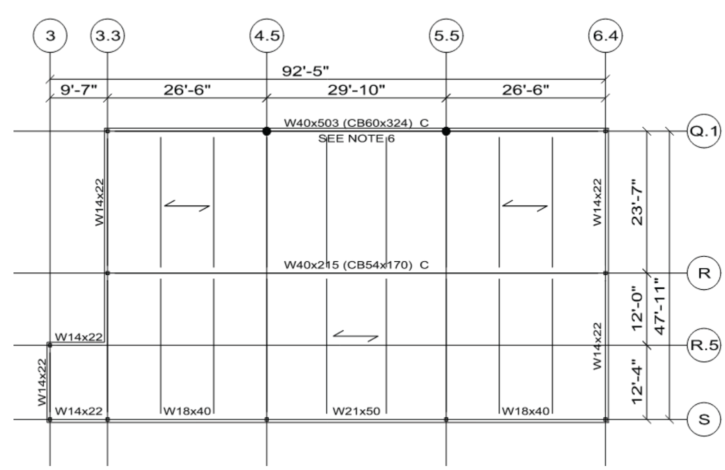
It's wise to conduct an LCA in conjunction with that bay study so you can make a more informed material choice. AISC offers industry-wide EPDs at **aisc.org/epds**, which are perfect for LCAs at this level.

A few caveats:

- Excessive spans and cantilevers will increase the embodied carbon (as well as the cost) of a structural system. If these features are necessary for the design, work with the architect to evaluate and minimize the impact on embodied carbon.
- Avoid non-rectangular bays, which can require additional columns and framing members that a rectangular bay of the same area would not need.



above and below: Bay studies are necessary for an accurate life cycle assessment and proper comparison of the embodied carbon of different materials.



above and below: A lateral force-resisting system's embodied carbon can vary based on the choice between braced or moment frames.

Consider Braced Frames Instead of Moment-Resisting Frames

Research* suggests that using braced frames instead of moment frames in a three-story building reduced the embodied carbon impact of the building structure by 12%.

Traditional moment-resisting frames and beams tend to be significantly heavier and require more material than braced frames to transfer forces and resist lateral loads, though there are many new systems on the market that address this concern. It takes more moment-resisting frames than braced frames to resist the same load and provide the same stiffness and serviceability.

Close collaboration between the engineer, architect, and owner will ensure the proper use of braced frames in the structure's programming.

Note: Braced frames are not solely concentric, but can be configured to be knee braces, chevrons, or eccentrically-braced frames to align with architectural openings.

Keep Geometry Simple

Transfer beams and columns can significantly increase tonnage and the associated embodied carbon. Architects should integrate a structural system early in the design process to avoid situations that might cause unnecessary complexity without compromising the image or function of the building. Non-orthogonal geometrics can also lead to upsizing and increased material use.

Hybrid Steel-Timber Structural Systems

No matter how sustainable your structural system is, the largest source of embodied carbon in a building is in its floor system.

RISD North Hall uses a hybrid steel-timber structural system.

courtesy John Horner Photography

*For more information, see the following:

ASCE/SEI *Structural Materials and Global Climate* (**www.ascelibrary.org**)

Nadoushani, Z.S.M. and Akbarnezhad, A. (2015), "*Effects of Structural System on the Life Cycle Carbon Footprint of Buildings.*" *Energy and Buildings*, Vol. 102, September 1, 337–346.

Combining a steel frame with CLT panel flooring takes advantage of the strengths of both systems. Designers have also had success with steel-braced mass timber buildings. Both approaches cut the amount of high-embodied carbon cement and the weight of the floor framing, which reduces the substantial embodied carbon impact of a conventional concrete-steel building.

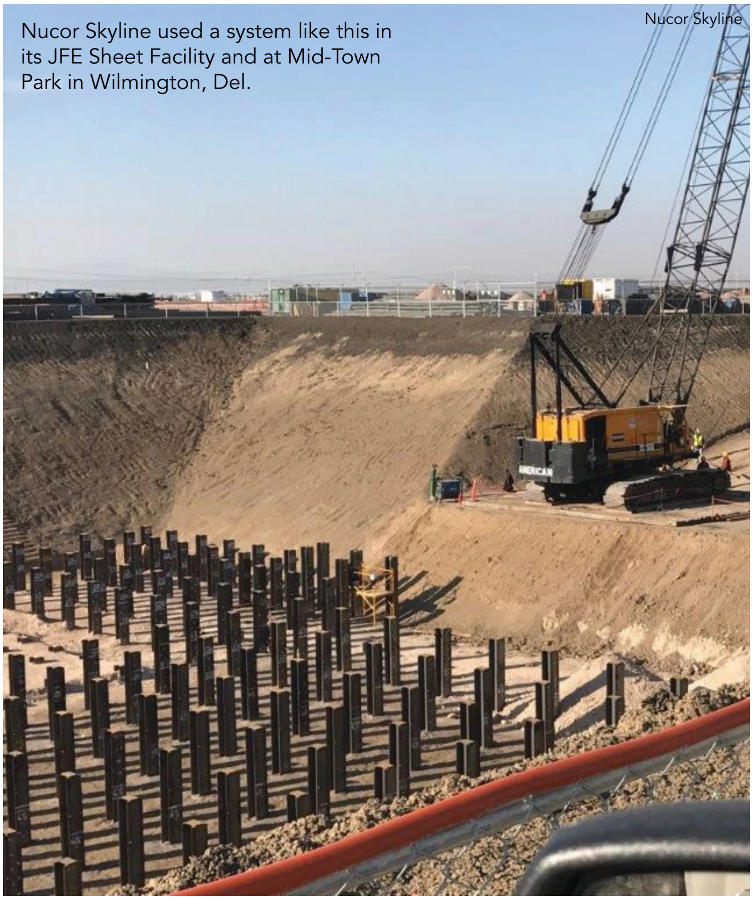
These approaches also allow designers to benefit from the longer spans (30–45 ft instead of mass timber's typical 20–25 ft) and shallower structural depth a steel frame offers while maximizing leasable space with steel's slimmer column profiles. Check out Design Guide 37: *Hybrid Steel Frames with Wood Floors* (download at **aisc.org/dg**) for more information. There is also a handy desktop Smart Reference available at **aisc.org/SRHybridDesign**.

Stay Above Ground When Possible

Underground construction requires a lot of material (and concrete, which has a relatively high carbon intensity), and that makes typical basement and foundation structures very carbon-intensive.

Limiting basement structures (particularly those with multiple subterranean levels) is one way to cut a structure's overall carbon intensity.

Steel foundations, while not commonly used yet, are available. Modularized systems using H-piles, for example, allow a foundation to be deconstructed and/or reused with a new superstructure.



Nucor Skyline used a system like this in its JFE Sheet Facility and at Mid-Town Park in Wilmington, Del.

Nucor Skyline

The Impact of Fire Protection

A structure's construction type classification (as defined in Chapter 6 of the *International Building Code*) dictates the level of required fireproofing, and the various fireproofing systems have different carbon intensity impacts.

Adding a fire sprinkler system or changing to a different building construction type would allow architects and designers to reduce the amount of fireproofing in their structure. Shaft openings drive fireproofing requirements in some construction types, so designers can also consider limiting shaft locations to fewer bays.

Alternative fireproofing materials, such as intumescent paint and mineral wool board, have lower associated carbon emissions than cementitious spray fireproofing, but designers should weigh the benefits against potential cost premiums.

Design Guide 19, *Fire Resistance of Structural Steel Framing* (available at **aisc.org/dg**) offers more information on various fireproofing systems. Visit **aisc.org/fire** for additional background information on UL Designs.

As an alternative to structural fire resistance ratings, ASCE 7-22 allows the use of performance-based structural fire design. This methodology permits synergy between the structural and fireproofing designs/specifications, which can significantly reduce reliance on fireproofing (e.g., allowance for non-uniform application of fireproofing). However, applying performance-based structural fire design typically requires consultation with a building code official and a peer review. For more information, refer to ASCE *Performance-Based Structural Fire Design* and ASCE 7-22 Table 1.3-5, which now provides applicable reliability targets for structural fire design.

End-of-Life Considerations

Buildings are often demolished not because they are worn out, but because they no longer are suitable for their purpose. In some situations, it can even cost less to tear down and reconstruct than to renovate. Designing for adaptability can reduce the future economic incentive to demolish a building when needs change.

Recent large-scale, real-world deconstruction projects have demonstrated that extracting materials and components for incorporation into new construction is a viable option at the end of a structure's service life.

Design for Adaptability and Deconstruction (DfAD)

Future adaptability relies on space—both physical wide-open plans that allow for flexibility and metaphorical space left for future designers.

If accommodating future use is part of a building's program, design systems with reserve strength and stiffness to accommodate alternate uses or be easily upgraded to carry more load.

These systems should be simple and transparent for easy evaluation and upgrades. Allow for MEP and other independent systems to be upgraded without disturbing the structural system. Do future designers a few favors:

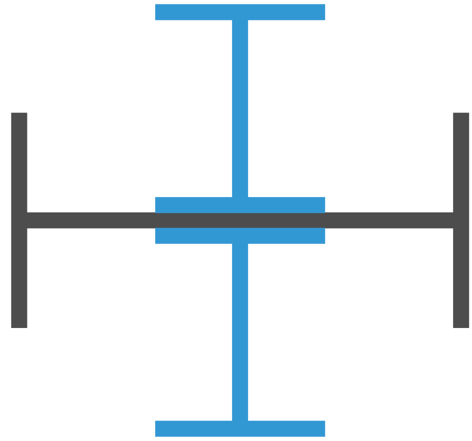
- Investigate situations where certain design criteria (i.e. loading, deflection criteria, vibration criteria) don't apply throughout the structure and provide clear direction on their application in the general notes to prevent unnecessary material use.
- Label components with their strength characteristics.

When it comes to disassembly, start by identifying the kind of buildings that lend themselves particularly well to deconstruction—for instance, repetitive structures such as parking garages.

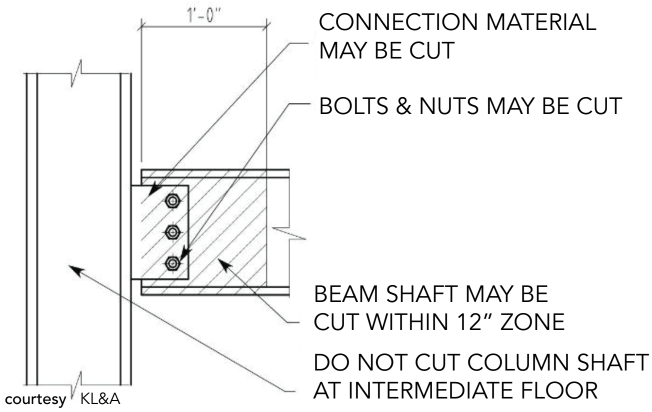
Standardizing your steel is hugely helpful if you're looking ahead to deconstruction or reuse—or if you're trying to save time and money on fabrication and erection. A smaller array of standardized shapes will be easier to work with than a broad selection of customized sections.

Avoid biaxial-lateral systems, box columns, and cruciforms, because they are difficult to retrofit and re-fabricate for reuse.

If your design requires a cruciform section, consider the configuration connecting two W shapes to the web of the larger W shape rather than the more labor-intensive option of splitting adjoining members into two T's. This configuration results in three reusable wide-flange sections instead of two T's that may not be as desirable for reuse purposes.



When planning for reuse, it's more efficient to connect two W shapes to the web of the larger W shape instead of splitting adjoining members into two T's to form a cruciform section.



Deconstruction of typical intermediate floor beam connection to column, an excerpt from the *Steel Deconstruction Specification: Example of Acceptable Cut Locations.*

Incorporate Salvaged Materials

Constructing with salvaged materials is a highly effective way to reduce embodied carbon. All the emissions associated with initial production of the materials may be neglected when they are reused, so emissions associated with salvaged materials are usually only related to transportation and refabrication.

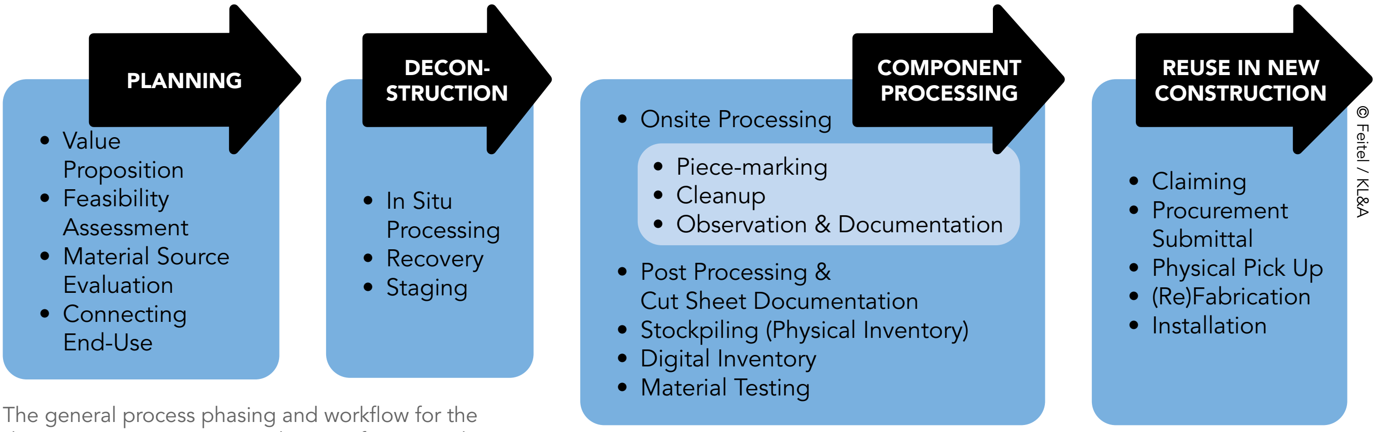
It may seem basic, but the key to successfully incorporating salvaged materials is good, old-fashioned organization. Salvaged steel should be earmarked for an end-use prior to deconstruction—and that requires a detailed inventory. This could be as simple as a spreadsheet.

If available, existing structural and architectural drawings make a perfect starting point for that inventory; be sure it includes details like:

- specific location in the physical stockpile
- need for a material testing sample
- claims by new projects
- total tonnage
- embodied carbon savings
- estimate cost compared to new steel
- onsite photos
- descriptive information (general condition such as finish and corrosion)
- accessory material and holes (connections, penetrations)
- observed damage (excessive bend, missing material)
- observed geometry (camber, sweep, tilt)

From there, you can develop individual cut sheets, assign historic AISC shapes, and flag noteworthy conditions for the end user. For example, steel members that have experienced cyclical loading or plastic deformation may not be suitable for structural reuse. Label components with strength characteristics (similar to grade stamps on wood framing).

Develop a deconstruction specification that details cut locations, level of cleanup, and piece-marking requirements. This defines the resulting condition of steel pieces, which allows new construction projects to bid the fabrication scope appropriately. Talk to the end user—they may be unconcerned about (or even want) extraneous material on a reused member.



The general process phasing and workflow for the deconstruction, recovery, and reuse of BCH steel.

After deconstruction, members should be cleaned and tested. This can include:

- Removing fireproofing and accessory material (plates, appendages, etc.)
- Removing all material that protrudes beyond the wide flange profile
- Leaving material within the web of the wide flange
- Developing a testing protocol specific to the project
- Tension testing (ASTM A370) on 10% of each size category
- Chemical analysis testing (ASTM A751) to verify weldability on 10% of total quantity of pieces

There are no industry standards or code requirements for testing and validating salvaged steel for structural reuse in North America, but these documents can help:

- ASCE 41, *Seismic Evaluation and Retrofit of Existing Buildings*
- Steel Construction Institute P427, *Structural Steel Reuse: Assessment, Testing and Design Principles*
- ANSI/AISC 360, *Specification for Structural Steel Buildings* appendix 5 (**aisc.org/specifications**)
- ANSI/AISC 342-22, *Seismic Provisions for Evaluation and Retrofit of Existing Structural Steel Buildings*
- Institution of Structural Engineers *Circular economy and reuse: guidance for designers*

For a deep dive into a deconstruction and steel reuse project, see "Ambitious Reuse" in the August 2024 issue (**modernsteel.com/archives**).

AISC thanks Julia Hogroian, PE, Simpson Gumpertz & Heger; Elena Good, SE, PE, Degenkolb Engineers; Brad Fletcher, SE, Atlas Tube; Brian McSweeney, SE, PE, FBRSE, Ehlert Bryan Consulting Structural Engineers; and Laura Hagan, PE, IMEG, for their expertise and insights that contributed to this article.

Sustainability Starts at the Top

BY KEVIN KUNTZ, SE, PE, IAN MCFARLANE, SE, PE AND JONATHAN TAVAREZ, PE

Sustainable buildings begin with owner and developer consciousness, and their sustainability-focused decisions begin long before design and construction.

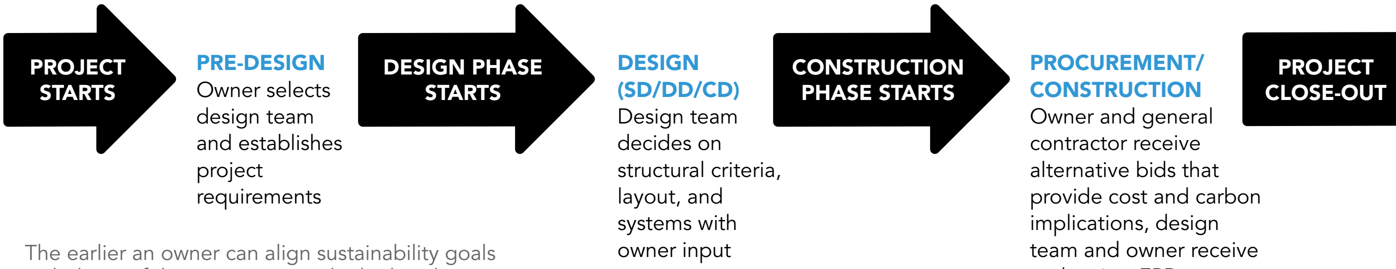
THE BUILT ENVIRONMENT accounts for about a third of the greenhouse gas emissions that contribute to climate change. As operational emissions from buildings in the United States—such as those produced by the energy that building systems use—have generally decreased with time, the building industry has turned more attention to embodied carbon reduction, which refers to the emissions from the production of construction products. The good news is that developers and owners can do a lot to set and meet their project's embodied carbon goals, and structural steel can help them.

To develop an environmentally friendly building, owners and developers should keep these considerations in mind:

- Build a team with the resources and expertise to make informed decisions in the design and construction process.
- Consider upfront costs and long-term savings involved in selecting a structural system.
- Understand whether adaptive reuse is a possibility, because the structure of a building can account for up to 80% of a building's embodied carbon.
- Know how present-day structural choices and design can be adapted in the future to save emissions and money.
- Know how to minimize carbon in the purchase of new materials.
- Inquire whether material reuse is an option.
- Tenants will continue to desire buildings with high sustainability, and decisions made early by the owner directly impact sustainability performance.

Ask the design team these questions before the project starts:

- Are you considering embodied carbon as one of the factors in selecting a framing system material?
- When comparing structural materials, are you optimizing the column grid for the unique characteristics of each material?
- How will the floor-to-floor height impact the quantity of materials being used?
- Are you evaluating vibration criteria?
- Is the resilience of the structure when experiencing extreme events (fire, earthquake, flood, hurricanes, tornadoes, high wind, terrorism) being considered?
- Are facility-specific EPDs available for the structural material being selected?
- Is the level of construction activity required and the waste generated on-site being considered?
- Have hybrid solutions been considered?
- Is the project subject to jurisdictional procurement requirements?
- Will procurement requirements be included in the specifications, and, if so, are the AISC guidelines being followed?
- Are you considering structural steel for the structural framing system? If so, is there a source for reused steel near the project?



The earlier an owner can align sustainability goals with those of the project team, the higher the chances for successful carbon impact reduction.

WBLCA Boundary–60 Years	Service Life	Product Stage	Construction Stage	Use Stage		End of Life Stage	Residual Value Adjustment	Emissions	Beyond Life (Benefits and loads beyond system boundary)
LCA Phase	(years)	A1–A3	A4–A5	B1–B5	B6–B7	C	(after 60 years)	Total	D
Carbon Type		Embodied	Embodied	Embodied	Operational	Embodied	Total	Total	—

SUPPLEMENTARY INFORMATION

An LCA divides a building's life cycle into stages to better quantify the carbon impacts.

How can structural steel help? Domestic steel is sustainable without a cost premium. Steel has significant advantages for recycling and possible reuse at the end of a building's life. The adaptability of steel structures is an advantage for the overall lifespan of a building, whether it is new construction or adaptive reuse. All U.S.-based steel mills produce facility-specific EPDs that clearly explain the carbon footprint associated with their production.

This article is an abridged version of AISC's *Owner Sustainability Toolkit* document, which was co-authored by AISC and Magnusson Klemencic Associates. It expands on these questions and considerations and explains how steel is a sustainability winner. Access the full document with case studies, appendices, and more for free at **aisc.org/sustainability-toolbox**.

Understanding and Measuring Carbon

While emissions related to building operations are relatively well understood and addressed in the design, operation, and maintenance of building infrastructure, emissions related to construction present a new challenge. The emissions from the construction of a building are dependent on the building design and types of materials used, including the structural materials and the quantity of those materials. Therefore, design decisions for the structure and the procurement of the structural material have a significant effect on a building's overall environmental impact.

Sustainability is no longer an optional trend. It's a crucial business strategy for building owners and stakeholders. Building tenants, government regulations and incentives, and societal obligations have applied necessary pressure on the industry to help motivate and accelerate reduced environmental impact on the built world. As a result, building owners and developers will need to be increasingly aware of the opportunities to reduce the embodied carbon of their buildings.

Global warming potential (GWP) is the metric used to measure greenhouse gases' impact on climate change, commonly expressed in kilograms of carbon dioxide equivalent ($kgCO_2eq$). Carbon is a colloquial and easy-to-understand term commonly used in place of GWP. Carbon can be broken down into two subsets:

Operational carbon is the GWP that results from the energy (lights, air conditioning, heating, etc.) and water consumed by a building during its operation. It is estimated that roughly two-thirds of the GWP from buildings is from operations. As energy codes improve, energy grids become less fossil fuel-dependent, and MEP engineers reduce the operating carbon emissions, the emphasis in sustainable building design and construction has shifted to embodied carbon.

Embodied carbon is the GWP that results from the production of construction products, construction activities, maintaining, renovating, and demolishing the physical elements of a building. In other words, it is the emissions associated with the full life cycle of the building, excluding operations.

A life cycle assessment (LCA) has been developed to measure the GWP of a building holistically, including the operation and embodied carbon. LCAs are conducted in accordance with the ISO 14040 standard developed by the International Organization for Standardization, which breaks the carbon impact into stages that represent different timeframes in the building's life cycle. LCAs of entire buildings, whole-building life cycle assessments (WBLCA), are governed by ASTM E-2921. The stages are organized as follows, and shown in the graphic above:

- **Product Stages (A1–A3):** Includes the extraction or collection of raw materials, transportation of raw materials, and manufacturing into building materials or products. This is also commonly referred to as a "cradle-to-gate" scope.
- **Construction Stages (A4–A5):** Includes the transportation of building components and their construction or installation.
- **Maintenance and Use Stages (B1–B7):** Includes the upkeep of building components, such as maintenance and replacement, and includes the energy and water consumption from the building's operations.
- **End of Life Stages (C1–C4):** Includes the demolition of a building and the disposal of its demolished materials.
- **Outside the Boundary of the Product System (D):** This includes the potential future recycling, reuse, and sequestration of products.

All stages except for the Use Stage contribute to the total embodied carbon impact of a component. In buildings, the initial Product Stage is often the largest contributor to total embodied carbon emissions. In some instances, this stage can accont for 75% or more of the embodied carbon total. The structural materials used in the primary structural systems of a building tend to be the largest contributor of embodied carbon emissions, followed by non-structural items such as architectural finishes. This makes the design and procurement of the structural system paramount to the overall embodied carbon performance of a building.

A quick comparison reveals that steel produced using an EAF, pictured opposite (much more prevalent in the U.S.), is cleaner than steel produced using a BOF, below.

While the building industry can measure operational carbon with relative sophistication by measuring energy usage, the ability to measure embodied carbon is more challenging and must be calculated based on the methodological practice of LCA. Environmental Product Declarations (EPDs) are one of the tools that can be used to help estimate the embodied carbon of building components. An EPD is the reported result of an LCA for the component under consideration. Unlike an ingredient label on a food product that reports what the product contains, an EPD reports the environmental impacts resulting from the production of a product, not its material ingredients.

Introduction to Structural Steel

The domestic iron and steel industry accounts for 1.9% of all U.S. energy-related CO_2 emissions. However, structural steel (which makes up a building's beams, columns, plates, etc.) accounts for only 8.5% of the U.S. market, meaning structural steel's share of emissions is somewhere around 0.16%. On top of this low upfront market impact, steel also has a distinct advantage over other materials in its ability to be reused or recycled. Steel can be repeatedly recycled by melting and recasting without losing its fundamental mechanical properties.

A basic understanding of how steel is made is helpful for understanding the carbon footprint of steel. The two main methods of steelmaking use a blast furnace and basic oxygen furnace (BF-BOF) or an electric arc furnace (EAF).

1. **Blast furnace and basic oxygen furnace (BF-BOF):** An extractive approach that uses mined raw materials as its primary input and predominantly coal power and natural gas as its fuel source.
2. **Electric arc furnace (EAF):** A circular approach that uses recycled scrap as the primary source of input and electricity as its source.

Approximately 70% of all steel production in the U.S. comes from EAF, while the remaining 30% comes from BF-BOF. All hot-rolled sections are made in EAFs. In other countries such as China, India, and Russia, BOF remains the predominant form of steelmaking, which is why environmentally conscious owners and developers should avoid using foreign steel.

Structural Systems: Why Steel?

The overall structural system selection will have a significant impact on the potential embodied carbon associated with the building. Structural steel is the ideal choice when considering sustainability, based on the following benefits:

- **Inherently sustainable:** All structural hot-rolled sections produced in the U.S. are made with EAF production, which, as mentioned above, uses an average of 92% recycled content and is 100% recyclable at the end of life. Domestically produced structural steel is already some of the cleanest steel in the world and doesn't cost extra.
- **Transparency:** All U.S. structural steel mills produce facility-specific EPDs that clearly explain the carbon footprint associated with their steel production, including a complete evaluation of the supply chain. This is the most accurate and transparent representation of the environmental impact of the specific facility when compared to an industry average evaluation, and the steel industry can boast 100% EPD coverage. No other construction material comes close to matching the level of data transparency and availability.
- **Adaptability:** A more adaptable structure will lead to a longer service life for a given building and potentially higher resale value. Structural steel has the distinct advantage of significant adaptability to incorporate future building modifications, such as the addition of new floor openings, an increase in floor loading capacity, or completely repurposing

a building. Compared to other structural systems where a more disruptive retrofit may be required or where retrofit is impractical, a structural steel building can achieve a longer service life and avoid the costly environmental impacts of replacing a building.

- **Resilience:** Steel structures are non-combustible, capable of handling unexpected extreme loads in both compression and tension, not subject to water damage, and durable, therefore offering a resilience advantage over other materials. This advantage can be realized as a lower risk for insurance during construction and for the entirety of the building's life.
- **End-of-life benefits:** Structural steel is 100% recyclable, making it a completely circular material. Additionally, deconstruction and reuse are feasible strategies that can offset the embodied carbon associated with new construction.

In summary, structural steel contributes many benefits to the sustainable built environment. Once a structural steel system is selected, the following sections describe options you can discuss with your design team that can further impact the embodied carbon of construction.

Building Optimization

Sustainability is just one of many different factors driving the design of a building. Others include cost, speed, availability of materials, available labor force, local experience, geotechnical requirements, and more. Design professionals need to consider all of these to make an informed decision on the structural material to use in the design, and only then can they optimize the structural system to reduce its environmental impacts. Many of these decisions are directed by the owner and can have a significant impact on the sustainability performance of the project. The design options impacting sustainability should be part of the early decision-making process to set the trajectory for the outcome of the entire project. Therefore, it is critical that building owners and developers establish their goals around sustainability early, in addition to schedule, budget, and programming requirements. See the carbon reduction potential chart on page 46 for the larger impact these crucial decisions can have when made earlier in the design process.

Available Tools and Data

Industry average and mill-specific steel EPDs
aisc.org/epd

AISC Sustainability Partner Program
aisc.org/partnerprogram

EC3 Database
www.buildingtransparency.org

Hines Embodied Carbon Reduction Guide
www.hines.com/embodied-carbon-reduction-guide

AGC Guide on Decarbonization and Carbon Reporting
www.agc.org/climate-change-playbook

CLF Embodied Carbon Policy Tracking Toolkit
carbonleadershipforum.org/clf-policy-toolkit

CLF Embodied Carbon Toolkit for Building Owners
carbonleadershipforum.org/clf-owner-toolkit

The sustainability of a steel structure is proportional to the quantity of steel required. The steel quantity is impacted by decisions that must be made by the owner and design team on the following:

- column grid spacing
- beam depth limitations
- floor-to-floor heights
- overall floor assembly, inclusive of concrete and steel decking

Where appropriate, building owners should also encourage the design team to explore innovative strategies, including:

Hybrid systems with steel framing and mass timber flooring. Recent innovations with mass timber products such as CLT, dowel-laminated timber, and nail-laminated timber have resulted in their incorporation into steel structural systems. These mass timber elements are produced by bonding or fastening together multiple layers of timber to achieve the necessary strength, stiffness, and fire rating.

The hybrid structure has many benefits compared to a conventional composite slab, including a reduction in carbon associated with reduced concrete topping and the replacement of metal deck with mass timber while still maintaining the benefit of steel's high strength-to-weight ratio in the framing below. This system can also present weight savings, resulting in reduced costs for foundations and lateral systems. Finally, where the construction type allows the deck to be exposed, hybrid systems can be an architectural benefit and offset ceiling costs. Care should also be taken when considering the accuracy of mass timber environmental data.

Incorporating salvaged materials. Constructing with salvaged materials is a highly effective way to reduce embodied carbon. All the emissions associated with the initial production of the materials may be neglected when reused, so emissions associated with salvaged materials are usually only related to transportation and refabrication.

High-strength steel. Domestic steel manufacturers have made tremendous progress in recent years in rolling higher grades of steel than previous industry norms. High-strength steel generally has the same carbon footprint as typical steel grades, resulting in a direct embodied carbon reduction proportional to the steel weight saved using high-strength steel.

Performance-based fire design. In lieu of prescriptive methods for determining fire ratings of floor and roof assemblies, performance-based fire design is a modern approach to ensure fire safety based on achieving safety outcomes through an in-depth analysis of fire risks, building performance, and safety tailored to the specific building characteristics. This analysis can help achieve a significant reduction or elimination of fireproofing of the structure, thus reducing overall embodied carbon for the building.

While many of these example studies are presented in isolation, the combined effects need to be evaluated on a project-specific basis. For example, the use of a hybrid steel-timber deck along with a larger column grid may result in overall savings in embodied carbon when evaluated holistically with foundation impacts. The owner should evaluate these design decisions for each project to assess their overall impact on embodied carbon.

Tracking Carbon Through Design and Procurement

To track the progress of the design and construction team's efforts in reducing environmental impacts on the project, embodied carbon should be evaluated at major design and construction milestones to show the project trajectory. A baseline comparison can be included to compare the embodied carbon totals at each milestone against an industry baseline. To earn points for an embodied carbon reduction in an LCA for the LEED rating system, this baseline approach is required to quantify the improvements made to reduce the environmental impact of the core and shell.

As design development progresses, the uncertainty in the building material quantities reduces, and eventually, quantities measured and purchased by the contractor can be used. Likewise, the carbon intensity of the structural materials can be challenging to estimate early in the design, given the variability in manufacturing processes. Therefore, industry-average embodied carbon values should be applied at the beginning of the design (**aisc.org/epd** has AISC industry-average EPDs). As the design is completed and steel is procured, project-specific information should be provided and applied to the LCA.

Procurement Strategies Using EPDs

The primary types of EPDs in the structural steel industry are industry-wide, which contain the average data that can be used early in the design process, and mill-specific, which are specific to the production facility and can be used during design refinement.

Care should be taken when comparing industry-wide and mill-specific EPDs, as many of these data sets are not directly comparable due to differences in background datasets used, age of data, uncertainty assumptions, LCA methodologies, PCR versions, and other variables. Overall, the structural steel industry is very transparent with its environmental data relative to other construction materials and has nearly 100% coverage of that environmental data for all structural steel products.

Procuring Based on Cost and Carbon

Procurement is another significant opportunity to impact the embodied carbon of a building. Embodied carbon can be used as another basis for bid evaluation, in conjunction with typical variables like cost and schedule.

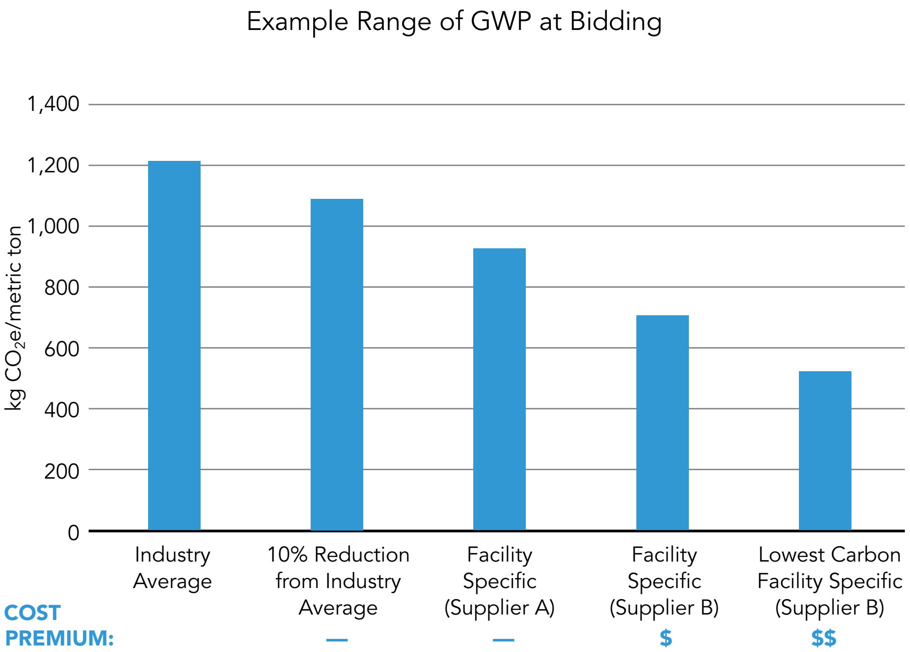
The most basic strategy would require the submission of mill-specific EPDs when bidding, allowing the owner to weigh the cost and anticipated embodied carbon associated with each bid. This strategy has been used on many projects and is not expected to impact costs.

Some owners have adopted strategies to require a specific GWP threshold in the bidding documents. Typically, this would be a targeted kg CO_2e/kg or a percentage reduction from the industry-wide EPD values (e.g. 10% reduction, the requirement for the LCA credit under LEED). Depending on the percentage reduction required, there may or may not be a cost impact associated with the lower carbon steel.

Another common approach is to require a minimum recycled content percentage for each steel product, although AISC does not recommend this approach. It's an indirect way to require GWP thresholds, which may not address all phases of LCA. Instead, state the required thresholds directly.

Owners and project teams should refer to the *Specification Strategies for Structural Steel Embodied Carbon Reduction* document (available at **aisc.org/sustainability-toolbox**) for commentary and sample specification language.

Projects have also successfully used bidding alternatives to provide various tiers of carbon reduction with various ranges of cost impacts. For example, the primary bidding instructions may be to bid based on "business as usual" with supporting EPDs. Then, an alternative for maximum carbon reduction could be requested that may have an associated cost premium. See the table below for an example of this approach.



Using bid alternatives can help an owner weigh cost and carbon performance to make an informed procurement decision.

Regulations and Rating Systems

In recent years, there has been significant momentum in the public policy realm regarding embodied carbon on all jurisdictional levels. The federal government, states, municipalities, and local building codes have implemented Buy Clean legislation or policies that leverage the government's purchasing power to encourage the construction industry to shift to lower-carbon material production. The policies incorporate requirements addressing greenhouse gas emissions into purchasing requirements.

The *International Building Code* (*IBC*) does not currently set GWP limits, however, local jurisdictions have adopted amendments that set GWP limits, either for specific individual materials like steel or for the entire building. A whole-building GWP limit could take the form of a limit on GWP/floor area or a percentage better than the baseline, an approach is similar to energy code limits currently set for operational energy use. It requires a WBLCA for the project.

The embodied carbon policy landscape is constantly evolving. To find the most current information on the policies in a project's jurisdiction, go to the Carbon Leadership Forum's (CLF) embodied carbon policy tracking map linked on page 59. The **aisc.org/buyclean** page contains helpful information for navigating Buy Clean policies.

Moving Forward

Building tenants are increasingly seeking high-performing sustainable buildings, and owners should keep the sustainability considerations in this article top of mind. When owners consider and prioritize these factors, structural steel will often prove to be an attractive material choice and help compliance with local or state regulations, such as Buy Clean legislation. No matter the building material, sustainability decisions begin long before any contracts are signed or design choices or made—and the *Owner Sustainability Toolkit* (download at **aisc.org/sustainability-toolbox**) can guide the decision-making. ■

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This month's new products include two laser cutting machines and an automatic plate storage and processing system.

Machitech Fiber PRIME S

Machitech's new Fiber PRIME S laser cutting machine sets a new standard in advanced cutting technology by combining high-speed 4G acceleration with high-power performance (12KW to 60KW) for cutting mild steel up to 4 in. thick. Fabricators and manufacturers can count on a laser cutting machine that delivers 24/7 reliable and efficient operation, provides rapid processing high-end performance for a wide range of heavy-duty applications, and comes with readily available customer service and support.

The Fiber PRIME S includes an exclusive Precitec cutting head designed for high-power applications and features the optional Machitech bevel head, enabling the creation of complex bevel cuts. Fiber PRIME S integrates an intelligent, intuitive, and easy-to-use large screen CNC controller, features Lantek expert cut nesting software, and has an innovative modular frame that addresses important concerns for high-power cutting. For more information, visit **www.machitech.com**.

Tecoi USA Stocktec

Tecoi USA's Stocktec automatic plate storage and processing system increases overall productivity by reducing operation time and expanding storage capacity while minimizing required floor space. The independent tray system is designed to store and dispense materials immediately based on production needs. Stocktec is designed to work well with all Tecoi USA large-format plate processing machines, as well as almost any plate processing system. By combining automated material handling with large format plate cutting and machining, users benefit from an advanced total plate processing solution.

Tecoi USA designs and manufactures customized solutions for a wide array of companies and industries that comprise a wide range of sectors in metal processing, including steel service centers, steel construction, heavy-duty machinery, the oil and gas industry, shipyards, and for wind power. For more information, visit **www.tecoiusa.com**.

BLM GROUP USA LTX

BLM GROUP's LTX is a new tube laser for tubular profiles, special sections, and open profiles from ½-in. to 6-in. diameters. Its bundle loader automates multiple processes such as cutting to length, notching, coping, and mitering all into one step. It can handle production start-ups and changeovers automatically, making it user-friendly to operators of any skill level. Everything starts with ArTube, BLM GROUP's CAD/CAM software for tube lasers. And when coupled with Prometheus, BLM GROUP's latest manufacturing execution system software, success is the only outcome.

The LTX has a small footprint that facilitates material handling around the machine and optimizes integration with the rest of production flow. The machine can manage loading and processing tube bundles using its automated bundle loader, while also offering the flexibility to manually load directly into the working line to minimize delays from production interruptions. After processing, the LTX has three unload destinations available to help sort parts, providing operators with excellent flexibility for large part mixes. In addition, the machine has been designed with large sliding doors that provide operators with clear access to the working line and cutting area while also keeping them safe and clean. For more information, visit **www.blmgroup.com**.

FELLOWSHIPS

AISC Announces 2025 Innovation Scholar

AISC is hosting its third Innovation Scholar for a two-week residency at its Chicago headquarters this month.

Cornell University professor Matthew Reiter, SE, PE, was named the 2025 AISC Innovation Scholar in May. He will collaborate with AISC's engineering and research team on a structural steel-focused project (to be determined) and take part in a variety of industry events, including committee meetings and local facility tours, between July 7–18.

"We are very excited to invite Matthew's expertise and insight into our technical activities this summer," said Chris Raebel, SE, PE, PhD, AISC's vice president of engineering and research. "We know he will bring so much to each conversation, and we look forward to showing him what makes our industry—and Chicago in the summertime—so special."

An integral member of Cornell's School of Civil and Environmental Engineering, Reiter teaches behavior and design-related structural engineering courses in addition to serving as faculty director for the Structural MEng program. He brings a breadth of experience in structural engineering from his previous work as a project engineer with Thornton Tomasetti and a section manager within Cornell's facilities engineering department.

In addition to fully reimbursed travel to and from Chicago, fully reimbursed lodging downtown, and a meal stipend, Reiter will receive $5,000 from the AISC Education Foundation.

AISC's Innovation Scholar program was established in 2024 and is designed to boost collaboration between engineering educators and the professionals who develop steel design standards. Last year's inaugural class of Innovation Scholars was University of Notre Dame professor Ashley Thrall, PhD and Gonzaga University professor Joshua Schultz, PE, PhD. Learn more about them and about the Innovation Scholar program at **aisc.org/innovation-scholar**.

People & Companies

Simpson Gumpertz & Heger (SGH) has opened an office in Tampa. Principal Francesco Spagna, PE and associate principal Brian Pailes, PE, PhD will lead the company's building enclosure consulting and corrosion and materials engineering practices, respectively, out of the Tampa office. The Tampa office is SGH's 12th U.S. location.

SMX Industrial Solutions acquired **Preston Eastin**, a renowned manufacturer of robotic and welding positioning systems. Preston Eastin, founded in 1972, has a longstanding reputation for delivering high-quality, precision-engineered robotic and manual welding positioners that improve manufacturing efficiency and productivity. Adding Preston Eastin's advanced positioning systems to SMX Industrial Solutions' existing offerings through Steelmax Tools and Scotchman Industries will provide customers with an expanded suite of solutions to meet diverse industrial needs. Combining the three companies' expertise and technological capabilities will drive innovation and accelerate the development of cutting-edge products. Preston Eastin's operations will continue out of its Tulsa, Okla., office.

AISC full-member fabricator **Macuch Steel Products, Inc.** (Augusta, Ga.) promoted **Randall Wenger** to vice president of sales and estimating. Wenger joined Macuch in 2024 with more than 18 years of experience in project estimating and management in construction and steel fabrication. He came to Macuch from the international general contracting firm Walbridge, where he served as senior estimator. He also worked in estimating at AISC full member Banker Steel.

CERTIFICATION CORNER

IN MEMORIAM

AISC Remembers Steel Erection Icon Rocky Turner

Charles "Rocky" Turner, one of the founders of LPR Construction in Loveland, Colo., died April 16 at age 74.

After graduating from Ball State University with a master's degree in industrial engineering, he spent some time teaching shop before moving west, where he and two close friends, Larry Boyd and Pete Carner, founded LPR Construction in 1979. Within a decade, LPR became one of the nation's leading steel erection firms, with notable projects including the America West Arena (now PHX Arena), Coors Field, Denver Art Museum, Dicks Stadium, and Marlins Park (now loanDepot Park).

"Rocky led LPR to much of its success," said Chip Pocock, a longtime friend and the safety and R&D manager at Barnett Steel Erection, Inc., in Thomasville, N.C. "He was also instrumental in moving the bar on fall protection safety in the steel erection industry. More importantly, he was a gentleman and a man of great character who did a lot for those who worked for him, as well as his community."

Beyond founding LPR, Turner's legacy is his work on standards that led to increased safety in the erection industry. As a member of the OSHA Steel Erection Negotiated Rulemaking Advisory Committee (SENRAC), he contributed to the drafting of a new fall protection standard that has dramatically reduced injuries and deaths. He was also named an ENR Top 25 Newsmaker in 1994 for LPR's advancements in erection safety and fall protection.

"The industry has lost the father of fall protection," said Rex Lewis, president of Puma Steel and an AISC board member. "Over three decades ago, Rocky told me he was going to make steel erection safer or he was going to get out of the business. That was the first I had heard of fall protection. Rocky and his fellow SENRAC members made the steel industry a much safer place to work."

Turner served as president of the Steel Erectors Safety Association of Colorado for 15 years, as a board member of the Associated Builders and Contractors of Colorado, and on the board of the National Center for Construction Education and Research.

AISC certification sets the quality standard for the structural steel industry and is the most recognized national quality certification program. It aims to confirm to owners, the design community, the construction industry, and public officials that certified participants, who adhere to program criteria, have the personnel, organization, experience, documented procedures, knowledge, equipment, and commitment to quality to perform fabrication, manufacturing, and/or erection. Find a certified company at **aisc.org/certification**.

The following U.S.-based companies were newly certified or renewed certification in at least one category from April 1–30, 2025.

Newly Certified Companies (April 2025)

Amsteel LLC, Canton, Ga.
Big 4 Steel Services, L.P., Spring, Texas
Evans Metal Fabricators, Portland, Ore.
KSU Corporation, Hesperia, Calif.
Legacy Steel LLC, Amherst, Wis.
PJR & Associates, Inc., Ava, Ill.
Reedbird Steel LLC, Odenton, Md.
Shurgar Manufacturing, Chester, S.C.
The Erection Company, LLC, Lake Stevens, Wash.

Certification Renewals (April 2025)

Agate Steel, Inc., Scottsdale, Ariz.
Alamo Structural Steel, Victoria, Texas
All Steel Construction, Inc., Malvern, Ark.
American Structural Metals, Inc., Somerset, Wis.
Ameron Pole Products, Tulsa, Okla.
Am-Tec Designs, Scandia, Minn.
Anderson Bridges, LLC, Colfax, Wisc.
Atlas Welding & Fabrication, New Castle, Del.
BAPKO Metal, Inc., Lakeside, Calif.
BAPKO Metal, Inc., Orange, Calif.
BAS Welding LLC, St. Leonard, Md.
Bludau Fabrication, Hallettsville, Texas
Bosworth Steel Erectors, LLC, Dallas
Cody Builders Supply, Austin, Texas
Design Build Structures LLC, Peosta, Iowa
Eastern Steel Works, Inc., Seagrove, N.C.
George Steel Fabricating, Inc., Lebanon, Ohio
Gira Steel, West Columbia, S.C.
Heavy Equipment Movers & Installations, LLC, Maysville, Ga.
High Structural Erectors LLC, Lancaster, Pa.
Jones Valley Fabrication, Oneonta, Ala.
Katelman Steel Fabrication, Inc., Council Bluffs, Iowa
Keith's Welding Service, Inc., Travelers Rest, S.C.
Kinsley Steel Inc., York, Pa.
L.R. Willson & Sons, Inc., Gambrills, Md.
Lane Supply, Inc., Arlington, Texas
LNI Custom Manufacturing Inc., Gardena, Calif.
Lonestar Welders and Erectors, LLC, San Antonio
M.L. Ruberton Construction Co., Inc., Folsom, N.J.
Maryland Iron, Inc., Odenton, Md.
MATHFAB LL, Oshkosh, Wis.
Merchant Iron Works, Inc., Sumter, S.C.
New Orleans Iron Works, Inc., Belle Chasse, La.
Nucor Vulcraft, Norfolk, Neb.
Olsen-Beal Associates, Lindon, Utah
Paldi Steel Services, North Las Vegas, Nev.
Pelco Structural, LLC, Claremore, Okla.
Phoenix Steel Erectors, Inc., Gainesville, Va.
Piedmont Structural Company, Mocksville, N.C.
Rast Iron Works, San Antonio
Rodgers Metal Craft, Inc., Fortson, Ga.
Slay Steel, Inc., Meridian, Miss.
South Central Steel, Inc., Harpersville, Ala.
Standard Iron, La Vista, Neb.
Steele Solutions, Inc., Waupaca, Wis.
Thornton Steel San Antonio, LLC, Elmendorf, Texas
Tubal-Cain Industries, Inc., Vidor, Texas
Vegter Steel Fabrication, Morrison, Ill.
W&W | AFCO Steel, Oklahoma City
Westeel Builders, El Cajon, Calif.
Whitley Steel Co., Inc., Jacksonville, Fla.
Wilton Corporation, Finksburg, Md.
XKT Engineering, Inc., Vallejo, Calif.

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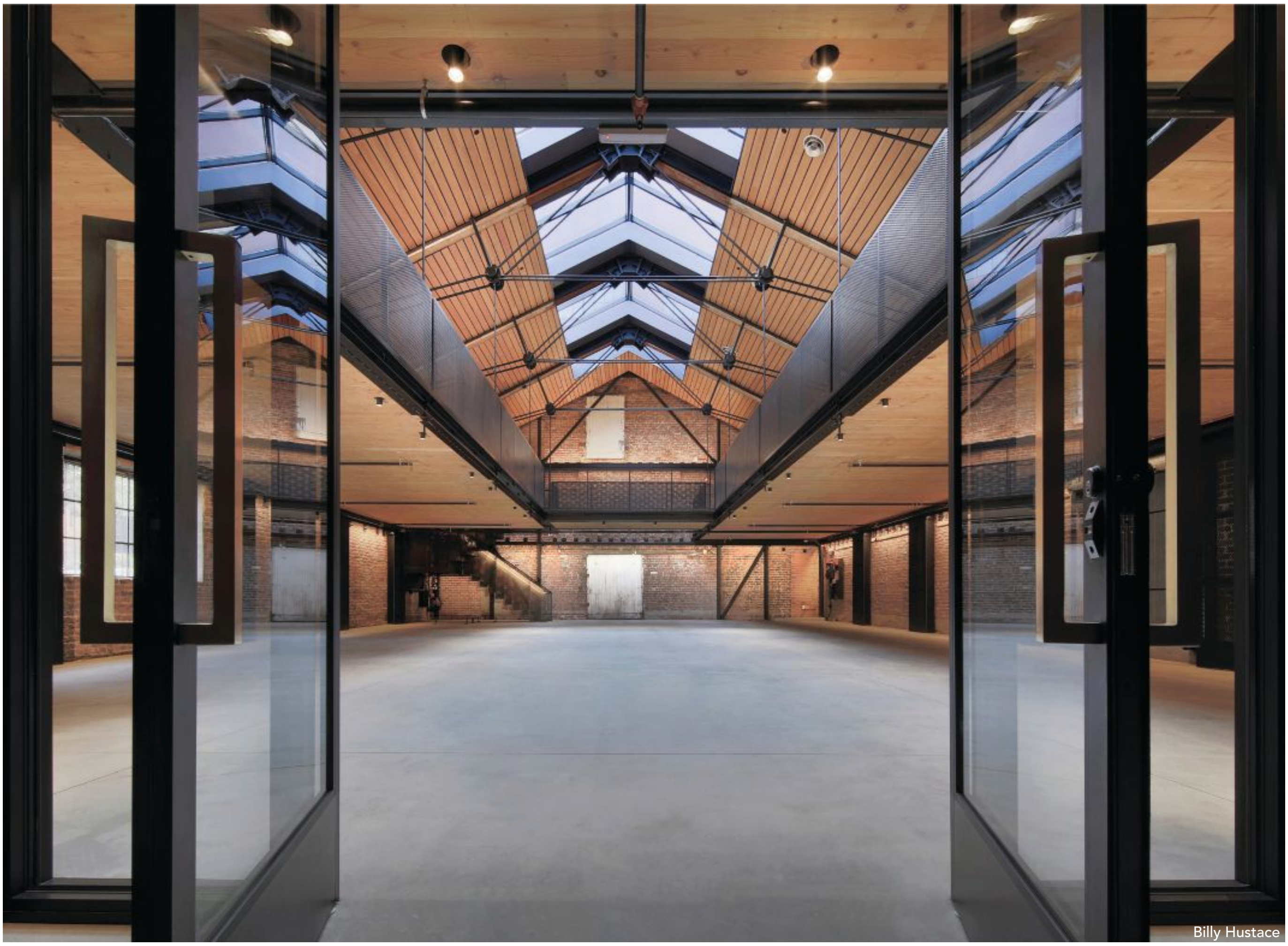

Abundant Ideas

STRUCTURAL STEEL SHINES in adaptive reuse projects, even ones where it's added to an existing building that had little steel in its original form. Steel members also easily integrate with other materials, especially cross-laminated timber (CLT). In San Francisco, The MacLac Building D rebirth (pictured above) turned an old paint factory into a commercial space with a hybrid steel-CLT design—highlighted by a new steel king post truss system. It's a testament to two of structural steel's advantages: adaptability and sustainability.

Adaptive reuse projects are sustainability winners, and AISC has several resources to help with them. Start with Design Guide 15: *Rehabilitation and Retrofit* and Design Guide 16: *Assessment and Repair of Structural Steel in Existing Buildings*. Hybrid steel-CLT designs bring out the best in both materials, and Design Guide 37: *Hybrid Steel Frames with Wood Floors* can provide a roadmap for them. All design guides are available at **aisc.org/dg**.

The MacLac project's use of steel's benefits earned an AISC IDEAS^2 award in 2023. Adaptive reuse and hybrid steel-CLT designs are just one way to display innovative steel design. If you have worked on a recently completed steel project or are currently designing one, that project could be recognized if you submit it for a 2026 IDEAS Award from AISC and *Building Design+Construction*.

The structural steel industry's flagship design award is back (minus the ^{2}, for sharp-eyed readers) and even better for 2026. The IDEAS Awards aim to showcase steel projects that demonstrate excellence in adaptive reuse, architecture, constructability, engineering, and sustainable design and construction. And this year, they have added a category: the IDEAS | next Award, which is for projects that are still on boards or in design software. If a concept has a site and a client, it's eligible.

Entries are due September 30, 2025. For more information (or to get inspired by past winners), visit **aisc.org/ideas**.