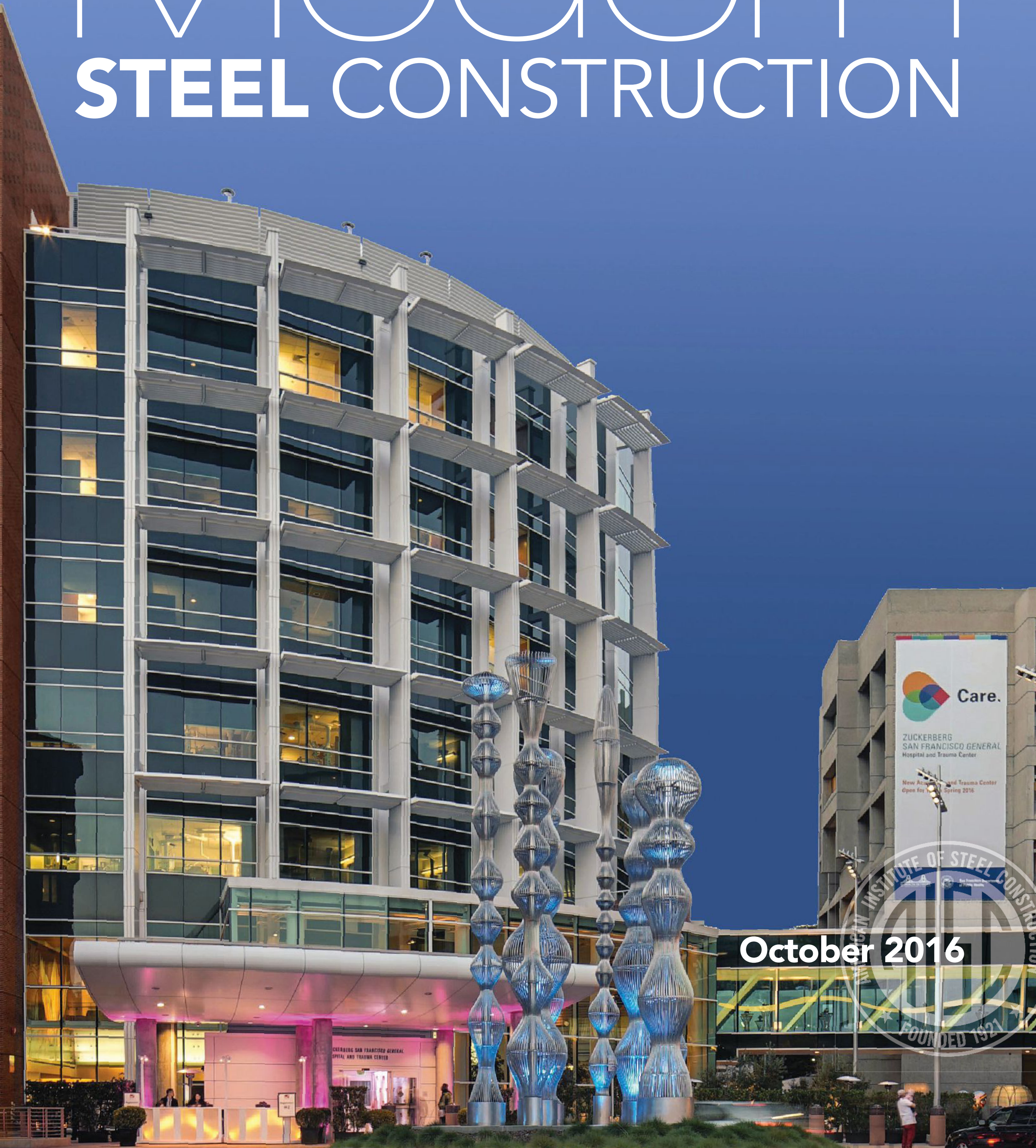
Modern STEEL CONSTRUCTION



October 2016


STEEL FABRICATORS
MAKE MONEY
WITH PEDDINGHAUS TECHNOLOGY
"We completed a project with a 35' W14x90 beam, and it took 1.5 hours to layout manually. We ran the same piece through the PeddiWriter in 8 minutes. The machine accuracy has reduced our shop errors from 17% to 2%."
Chance Doherty - Project Manager
Doherty Steel Inc.
Paola, KS
Peddinghaus
Doherty
DSI
Steel, Inc.
Dennis Doherty
President
Lisa Stephen
Secretary/Treasurer
Chance Doherty
Project Manager
WATCH VIDEOS HERE
www.peddinghaus.com/peddiwriter
Peddinghaus
www.peddinghaus.com | info@peddinghaus.com | (815) 937-3800

Modern STEEL CONSTRUCTION | October 2016

32

columns

in every issue

features

ON THE COVER: San Francisco's newest addition to one of its oldest hospitals, p. 26. (Photo: Molly Carter)

MODERN STEEL CONSTRUCTION (Volume 56, Number 10) 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. Subscriptions: Within the U.S.—single issues $6.00; 1 year, $44. Outside the U.S. (Canada and Mexico)—single issues $9.00; 1 year $88. 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.

editor's note

ONE OF MY DAUGHTER'S FAVORITE BOOKS IS *THE GREAT GATSBY*, A CLASSIC NOVEL THAT, RIGHT OR WRONG, I'VE NEVER BEEN PARTICULARLY FOND OF. BUT SEEING IT THROUGH HER EYES HAS GIVEN ME A NEW APPRECIATION FOR F. SCOTT FITZGERALD'S MASTERY OF PROSE.

We were discussing the book the other day, and Julia used a word I had never heard before: polysyndeton, referring to the use of several coordinating conjunctions in succession. The sentence in question, "By seven o'clock the orchestra has arrived, no thin five-piece affair, but a whole pitful of oboes and trombones and saxophones and viols and cornets and piccolos, and low and high drums," is emblematic of how language can paint a picture and influence your thinking.

And it doesn't have to be an entire book or even a long phrase. Sometimes a single word can do it. "Green" is one such trigger word. When I hear it, my imagination travels to pristine beaches and virgin forests. And that mental image can be a problem.

As a matter of fact, the wood industry has capitalized on that image to create a false impression of environmental stewardship in association with wood construction. However, the truth is far more complex than our daydreams.

The wood industry would have us believe lumber comes from sustainably managed forests and is harvested in an environmentally sensitive manner. Unfortunately, in 2016 the American Forest and Paper Association reported that only 20% of forests in the U.S. are certified as being managed sustainably, with less than half of those using harvesting practices that are certified as being sustainably performed.

When considering the green pedigree of wood, you also need to consider waste—and only 34% of a tree's biomass is used in typical harvesting and milling practices. Why? It turns out that 40% of the tree (small branches, leaves, bark, roots) is left behind to decompose and release carbon, and of the remaining 60%, more than half is lost to sawdust, trimmings and other odds and ends, according to forestry experts at North Carolina State University. (Think of it this way: When you convert a cylinder into rectangles, you lose a lot of material.) And claims that the waste results in a reduction in environmental impacts by being converted for energy production are misleading. Burning wood waste actually results in a larger production of CO_2 per BTU than coal!

And these issues don't even take into account the use of adhesives and other materials to produce cross-laminated timber, glulam and other wood products.

So don't be lulled by flowery language. Almost all construction materials have green attributes and almost all have an Achilles' heel. Energy use, carbon emissions and waste are just a few of the issues that have to be taken into consideration. While almost every material offers a life cycle assessment (LCA), to be truly meaningful you need to instead look at a whole-building LCA on a case-by-case basis.

If you need to know more about green construction, please visit **www.aisc.org/sustainability** or contact the AISC Steel Solutions Center (866.ASK.AISC).

SCOTT MELNICK
EDITOR

Modern
STEEL CONSTRUCTION

Editorial Offices
130 E Randolph Street, Suite 2000
Chicago, IL 60601
312.670.2400

Editorial Contacts
EDITOR AND PUBLISHER
Scott L. Melnick
312.670.8314
melnick@modernsteel.com

SENIOR EDITOR
Geoff Weisenberger
312.670.8316
weisenberger@modernsteel.com

ASSISTANT EDITOR
Tasha Weiss
312.670.5439
weiss@modernsteel.com

DIRECTOR OF PUBLICATIONS
Keith A. Grubb, SE, PE
312.670.8318
grubb@modernsteel.com

PRODUCTION COORDINATOR
Megan Johnston-Spencer
312.670.5427
johnstonspencer@modernsteel.com

GRAPHIC DESIGN MANAGER
Kristin Hall
312.670.8313
hall@modernsteel.com

AISC Officers
CHAIR
James G. Thompson

VICE CHAIR
David Zalesne

SECRETARY AND GENERAL COUNSEL
David B. Ratterman

PRESIDENT
Roger E. Ferch, PE

VICE PRESIDENT AND CHIEF STRUCTURAL ENGINEER
Charles J. Carter, SE, PE, PhD

VICE PRESIDENT
Jacques Cattan

VICE PRESIDENT
John P. Cross, PE

VICE PRESIDENT
Scott L. Melnick

Editorial Advisory Panel
Caroline R. Bennett, PE, PhD, University of Kansas

Keith R. Griesing, PE, Hardesty and Hanover

Steve Knitter, Geiger and Peters

Janice Mochizuki, PE, Arup

Dylan Olson, Olson Steel

Advertising Contact
ACCOUNT MANAGER
Louis Gurthet
231.228.2274
gurthet@modernsteel.com

For advertising information, contact Louis Gurthet or visit **www.modernsteel.com**

Address Changes and Subscription Concerns
312.670.5444
subscriptions@aisc.org

Reprints
Megan Johnston-Spencer
312.670.5427
johnstonspencer@modernsteel.com

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

steel interchange

Transverse Stiffeners as Stability Bracing

It seems that full-depth transverse stiffeners prevent relative movement of a beam's flanges. Can the location of transverse stiffeners in a beam be considered a brace point?

We receive this question on a regular basis. The answer is no. Transverse stiffeners are simply along for the ride as the section rotates and provide no resistance to lateral-torsional buckling on their own. As a result, they do not affect the unbraced length of the beam, L_b. Stiffeners can be used to reduce the web deformation and improve the efficiency of torsional braces. However, used alone, web stiffeners are ineffective in enhancing the stability of members.

Bo Dowswell, PE, PhD

Mill Orders

Are there published criteria or requirements for a steel mill order package?

No. There are published documents, such as Sections 107 or 1603 of the 2015 *IBC* and Section 3 of the AISC *Code of Standard Practice for Steel Buildings and Bridges* (a free download from **www.aisc.org/code**), which give requirements for information to be included in the final "for construction" documents, but a "steel mill order" or a "steel fabrication package" are partially developed packages negotiated on a project-by-project basis to provide information to the contractor.

For better or worse, it has become quite common for an owner or contractor to request an early release steel package in advance of the final "for construction" documents. Different clients, owners, contractors, fabricators, erectors, architects and engineers often have different expectations with regards to what that means with respect to the level of detail that should be included in the design documents. Ideally, there should be a dialogue between the design team and the construction team to clearly define the intent of the early package and the information that should be included prior to releasing the design documents. In my experience, I have seen the phrase "mill order" used generically to describe a broad spectrum of deliverables—from something that simply allows a fabricator to reserve material from a mill roll all the way up to structural drawings that have sufficient detail to allow shop drawing production to occur.

While the phrases "steel mill order" and "steel fabrication package" do not have standard definitions, in my mind a mill order package should provide the fabricator sufficient information to interface with the steel mill and establish an advanced bill of material purchase. This would include primary member sizes, member material designations and the geometry defined with enough detail to establish individual member lengths.

Given all this, when a request is made for a structural designer to issue an early steel package under any name—early package, mill order, fabrication package, etc.—the designer should seek clarification as to the intended use of the package and adjust accordingly.

Susan Burmeister, PE

Stability Bracing for Members Other Than Wide-Flange Members

When checking relative bracing for a beam Equations A-6-5 and A-6-6 of the AISC *Specification*, Appendix 6 includes the term h_o, the distance between the flanges centroids. When checking bracing requirements for a tee, what value should be used for h_o?

The *Specification* does not address that condition, so you will have to use your own engineering judgment. I will provide some further information to assist you.

Appendix E of AISC Design Guide 28: *Stability Design of Steel Buildings* (a free download for members from **www.aisc.org/dg**) provides background related to the stability bracing requirements beyond what is included in the Commentary to the *Specification*.

Stability is very important, and for typical members it is not difficult to provide. The adequacy of the vast majority of member stability bracing is commonly judged by inspection. Stability concepts can be traced pretty far back into the history of steel design. However, their explicit presence in the *Specification* is fairly recent. For example, the 1986 *Specification* (the first LRFD specification) states: "The stability of individual elements must also be provided." And this appeared in the Commentary. It did point to other resources as well: "Considerable attention has been given to this subject in the technical literature, and various methods of analysis are available to assure stability. The SSRC *Guide to Design Criteria for Metal Compression Member* devotes several chapters to the stability of different types of members considered as individual elements, and then considers the effects of individual elements on the stability of the structure as a whole."

None of this directly helps you with your issue. However, it may help you feel a sense of relief that although it is possible to provide insufficient bracing, it is usually apparent that you may have done so.

In your case, all you need to recognize is that the moment is an indirect measurement of the force you are actually bracing against. You do not need h_o—it is a means to an end. Equation C-A-6-5 in the *Specification* Commentary provides a more direct perspective. You are evaluating the bracing against the compressive force in the flange, not the moment in the beam. The Commentary states: "(C_bP_f) can be approximated by M_r /h_o." All of the discussion I have cited relates to stiffness checks, but the basic ideas apply equally to strength.

One issue that sometimes gets overlooked is that the stiffness equations assume one end of the brace is attached to something very stiff. A W14×730 can be a brace but if one end attaches to the face of a piece of sheet metal, it still may not have sufficient stiffness. Though shown relative to a different condition, Equation C-A-6-12 illustrates how to calculate the stiffness of a series of elements. Again, I suspect explicit checks are rarely performed after one is familiar with the usual results from the checks provided in the *Specification*, but it is good practice to look at both ends of whatever you are assuming to be a brace.

Larry S. Muir, PE

Transverse Reinforcement of Composite Beams at Edge Conditions

We are investigating the need for transverse reinforcing over composite beams and have noticed that some foreign standards have specific requirements for additional transverse reinforcement. These seem to apply at spandrel beams near the edge of the slab. We can find no similar requirements in the AISC *Specification* and are curious as to how the AISC *Specification* considers edge conditions.

We can only comment on requirements set by the AISC *Specification*. Relative to edge conditions, the Commentary to the *Specification* states:

"The use of edge distances in ACI 318 Appendix D (which is now ACI 318 Chapter 17 in the reorganized version) to compute the strength of a steel anchor subjected to concrete crushing failure is complex. It is rare in composite construction that there is a nearby edge that is not uniformly supported in a way that prevents the possibility of concrete breakout failure due to a close edge. Thus, for brevity, the provisions in this *Specification* simplify the assessment of whether it is warranted to check for a concrete failure mode. Additionally, if an edge is supported uniformly, as would be common in composite construction, it is assumed that a concrete failure mode will not occur due to the edge condition. Thus, if these provisions are to be used, it is important that it be deemed by the engineer that a concrete breakout failure mode in shear is directly avoided through having the edges perpendicular to the line of force supported, and the edges parallel to the line of force sufficiently distant that concrete breakout through a side edge is not deemed viable."

The research cited in the Commentary (Pallarés and Hajjar, 2010a, 2010b) also asserts such restraint commonly exists, but does not clarify the basis for this. AISC Design Example I.2 clarifies, stating: "The slab edge is often uniformly supported by a column flange or pour stop in typical composite construction, thus preventing the possibility of a concrete breakout failure and nullifying the edge distance requirement as discussed in AISC *Specification* Commentary Section I8.3." Design Examples are a free download at **www.aisc.org/manualresources**.

The User Note in Section I8.3 again points to this sort of restraint, stating: "If concrete breakout strength in shear is an applicable limit state (for example, where the breakout prism is not restrained by an adjacent steel plate, flange or web), appropriate anchor reinforcement is required for the provisions of this Section to be used. Alternatively, the provisions of the applicable building code or ACI 318, Appendix D may be used."

Larry S. Muir, PE

Eccentric Stability Bracing

I have a wide-flange beam attaching near the face, as opposed to the center, of an HSS column. Can the beam be assumed to be a lateral brace in the design of the column?

The brace must have adequate strength and stiffness, as required by Appendix 6 of the AISC *Specification*. A complicating factor is the location of the brace point. The equations in Appendix 6 were developed assuming the brace acts at the column shear center.

There are two ways to account for the brace being off-center:

1. Design based on the assumption that the brace point is located at the column centroid. The connection must have adequate strength and stiffness to accommodate this assumption, based on calculations or judgment.
2. Check the column for constrained-axis buckling. Constrained-axis buckling is discussed on Page 36 of AISC Design Guide 25: *Frame Design Using Web-Tapered Members* (a free download for members from **www.aisc.org/dg**). The theory behind the equation is in the classic book *Theory of Elastic Stability* by Timoshenko and Gere. For wide-flange shapes, design examples and tables were developed by Liu et al. (2013). Because HSS sections are very stiff in torsion, and therefore constrained-axis buckling, this may be the best option.

Reference:

Liu, D., Davis, B., Arber, L. and Sabelli, R. (2013), "Torsional and Constrained-Axis Flexural-Torsional Buckling Tables for Steel W-Shapes in Compression," *Engineering Journal*, AISC, Fourth Quarter. *Engineering Journal* papers can be downloaded from the AISC website at **www.aisc.org/ej**.

Bo Dowswell, PE, PhD

The complete collection of Steel Interchange questions and answers is available online. Find questions and answers related to just about any topic by using our full-text search capability. Visit Steel Interchange online at **www.modernsteel.com**.

Larry Muir is director of technical assistance at AISC. Bo Dowswell and Susan Burmeister are consultants to AISC.

Let Greiner's **Transit Division** do your **Heavy Hauling and Rigging.**

With this combination of a 3-Axle Jeep and Greiner-built 4-Axle Steerable Dolly, we can transport a maximum weight of 157,500 lbs. Railroad Girder shown is 9 feet high by 121 feet long, and weighs 129,000 lbs.

We have the people and resources to move and position just about any wide, long, over-height and heavy load.

Greiner's Transit Division is the expert at providing oversize load transport for big, heavy products like fabricated buildings and railroad girders. Our experienced, fully insured, licensed drivers have excellent safety records and exhibit professionalism at all times and in all situations. We can escort oversized loads that require Department of Transportation (DOT) mobilization permits. We also provide service for legal loads.

Greiner: Taking on Tomorrow's Transit Needs Today.

Call us at 800-782-2110 for a free quote on your next Oversize Load Transport job.

GreinerIndustries.com

GREINER
INDUSTRIES

TRANSIT FLEET

- Several tandem-axle tractors
- Four-axle tractors
- Steerable dollies
- Escort vehicles
- 35-ton landoll
- 50-ton triple-axle lowboy
- Triple-axle single drop (45' to 50')
- Double-axle stretch (up to 70')
- Double drop stretch (26' to 45')
- Spread-axle flats (48')
- Triple-axle stretch (75' to 90')
- Four-axle stretch (up to 82')

OTHER EQUIPMENT

- E-Z Lift with 50-ton lifting capacity
- Versa-Lift with 40-ton lifting capacity

steel quiz

Steel Quiz made its first appearance in the November 1995 issue of *Modern Steel Construction*. This month's Quiz takes a look at some of the best questions from 1997.

1 The torsional constant J can be accurately approximated for W-shapes and similar shapes of open cross section as $\Sigma(bt^3/3)$ where b and t are the width and thickness of each element, respectively. Does this simple approximation also work for a hollow structural section (HSS)? Hint: See Figure 1.

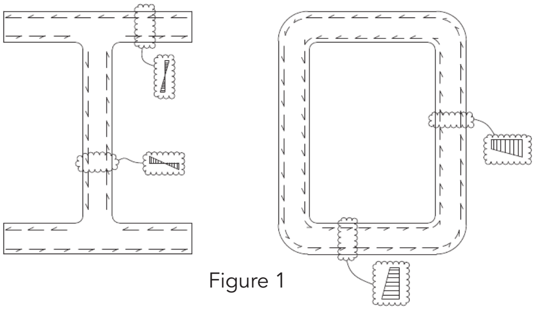


Figure 1

2 Which of the following ASTM *Specifications* is a production specification and not a material specification?

a. ASTM A992
b. ASTM A36
c. ASTM A6
d. ASTM A709
e. None of the above

3 Name three common sources of residual stress.

4 Philosophically, what is the difference between a filler and a shim?

5 In laboratory testing of steel specimens, what is whitewash and what does it do?

6 A structural member has been properly designed to meet all applicable load and strength criteria. Can it be said that this member will never fail? Hint: See Figure 2.

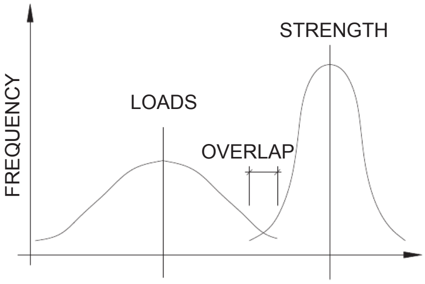


Figure 2

7 Why are beveled washers square or rectangular but not round?

8 What is a leaning column?

TURN TO PAGE 14 FOR ANSWERS

1 No, because the mode of torsional resistance differs. Open cross sections resist torsion with in-plane shear stresses that vary linearly across the thickness of each element of the cross section, as illustrated in Figure 1 (on the previous page) for a W-shape. Closed cross sections resist torsion with shear stresses that are distributed over the thickness of the cross section for a rectangular HSS (the right side of the figure). See AISC Design Guide 9: *Torsional Analysis of Structural Steel Members* for more.

2 **c.** ASTM A6 covers the cross-sectional dimensions and production tolerances for hot-rolled structural shapes. The others listed cover various material grades, including material tensile properties and chemistries.

3 Common sources of residual stress include: cooling after rolling, cold bending and weld shrinkage.

4 A filler is furnished to occupy spaces that will be present because of dimensional separations between elements of a connection. For example, a filler is used in a flange-plated column splice when wide-flange columns are of differing sizes. A shim is furnished for use during erection to fill spaces that may or may not be present because of the required field assembly clearances. For example, shimming may be required with moment end-plate connections for which the beam is typically fabricated short by a small erection clearance.

5 Whitewash is a mixture of lime and water—a paint with no binder—that is applied to a steel assembly that will be tested. In areas of yielding during testing, mill scale (tightly adherent surface rust) is released. When coated with whitewash, the mill scale flakes, taking the whitewash with it, and visually distinct patterns of yielding result.

6 No, but it can be said that the risk of failure is acceptable by common standards. As illustrated in Figure 2 (on the previous page), the statistical distributions of load and strength will always overlap by some amount. Our design methods reduce this statistical overlap so that the risk of failure is acceptably low.

7 Beveled washers are used to compensate for a lack of parallelism between the outer faces of a bolted joint as is found in such cases as a joint involving the flange of an S-shape. To do so, the beveled washer must be properly oriented in the assembled joint. The square or rectangular shape simplifies proper orientation during installation.

8 A column that is pinned at its top and bottom and does not contribute to the strength or the stability of the frame is known as a leaning column.

steelwise

THE RIGHT MOMENT

What's so special about steel special moment frames? A lot, actually.

BY JOE DARDIS, PE

DESIGNING A PROJECT in a high-seismic area? Have you thought about using steel special moment frames?

The SMF is one of a few select systems that U.S. building codes permit without restriction in buildings exceeding 160 ft in height. What truly makes the system "special" is the unique proportioning and detailing used for the beams, columns and beam-column connections. When following these special criteria, engineers can design SMFs for the most critical occupancies, even in areas with the highest mapped ground motions.

Aside from the absence of a height restriction in high seismic areas, SMFs can provide another huge benefit: architectural freedom with no braces or shear walls to hide or work around. This is also advantageous if the building ever goes through a remodel or retrofit, since the new layout will still be free from conflict with braces or shear walls. Open bays, unobstructed views and flexibility with initial and future layouts are all huge pluses.

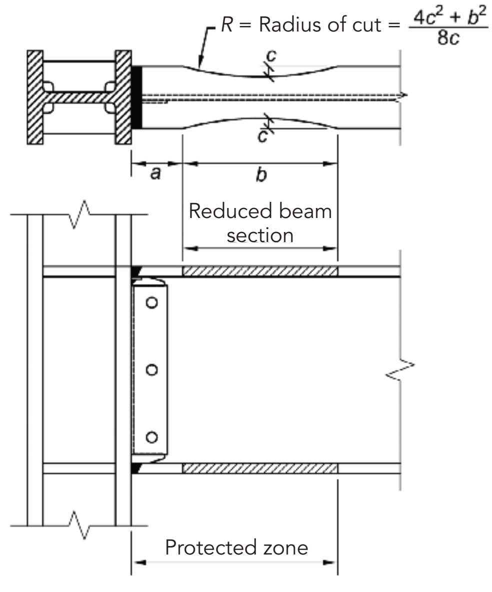
In recent years, many tall buildings with core-style construction have taken advantage of using a dual system consisting of SMFs at the perimeter and either braced frames or shear walls in the core. If the SMFs are designed to provide at least 25% of the building's lateral strength, then the building is not subject to any code height restriction in high-seismic areas (per ASCE 7-10 12.2). Otherwise, the building height is limited to 240 ft.

Inelastic Deformation

SMFs are generally expected to experience significant inelastic deformation during large seismic events. If you're not too familiar with the AISC *Seismic Provisions for Structural Steel Buildings* (AISC 341), you may be asking yourself, "Why is this a good thing?" The answer is relatively simple: Large seismic events occur at average intervals of hundreds of years, and to design every structure to remain essentially elastic as they resist such rare events would be far too expensive and impractical. Instead, we allow structural damage to occur. This implies future repair costs in the event of an earthquake, but the expected return on the life of our building stock as a whole is much higher following this design philosophy. Additionally, there is a high level of uncertainty regarding earthquake demands on a building. Providing a ductile design provides an additional level of life safety.

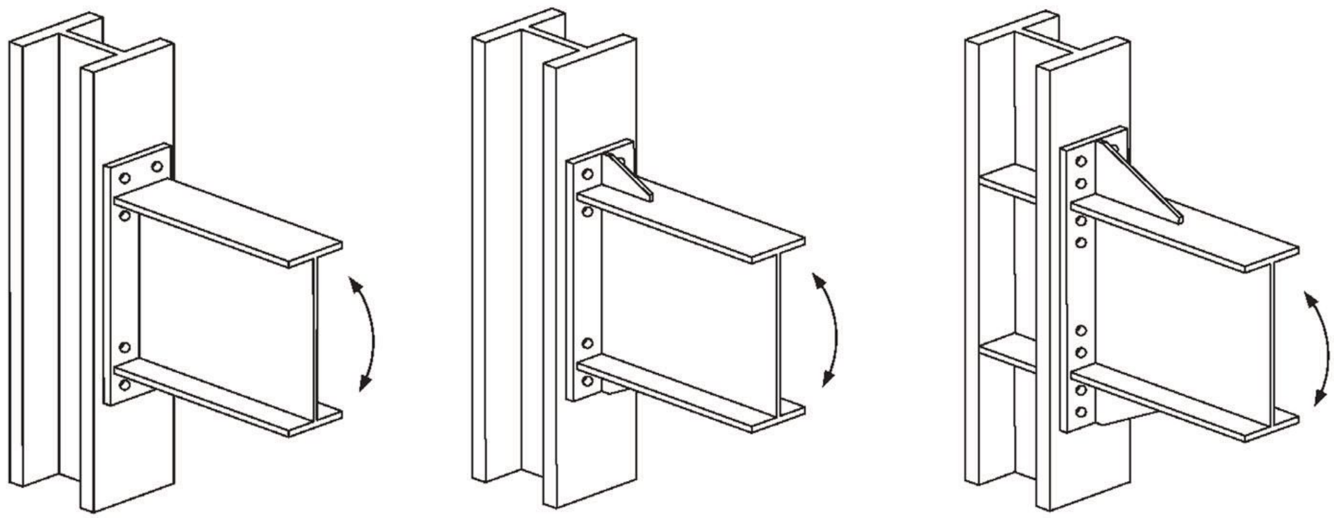
We also isolate inelastic deformation to occur at locations where it can be tolerated, usually in the beams at the beam-column joints and at column bases. AISC 358: *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* provides several connection options (shown in the various figures) that conform to AISC 341 requirements and accomplish location-specific deformation, and also explains in detail how to design each type of connection. Alternatively where desired, another connection detail can be qualified to meet the requirements in AISC 341.

SMF members and connections are configured to achieve the so-called strong column-weak beam design philosophy AISC 341 states that the sum of column flexural strengths must exceed the sum of the beam flexural strengths at each joint. This promotes a more uniform distribution of lateral drift and beam hinging over the height of the structure. It functions as a check of the column's ability to remain elastic outside of the panel zone in a strong column-weak beam design, but we recognize that there may be some inelasticity in columns because the actual distribution of seismic effects may be different from our analyses.



A reduced beam section moment connection.

Joe Dardis (dardis@aisc.org) is an advisor in AISC's Steel Solutions Center.



Extended end-plate moment connections. From left to right: four-bolt unstiffened, four-bolt stiffened and eight-bolt stiffened.

It is important to understand the strong column-weak beam design process in order to design an efficient SMF, particularly when considering drift. The sizing of steel beams in SMFs is typically drift controlled, and due to the requirements of strong column-weak beam design, the columns follow suit. When increasing beam and column sizes to control drift, one must balance the effect that increasing sizes has on tonnage and shape geometry.

Long-span frames that require deeper beam sections are more susceptible to lateral torsional buckling and therefore would typically require bracing, which makes frames with spans greater than 40 ft rarely practical. Additionally, longer-span frames are less stiff, making them more susceptible to drift. Similarly, frame spans of less than 20 ft can result in inelastic behavior in beams dominated by shear yielding as opposed to flexural yielding. AISC 358 conveniently provides span-to-depth limitations for several different connection types and also addresses the fact that deeper sections, when undergoing the same drift as a shallower section, experience larger levels of strain.

In addition to proportioning, redundancy and distributing the lateral forces over multiple moment frames will allow the use of lighter, more compact members with higher inelastic deformation capacity. In some cases, the reduced tonnage can offset the cost of the additional framework and provide additional clearance and floor space by using shallower beams and smaller columns.

Another technique used to control tonnage is the use of a deep-column section. A deep column is an economical choice that controls drift and satisfies strong column-weak beam design. AISC 358 allows the use of a column section up to 36 in. in depth. The strong axis of a deep-column section can typically provide as much capacity as a compact column section with a lower weight per foot of column length. Even after taking into account all of the great benefits of deep columns, architects are still sensitive to column depth in relation to floor space. However, the truth is that even a deep steel column will typically take up less space than a comparable concrete column.

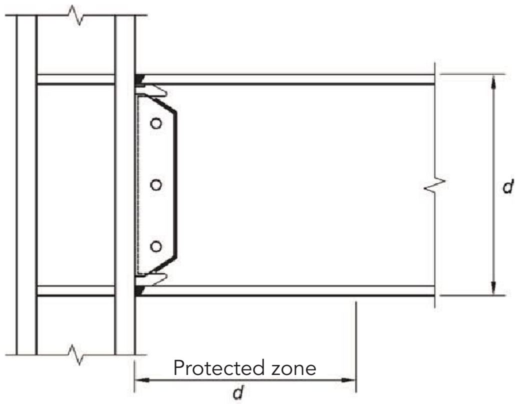
All About that Base

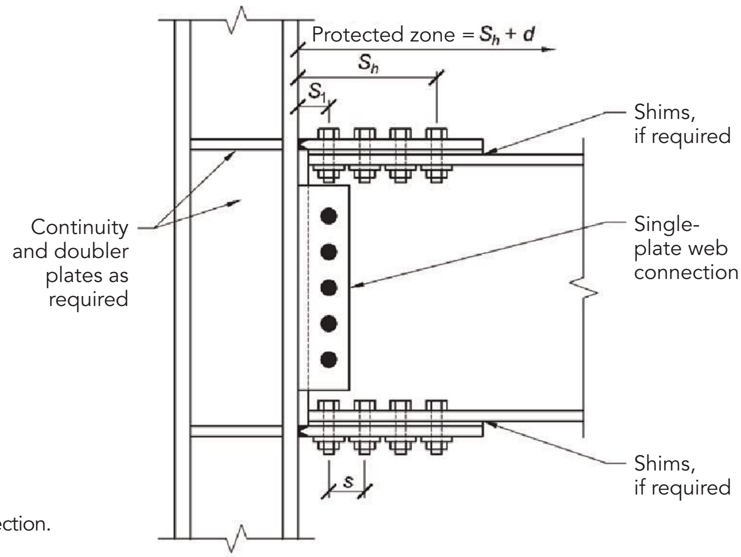
When trying to design the most economical SMF possible, it is important to consider the column base's contribution to drift. The first level of a building is typically taller than the higher floors, resulting in a larger story drift. Using a fixed-base column can significantly reduce drift at this level and subsequently overall building drift. Attention must be given to the fixed base requirements outlined in AISC 341, and following these requirements can prevent the need to increase member sizes at the first level. Similarly, if a pinned base is chosen, the engineer must still take into account large anticipated base rotations and design this connection accordingly. Note also that SMF systems typically impose smaller axial loads on foundations than other lateral systems, which may result in smaller foundation sizes.

Web doubler plates and continuity plates are other important considerations when designing for economy. Adding doubler plates will increase shop fabrication time, labor, inspection time and cost, which can be avoided by increasing the column size. As a general rule of thumb, a column size increase of 100 lb per ft will cost less than adding a doubler plate. This also will simplify the detailing of the continuity plate (stiffener) interface, which can become complicated when doubler plates also are present. Additionally, increasing size often eliminates the need for a continuity plate.

Talk to a Fabricator

You may think that moment frames are more expensive than alternative systems. Maybe so, but keep it all in perspective; a building's carpet usually costs more than the framing system! The key is to make the structural system as economical as it can be.



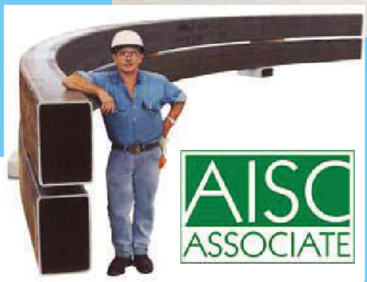


▲ A welded unreinforced flange/welded web moment connection.

➤ A bolted flange plate moment connection.

To do so, ask your fabricator for assistance. Is it more cost-effective to add redundancy and decrease member size? Will using a fixed base be more economical? Should I look at deep columns? What is the right balance between column size and doubler and continuity plates? Your fabricator can answer these and other questions and help you deliver the greatest value to a project.

You can also contact your AISC regional engineer or the Steel Solutions Center with any project-related inquiries, and we will be happy to put you in touch with a local AISC member fabricator. To find your regional engineer, visit **www.aisc.org/myregion**. And to contact the solutions center, email **solutions@aisc.org**, call 866.ASK.AISC or visit us on the web at **www.aisc.org/solutions**. ■




INTRODUCING THE NEW AND IMPROVED FASTENER STEEL KEG.
STORING AND ACCESSING FASTENERS HAS NEVER BEEN EASIER.


IMAGINE CONNECTING
AN ENTIRE PROJECT WORKFORCE WITH ONE SOLUTION
When Barton Malow Company was tasked with a $400 million reimagining of the historic Daytona International Speedway®, project engineer Jennifer couldn't let paper slow down the coordination of over 60 project partners and 1,000 trades workers. Learn how the PDF creation, markup and real-time collaboration features in Bluebeam® Revu® were deployed across the entire DAYTONA Rising workforce, streamlining communication and keeping everyone on the same page throughout this project.
Imagine the possibilities
bluebeam.com/streamlining
bluebeam®
A NEMETSCHEK COMPANY
Barton Malow
©Copyright 2016 Bluebeam, Inc. DAYTONA and Daytona International Speedway are registered trademarks and used with expressed permission.

Six cornerstones to building a culture of trust.

business issues
TRUST ISSUES

BY WALT GRASSL

ALICE AND BOB ARE BOTH SUPERVISORS at a medium-sized company.

One day over lunch, they were comparing the pluses and minuses of some of their past bosses. During the discussion, they were reminded of Greg, probably the best leader they'd ever had.

While Greg was personable and focused and set high standards, they concluded Greg's greatest quality was that he created a culture of trust.

Greg did not yell, threaten or lie to get his teams to meet short-term deadlines. He also did not, and would not, sacrifice long-term success to meet short-term deadlines.

This was in stark contrast to Mack, who was Greg's polar opposite. Mack would lie to his customers about the ability to meet accelerated schedules. In turn, he would peddle these same falsehoods to his team about a nonexistent urgent customer need to meet the accelerated schedule. The kicker? After the team rallied to accomplish its goals on a sped-up timeline, Mack would proudly—and fraudulently—claim success for their results. He abused his team for his personal gain, and the team members would leave Mack's team at the earliest opportunity.

Alice and Bob were both students of leadership and decided to compile a list of some of the things that Greg did to create a checklist for themselves as emerging leaders.

Here are six things they came up with—six things that leaders do to create a culture of trust:

1. Trusted leaders are dedicated to doing the right thing. Trusted leaders have a keen sense of right and wrong. When circumstances arise that threaten to change their moral compass, these leaders stand their ground and hold firm to their morals. They resist the urge to do the wrong thing to avoid uncomfortable situations. They do the difficult right over the easy wrong.

2. Trusted leaders keep their word. Trusted leaders keep commitments. They do what they say they will do and don't make promises they can't keep. Leaders dedicated to constructing a culture of trust place a high priority on meeting deadlines. They realize that if they don't keep their word, there is no way that they can hold others accountable for theirs. "Do as I say, not as I do" does not breed trust.

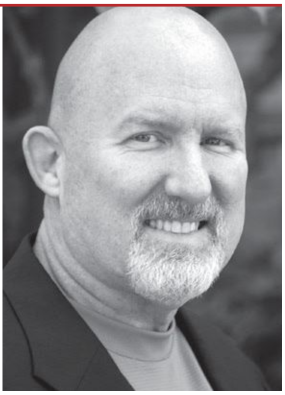
3. Trusted leaders explain the politics of the workplace. Politics exist everywhere—including the workplace. Trusted leaders are aware of the politics and make sure their team is aware of them as well. There is often tension between the needs of the bigger organization and the needs of the team. Trusted leaders seek balanced solutions. When decisions flow down from higher authorities that may not make sense to the team, they explain the politics and the big picture. When it is important, they push up the concerns of the team.

> There is often tension between the needs of the bigger organization and the needs of the team. Trusted leaders seek balanced solutions.

4. Trusted leaders do not expect blind obedience. Trusted leaders realize that trust is a two-way street. They empower their team members. They want team members to be comfortable speaking up when they don't understand something. They *insist* that they speak up when they see a potential problem. Should someone make an error in judgment, it becomes a teaching moment, not an inquisition. This is the highest form of trust.

5. Trusted leaders focus the credit on deserving team members. When a team is successful, leaders are immediately recognized for the success of their teams. Trusted leaders shine the spotlight of success on *deserving* team members. They don't hog the spotlight. They publicly recognize their team members so that others may know who they are. That improves their opportunities for advancement. They don't use the "peanut butter" approach

Walt Grassl is a speaker, author and performer. He hosts the radio show "Stand Up and Speak Up" on the RockStar Worldwide network and has performed stand-up comedy at the Hollywood Improv and the Flamingo in Las Vegas. Visit **www.waltgrassl.com** for more information.



and spread credit around to everyone equally—even the undeserving. When they share the spotlight, it does not take away from the leader's prestige. It greatly improves the relationship with the team.

6. Trusted leaders accept the blame when the team fails. Trusted leaders do not create scapegoats. They live by the old maxim "The buck stops here." When things don't go well, they step up and accept the blame. Team members that report to these individuals know that they will not be thrown under the bus in the event that a project does not turn out the way it was intended. To the extent that a team member's behavior or judgment contributes to a lack of success, these leaders will *privately* correct them. They investigate and analyze to find the root cause of the problem and then publicly address opportunities to improve, provide training if needed and/or introduce process improvements.

> When an employee makes an error in judgment, it should become a teaching moment, not an inquisition.

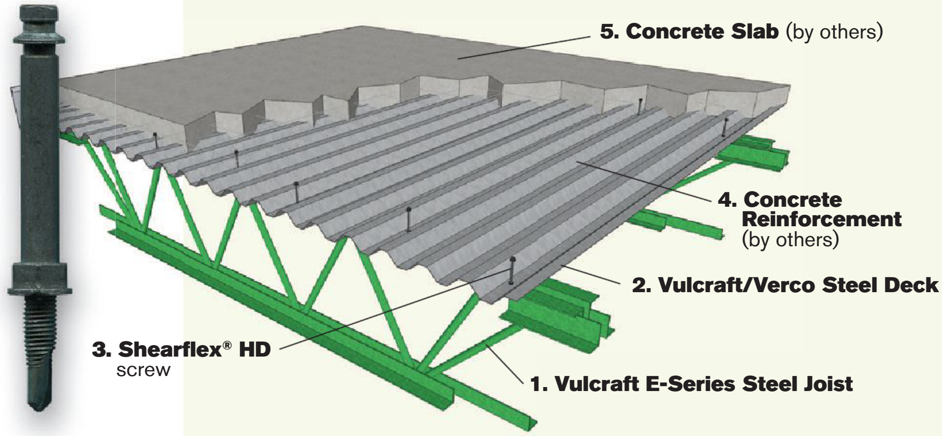
Alice and Bob became accountability partners in trust. Once a month they would meet for lunch and review the six cornerstones, and share when they had the opportunity to practice and where they might have missed opportunities. Their leadership skills improved. They had higher levels of trust with their teams. Team morale improved and their teams became more successful.

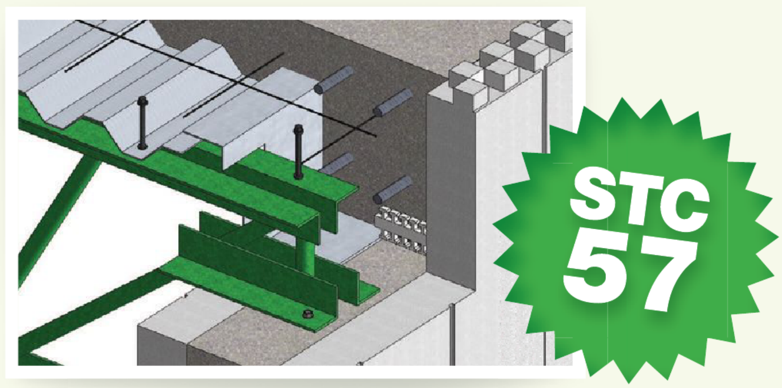
At the end of the day, we all want to trust our leaders and our teammates. Creating a culture of trust is one of the most important roles of a leader. ■

CAN A STRUCTURAL FLOOR SYSTEM BE **EASY** TO INSTALL, **COST-EFFECTIVE** AND **GREEN?**

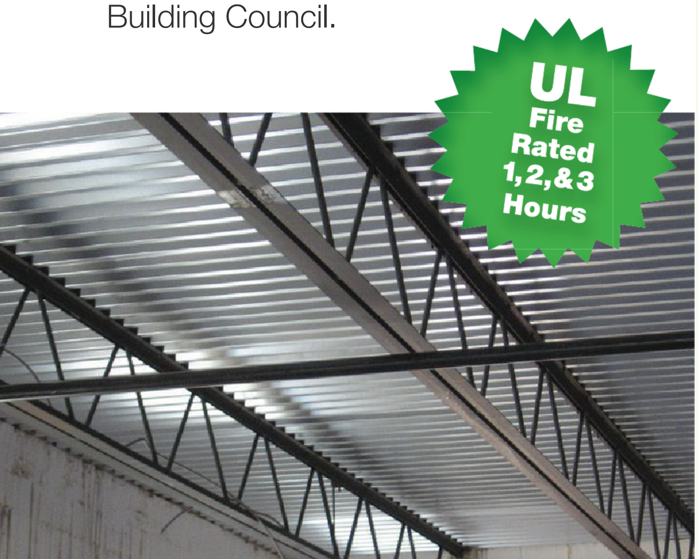
YES.

Ecospan is an innovative, simple, and economical solution for elevated concrete floor and roof systems. The Ecospan Composite Floor System offers all these advantages and more. A safe, innovative choice, Ecospan helps reduce building costs while offering the benefits of sustainable building materials that qualify for LEED® certification through the U.S. Green Building Council.





Ecospan is perfect for ICF wall framing systems (Insulated Concrete Forms)



Ecospan is the natural choice for:

- Senior Living and Care Facilities
- Apartments
- Condominiums
- Student Housing
- Military Housing
- Hotels and Resorts
- Medical Facilities
- Office Buildings
- Mezzanines
- Schools

THE VULCRAFT BIM EVOLUTION

NUCOR® VULCRAFT/VERCO GROUP

ECOSPAN® COMPOSITE FLOOR SYSTEM

Ecospan Composite Floor System
Nucor Vulcraft National Accounts
6230 Shiloh Road, Suite 140
Alpharetta, GA 30005
(678) 965-6667
888-375-9787

www.ecospan-usa.com

San Francisco's new Zuckerberg General Hospital effectively combines state-of-the-art seismic engineering and medical technology with features designed to provide compassionate care for patients.

Engineering the HEART of the City

BY LUKKI LAM, SE, AND ERIC KO, SE

Lukki Lam (lukki.lam@arup.com) is a senior structural engineer with Arup and the project engineer for Zuckerberg San Francisco General Hospital and Trauma Center. **Eric Ko** (eric.ko@arup.com) is a principal with Arup, project director and structural engineer of record.

SAN FRANCISCO GENERAL HOSPITAL came into being not long after the gold rush of 1849.

More than a century-and-a-half later and following several expansions, its latest iteration was helped along by and named for a pioneer of a different sort of gold rush—the social media boom—Facebook founder Mark Zuckerberg. Along with wife Priscilla Chan, Zuckerberg provided $75 million in funding for the new facility, the Zuckerberg San Francisco General Hospital and Trauma Center (ZSFGH).

Located at the foot of Potrero Hill in San Francisco's Mission District, the new 284-bed hospital is a 550,000-gross-sq.-ft steel-framed, base-isolated building with seven stories above grade and two basement levels. The facility replaces the most recent SFGH, which was built in 1974 and did not comply with the seismic safety requirements set out in California Senate Bill 1953 (passed in 1994). The new general acute care facility, which opened this past spring, provides the most up-to-date equipment and technology in full diagnostics and treatment departments, while doubling the capacity of the new emergency department.

Tim Griffith

Patrik Argast

▲ The new Zuckerberg San Francisco General Hospital and Trauma Center is a steel-framed, base-isolated seven-story building.

▲ A 35-ft-diameter steel halo sculpture stands at the ground-level entry of the hospital campus.

Base Isolation

ZSFGH is the only Level 1 trauma center in San Francisco County, so its seismic resiliency is paramount. The project team decided early in the design process to integrate base isolation—one of the most advanced earthquake-resistant methods in use today—in the design of the steel-framed building. Steel is an ideal framing material for a base-isolated structure because steel-framed floors are relatively lightweight, greatly reducing the demands—especially uplifts—on the base isolators and foundations. The steel superstructure is supported on 115 triple-pendulum bearings (manufactured by Earthquake Protection Systems), a pioneering isolator type that allows the building to slide 30 in. in any direction. Around the perimeter of the building, a 3-ft-wide moat between the top of the mat foundation and the finished grade accommodates movement of the isolated structure. In the event of a major earthquake, the new hospital is designed to remain fully operational and serve as an emergency response center.

This project challenged the common perceptions that base-isolated buildings are too expensive or take too long to build, proving that with proper planning and close collaboration among team members, base isolation can be a cost-effective system to integrate into a building without increasing the project schedule. For ZSFGH, the City adopted integrated project delivery (IPD), assembling the design team and general contractor to work collaboratively during design, which helped to compress the project schedule to meet the Senate Bill 1953 deadline.

The IPD method facilitated a number of cost- and time-saving strategies. For example, the design team implemented prototype bearing testing in the early design phase of the project, which was made possible by efficiently identifying the best bearing type and isolator sizes for the project. Following the city's successful commissioning of early prototype bearing testing, the team used the prototype testing results to optimize the superstructure design. This strategy led to early procurement of the

The cruciform-shaped steel column base was shop-welded, while the moment connections to the adjoining beams were field-bolted to eliminate self-straining stresses due to weld shrinkage.

The steel-framed superstructure is relatively lightweight and reduces demands on the base isolators and foundations.

isolators and an early steel bid package, as well as significant cost and material savings when it came to the structural steel.

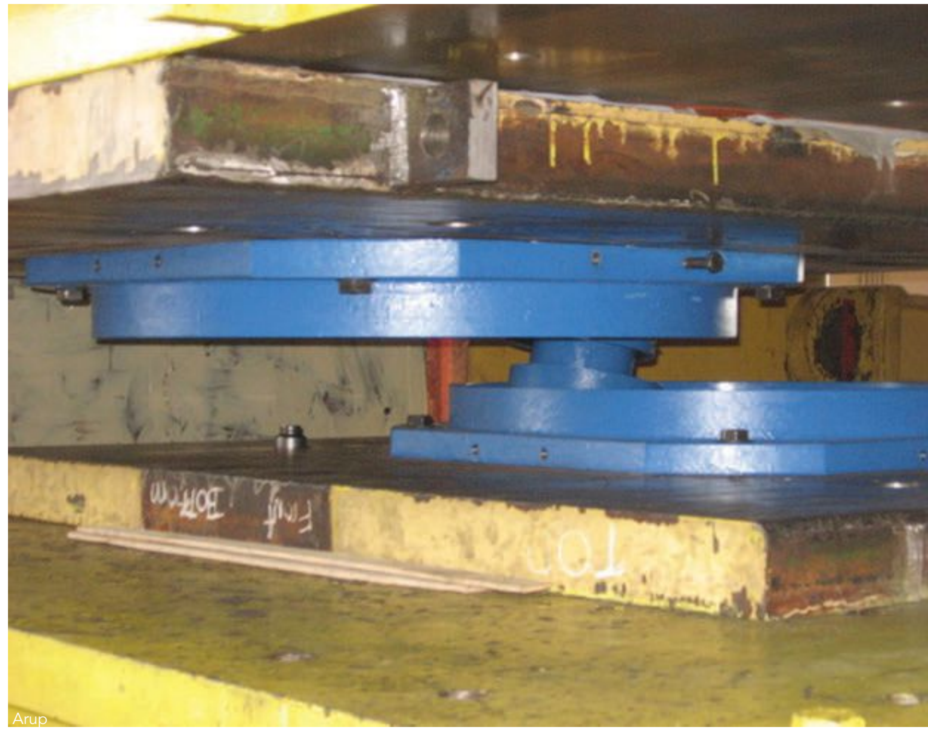
It's also important to note the benefits that the project's base-isolated design has over a conventional fixed-base design, including performing much better in a major earthquake, better protecting the building's contents and allowing the superstructure to withstand maximum-considered-earthquake-level earthquakes and remain elastic. In a fixed-base design, the moment frame connections would yield, and replacing them would be difficult and expensive, resulting in significant downtime. In addition, floor accelerations in the base-isolated hospital are significantly reduced, which results in lower demands on the anchorage and bracing for equipment and nonstructural elements.

Compared with a conventional fixed-base design, the base-isolated design also used significantly less steel—as in 3,000 tons (the project used 8,500 tons of steel in all). A fixed-base design would have also required deeper columns and beams, thus limiting the space available for utilities and make coordination more difficult. Base isolation allowed steel intermediate moment frames to be used for the superstructure, and a fixed-base building would have had to meet requirements for steel special moment frames, leading to additional building costs.

Superstructure

The hospital has two distinct floor plans: a four-story rectangular podium and a five-story bed tower comprising two interlocking circular cylinders bisected by a parallelogram core. The glazed cylindrical tower houses the patient rooms and support spaces, while the brick podium houses the diagnostic and treatment departments. The framing system uses composite flooring supported by steel beams and girders, which in turn are supported on steel wide-flange and built-up cruciform columns.

➤ A triple-pendulum bearing was subjected to lateral displacement during the prototype testing.



Arup

Arup

▲ Prototype bearing testing early in the design phase.

Webcor Builders

➤ The building is supported on 115 of these bearings, allowing it to slide 30 in. in any direction.

As the building transitions from the rectangular podium to the cylindrical tower, transfer beams of W36 sections are used at levels 2 and 3 to receive the W10 columns supporting the in-patient beds and rooftop garden in the cylindrical tower above.

To accommodate ZSFGH's ambitious program and the significant amount of overhead utilities typically required in a hospital, steel moment frames were selected in lieu of braced frames or shear walls, as the lateral resistance system to create more space for an efficient health-care floor layout. The moment frame beams are W27 and W36 sections, and the moment frame columns consist of W27 and W36 wide-flange columns and flanged cruciform columns for orthogonal moment frames. High-strength steel plate (65-ksi) is used for built-up wide-flange columns at selected locations for increased capacity.

Constructability was a central focus when designing the steel details of the new hospital, exemplified by the steel column base detail. Cruciform-shaped steel column bases are placed above the isolators to resist the offset between the superstructure and the isolators that occurs when the isolators undergo large displacement. The cruciform column bases are shop-welded and delivered to the site as modular assemblies, which enhanced installation and saved time in the construction schedule. In addition, splices of the beams adjoining to the cruciform assemblies are field-bolted moment connections—not welded—in order to eliminate the self-straining stresses due to weld shrinkage that would impose on the structure.

In the X-ray, radiology, resuscitation and operating rooms—where the overhead ceiling spaces are the busiest—a steel overhead-equipment-support modular grid supports all of the overhead medical equipment such as lights and booms. The modular grid is composed of horizontal HSS4×3 and HSS3×3 sections forming an orthogonal grid, which is hung from the floor beams above through

Steel canopies at the top of the sunshade fins are visible from the rooftop terrace garden (left). Overhead medical equipment is supported by a steel modular grid hung from the floor beams above (right).

unistrut drops. Unistrut bracing provides lateral stiffness for the support grid, and this modular grid facilitated the coordination and installation of utility runs, ductwork and equipment supports in these vital rooms.

Exposed Steel

A number of exposed structural steel components are featured on the hospital campus. A vertical fin sunshade structure, built from HSS8×8 steel sections, was placed on the south- and west-facing facades of the podium structure. The sunshade elements are oriented according to the path of the sun and are painted in bright white. Expressive steel canopies at the top of the curved facade's sunshade fins are also visible from the rooftop terrace garden, which is open to the public.

A steel halo sculpture—a 35-ft-diameter ring cantilevered off of two 16-ft-tall columns—stands prominently at the ground-level entry of the hospital campus. The halo is built from 14-in.-diameter stainless steel pipe sections, with the ring and elbows fabricated to fit the architect's curved geometry design. On the opposite side of the campus, a trussed pedestrian bridge with exposed HSS6×6 provides the important pathway between the new hospital building and the original medical facility at the second floor.

Heart of Gold

The material-saving base isolation system is one of the sustainable design features expected to earn the hospital a LEED Gold certification. Other green features include the use of building materials containing at least 30% recycled content, including steel, ceiling tiles, porcelain tiles,


Perretti and Park

Perretti and Park

A trussed pedestrian bridge links the new hospital building to the original medical facility (left). The new base-isolated building on the left serves as a replacement of the original main hospital on the right (right).

terrazzo flooring and Forest Stewardship Council-certified wood. The hospital also features full-height curtain walls that use low-emissivity glass and insulation to protect against heat gain, as well as window shades and room lighting fixtures that are automatically adjusted based on sunlight levels as detected by photovoltaic sensors.

Financed by an $887.4 million voter-approved bond, as well as a record number of significant donations, ZSFGH is a city lifeline that, according to Mayor Ed Lee, "represents San Francisco's values at their best, and demonstrates that our city is a leader in innovation and compassion… for creating a world-class, seismically safe, technologically advanced and sustainably built hospital for all San Franciscans"—truly the beating heart of a vibrant city. ■

Owner
San Francisco Department of Public Health

General Contractor
Webcor Builders, San Francisco

Architect
Fong and Chan Architects, San Francisco

Structural Engineers
Arup in collaboration with Bello and Associates Structural Engineers, a Local Business Enterprise participant, San Francisco

Steel Team

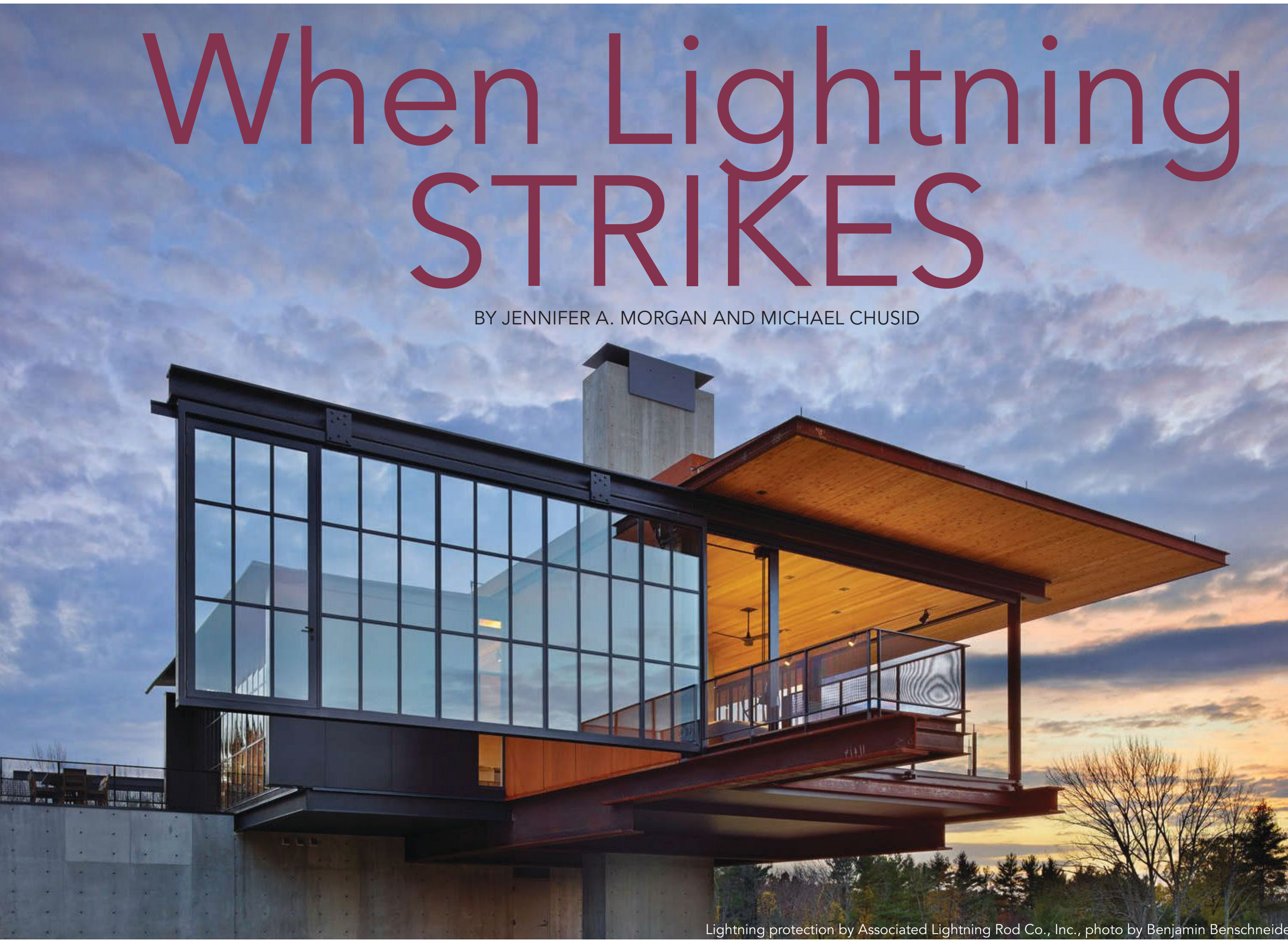
Fabricator and Erector
The Herrick Corporation, (AISC Certified Fabricator and Erector) Stockton, Calif.

Detailer
Candraft Detailing, Inc., (AISC Detailer) New Westminster, B.C., Canada

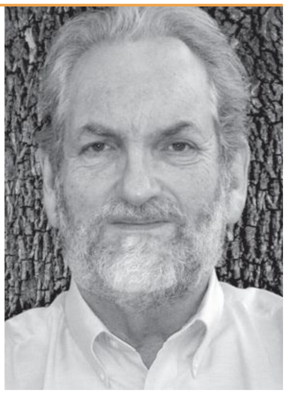
A lightning-protection system can add value to steel framing and resilience to an entire building.

When Lightning STRIKES

BY JENNIFER A. MORGAN AND MICHAEL CHUSID



Lightning protection by Associated Lightning Rod Co., Inc., photo by Benjamin Benschneider



Jennifer A. Morgan is secretary/treasurer at East Coast Lightning Equipment, Inc., and an officer of the Lightning Safety Alliance (LSA). **Michael Chusid** is an advocate for improvements in building materials and design practices. The authors are LSA-certified to present continuing education programs about lightning protection.

LIGHTNING HAPPENS.

And designers and builders can take advantage of steel's electrical conductivity to get extra value from the structural framing system. That's because it typically costs less to install lightning protection systems in buildings with structural steel frames compared to concrete, wood and other less electrically conductive materials.

Lightning-protection systems (LPSs) require a network of electrically conductive paths to safely transmit a lightning strike's 300 million volts from rooftop air terminals—formerly called lightning rods—to ground electrodes. In most buildings, lightning's energy is conveyed through large, multi-strand cables made from highly conductive grades of copper or aluminum. However, the cost of cables, connectors and fittings, plus installation labor, can be reduced by using the structural steel framing as conductors.

National Fire Protection Association (NFPA) 780, 2017 ed.–*Standard for the Installation of Lightning Protection Systems*, Paragraph 4.19.1 states:

Lightning protection by Burch[illegible] Lightning Protection Ltd., Photo by Udo Dengler

◄ Air terminals are required on the wood-framed roof of this residence by Olson Kundig Architects in the Berkshires. But the steel chimney cap and cantilevered beam do not require air terminals; they are connected to the grounding system and act as strike termination devices. The beam supports a trolley-mounted glass wall that can be rolled into place to seal the house against weather.

▲ The steel framing of Toronto's L Tower was used as lightning conductors reaching more than 670 ft from crown to grade. This eliminated the expense of running Class II down conductor cables and intermediate equalization loops around the structure's girth. The building's curved shoulder required special calculations to determine acceptable spacing of the air terminals. The building is designed by Studio Libeskind and structural engineer Jablonsky, Ast and Partners.

> "The metal framework of a structure shall be permitted to be utilized as the main conductor of lightning protection system if it is equal to or greater than ³⁄₁₆ in. (4.8 mm) in thickness and is electrically continuous, or made electrically continuous…"

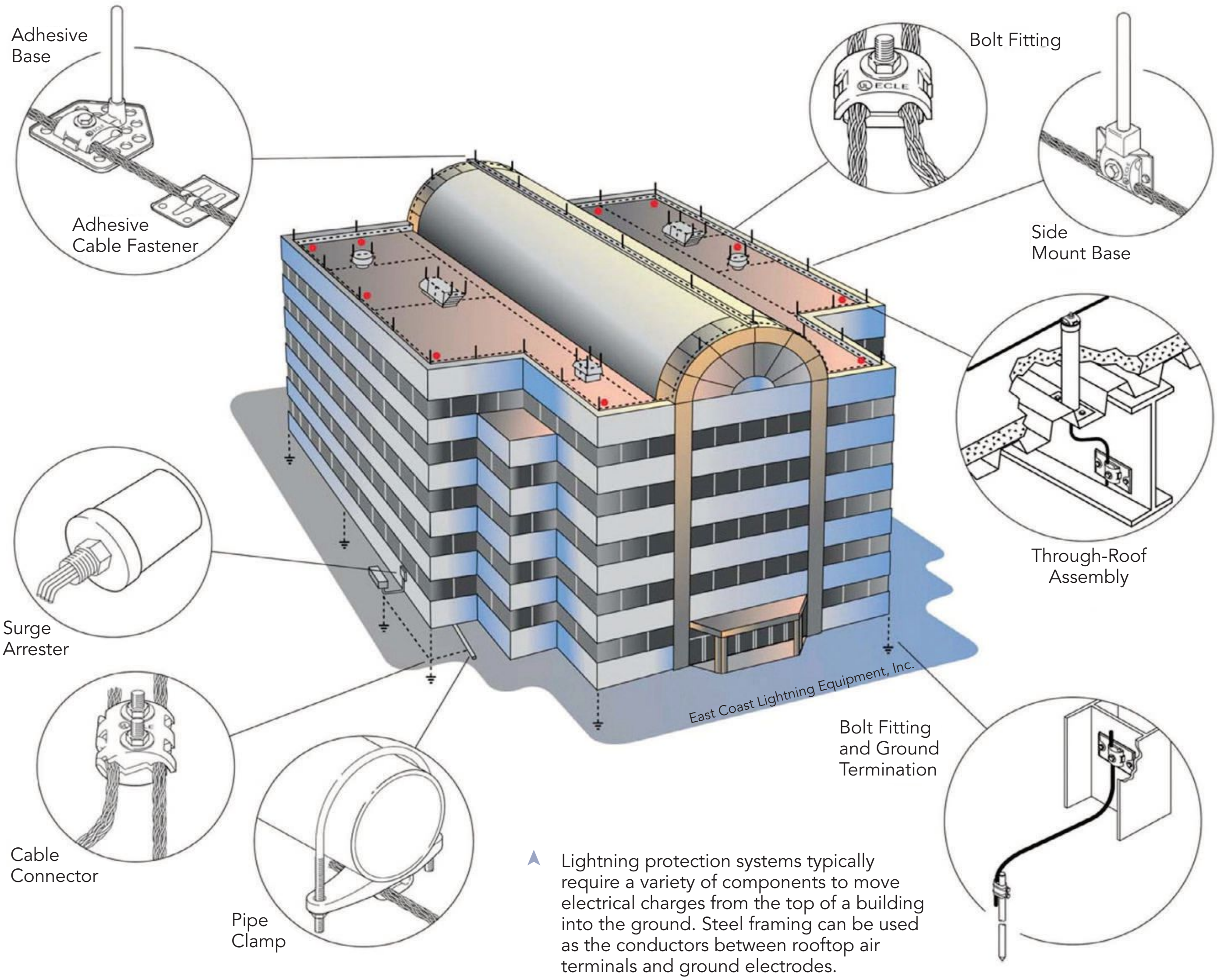
Under special situations, even thinner metal can be used. NFPA 780 Paragraph 4.9.3.2 allows exposed roof-top steel handrails and ladders to be used as main conductors if they are at least 0.064 inch (1.63 mm) thick. (Note that components of a lightning protection system should comply with UL 96–*Standard for Lightning Protection Components* and be listed by UL. Components listed for ordinary electrical service are not safe for lightning protection.)

While steel framing can be used to interconnect air terminals and other roof level equipment, doing so could require many penetrations through the roofing. Instead, cables are used to interconnect items on the roof and then lead to special through-roof penetration devices. Under the roof deck, cables connect to down conductors that extend to the bottom of the building.

It is when steel framing is used as down conductors that it shows its mettle. NFPA requires at least two widely separated down conductors on a structure—or if the building perimeter exceeds 250 ft, a down conductor for each 100 ft of perimeter. Steel framing can therefore eliminate the expense of installing many down conductor cables in a large building.

Cost savings are even greater on structures over 75 ft in height. Considered Class II buildings by NFPA, they require down conductor cables with larger cross-sectional areas. Steel-framed buildings are also exempt from Class II requirements for intermediate cables around a building's girth for electrical potential equalization loops.

At grade level, framing needs to be connected to ground electrodes at spacings that "shall not average more than 60 ft apart," as stated in UL 96A–*Installation Requirements for Lightning Protection Systems.* Coupled with the requirement to widely separate grounding points, this commonly means grounding every other column around the building perimeter. It also means that the steel frame may require more LPS connections at grade than at the roof. For example, a building with a 250-



Lightning protection systems typically require a variety of components to move electrical charges from the top of a building into the ground. Steel framing can be used as the conductors between rooftop air terminals and ground electrodes.

ft perimeter may require four or five ground terminations but only three connections at the roof level.

If, for some reason, cables are used for down conductors, it may still be necessary to bond steel structural elements and metal bodies to the LPS. Seeking the path of least resistance from sky to ground, lightning will arc or side-flash from conductors into electrical, plumbing, HVAC and other metallic systems—including structural framing—if electrical potential is not equalized between all grounded systems.

Detailing

If steel is used as conductors, NFPA 780 requires the following:

- 4.19.3 Connections to framework. Conductors shall be connected to areas of the structural steel framework that have been cleaned to base metal, by use of bonding plates having a surface contact area of not less than 8 sq. in. or by welding or brazing.
- 4.19.3.1 Drilling and tapping the steel column to accept a threaded connector also shall be permitted.
- 4.19.3.2 The threaded device shall be installed with five threads fully engaged and secured with a jam nut.
- 4.19.3.3 The threaded portion of the connector shall be not less than ½ in. in diameter.
- 4.19.3.4 Bonding plates shall have bolt-pressure cable connectors and shall be bolted, welded or brazed to the structural steel framework so as to maintain electrical continuity.
- 4.19.3.5 Where rust-protective paint or coating is removed, the base steel shall be protected with a conductive, corrosion-inhibiting coating.

Using steel as conductors can eliminate the need for some through-structure penetrations and trade coordination issues where cables pass through floors or walls. Exposed cables can be damaged or stolen for scrap, and concealing cables incurs the cost of applying finishes.

The LPS grounding system is much more robust than the building's electrical grounding system and therefore must be grounded separately from the electrical grounding system. Steel pilings may be able to serve as the lightning protection ground.

Using structural members for conductors can also be useful when retrofitting an LPS on an existing building. For example, at the Virginia Museum of Fine Arts in Richmond, Va., existing

From air terminals above the roof, lightning travels via a roof-penetration device to a cable and bolted connection into the steel framing (left). At column bottom, an exothermic weld connects a cable leading to ground electrodes (right).

steel columns provided electrical continuity between new rooftop air terminals and ground electrodes—without damaging interior finishes.

Strike Termination Devices

Air terminals rise above a building to intercept lightning before it reaches the structure. Lightning is modeled as a 300-ft diameter sphere being rolled over a building's envelope; anywhere the sphere touches the building is susceptible to becoming lightning's attachment point. Based on this, NFPA 780 requires air terminals at roof corners and 20 ft on center along roof ridges and edges, on top of roof top equipment that is not within the zone of protection of an air terminal mounted higher on the structure and 50 ft on center through the field of the roof.

Air terminals are not highly visible from the ground. They can be as slim as 3/8 in. in diameter, just 10 in. tall and set up to 24 in. in from roof edges. Light colored air terminals—either aluminum or plated copper—reflect and blend into the sky. Yet there are locations where a traditional air terminal might be visually or functionally objectionable.

NFPA 780 Paragraph 4.6.1.4 allows air terminals to be replaced by other strike termination devices made from metal at least 3/16 in. thick. Examples of strike termination devices include:

- Structural elements such as pylons or exposed trusses and beams that rise above the roof.
- Railings around balconies and terraces where air terminal might

Credit: Priestley Lightning Protection, LLC

Steel components must be 3⁄16 in. thick to be used as conductors. Framing this wood-framed corner was simplified and visually cleaner by not having to run a full-height cable. Conductors can contact wood and other combustible materials because they are sized to create a low-resistance path that does not get hot during a momentary lightning surge.

interfere with views or be subject to damage due to proximity to pedestrians.

- Rooftop structures such as sculptures, decorative elements or equipment screens are fabricated metal.
- At the supertall 432 Park Avenue residential tower in New York City (nearly 1,400 ft tall), parapet caps made from metal plate are being used instead of vertical air terminals to comply with strict enforcement of building height limitations.
- Helipads and other structures with exposed metal framing.

These fabrications must be electrically continuous and connected to the building ground.

Resilience

As lightning strikes increase in frequency thanks to changing weather patterns (in large part due to climate change) LPSs are on the rise. The growing use of electronic devices and the internet of things also make buildings more vulnerable to lightning

The steel turret atop Le Méridien-MIT Hotel in Cambridge, Mass., acts as a strike-termination device and is connected via the LPS to ground. A conventional air terminal is visible on the parapet in the lower-left corner of the left photo.

surges. According to insurance industry estimates, lightning results in $1 billion of residential insurance claims and $108 million in direct property damage to nonresidential buildings. These estimates are conservative since damage caused by lightning surges can be misattributed. Lightning can accompany tornadoes, hurricanes and floods, and lightning protection programs must be considered as part of building and community resilience.

Lightning protection is not mandated under national building codes but is required in some local codes, by government agencies and by an increasing number of sophisticated building owners. It is the design professional's responsibility to evaluate the need for LPS and advise his or her client accordingly. For example, American Institute of Architects document AIA D200–*Project Checklist* requires designers to "obtain seasonal climate and microclimate data from the weather service" as part of site analysis.

Structural engineers should ask their clients and design team members about lightning protection during design development so it can be taken into account when selecting a building's structural system and subsequent detailing.

NFPA 780 Appendix L contains a simplified lightning risk assessment with criteria for assessing a building's vulnerability to lightning and tolerance for damage. Calculations can be performed online in just a few minutes at **www.ecle.biz/riskcalculator**.

A Lightning-Protection Installer Speaks

Justin Harger, is certified as a Master Installer-Designer by the Lightning Protection Institute. He is executive vice president for HLP Systems, Inc., and has installed lightning protection systems on many major buildings in the Chicago area and the Midwest. He shared these thoughts:

In our market, LPSs on mid- to high-rise steel-framed buildings are 20% to 30% less expensive than on a reinforced concrete structure. The cost advantage is lower on low-rise buildings, but it still can be found when dealing with complex structures.

For connections between lightning-protection components and structural steel, we use UL-listed clamps or exothermic welds depending on the requirements of the specifications and the project. On most projects we make connections to bare steel and prior to fireproofing. The standards do not have specific testing or resistance requirements for the electrical continuity of the framing, but the necessary continuity is there due to steel-to-steel contact. Occasionally, we have to provide jumper cables if continuity is broken by epoxy coatings or other conditions, but that is rare.

Structural steel gives the most flexibility to an LPS, in my opinion. It is easier to conceal, install and maintain an LPS on steel buildings. Grounded structural steel is very versatile in allowing for changes to the LPS that might be required down the road. It is also far easier to incorporate architectural elements into the design of the lightning protection as such elements are often already connected to the structural steel and require very little work by the lightning-protection installer. That means less expense to the building owner and less visual impact to the architectural design.


Bonded Lightning Protection Systems, Inc.

Loehr Lightning Protection Co.

▲ Steel railings act as a strike termination device around this mechanical equipment penthouse at a Florida hospital. The UL-listed cable at the bottom of railing connects it to the rest of the lightning penetration system.

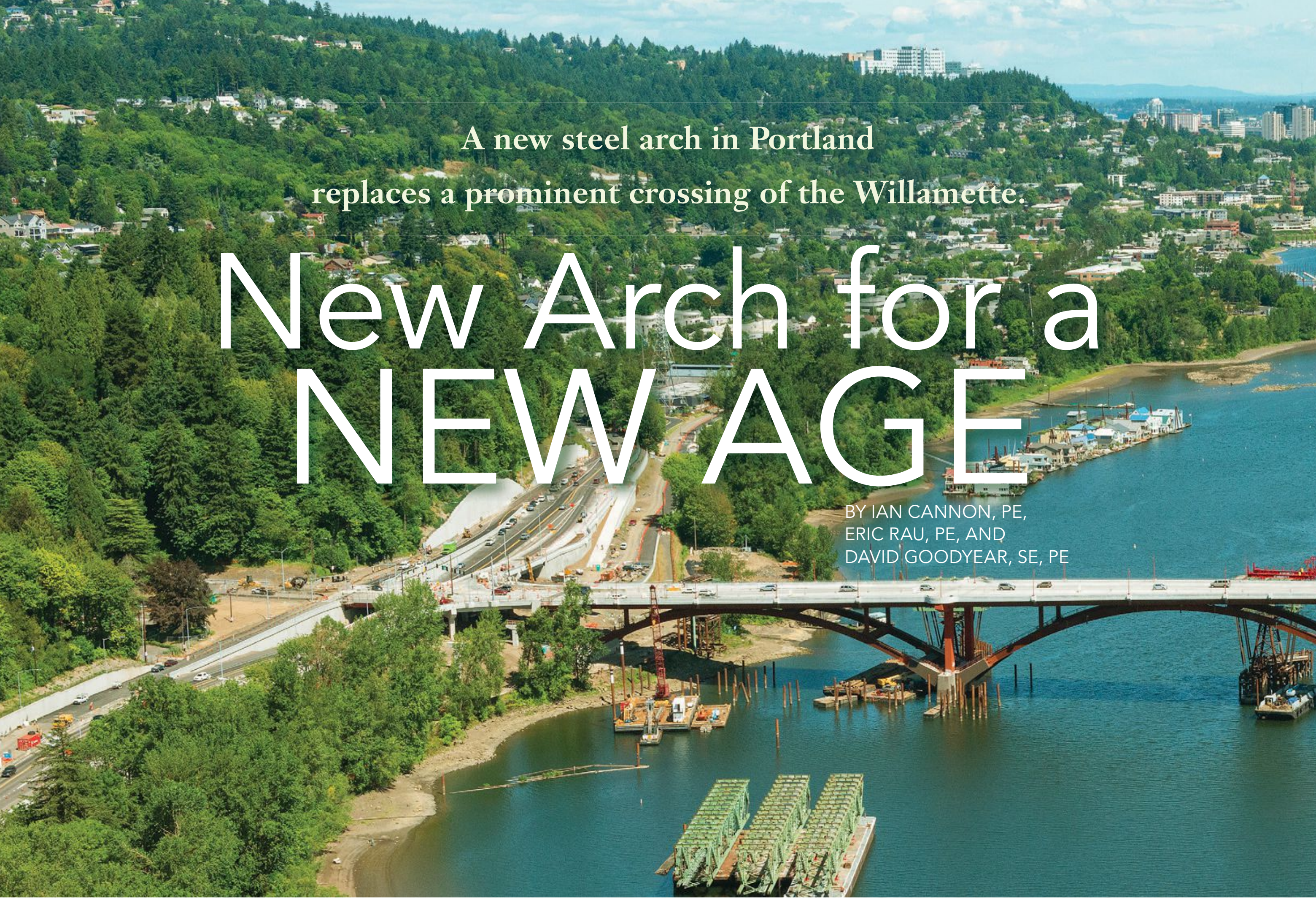
◄ Existing steel columns were used as down conductors when lightning protection was installed on the existing Virginia Museum of Fine Art. Openings in the brick fire protection were made so that cables, leading to ground electrodes, could be fixed to the steel with bolted copper fittings. The fitting was sealed and painted to provide additional corrosion protection.

Project specifications usually delegate LPS design to installers employing a Master Designer-Installer certified by the Lightning Protection Institute (LPI). In addition to NFPA standards, specifications should require compliance with UL and LPI standards. The general contractor should meet with the steel erector and lightning protection installer to coordinate locations of and scheduling for installation of penetrations and other connections. Finally, third-party inspection services are available through UL and LPI-Inspection Program and should be part of the building commissioning process. A nonproprietary, CSI-formatted guide specification can be downloaded at **www.constructionspecifier.com/lightning-specs**.

And of course, there's the ever-present issue of money, so it's important to point out that lightning protection provides affordable security; a construction cost study of nonresidential buildings five stories or less found that LPSs cost between $0.30 and $0.60 per sq. ft of floor area. Additionally, a system can last the life of a building with little maintenance expense, and its metallurgical value can be recovered at the end of a building's life cycle. (Download cost study at **www.ecle.biz/coststudy**.)

Even so, designers and builders can seize economies when they present themselves. Steel framing plays a vital role in protecting structures, their contents and their occupants against wind storms, earthquakes, flood surges and other ravages of nature. It is comforting to know that steel can also play an important role in protection against lightning without adding to the cost of the framing. ■

For a more complete architectural overview of lightning protection, see "Lightning Protection and the Building Envelope" in the August 2015 issue of Construction Specifier, *available at* ***www.ecle.biz/constructionspecifier***.



A new steel arch in Portland replaces a prominent crossing of the Willamette.

New Arch for a NEW AGE

BY IAN CANNON, PE, ERIC RAU, PE, AND DAVID GOODYEAR, SE, PE

TWO OUT OF 100.

That was the National Bridge Inventory (NBI) sufficiency rating that the 90-year old Sellwood Bridge received in 2005 after the latest round of engineering studies, emergency repairs and additional load restrictions. Multnomah County, Ore., the owner of the bridge, was keenly aware that shoring up the old bridge was no longer an option.

Constructed in 1925 to replace the Spokane Street Ferry, the Sellwood Bridge spans the Willamette River just south of downtown Portland. It was designed by Gustav Lindenthal, a noted bridge engineer of the time and—along with the nearby Ross Island and Burnside bridges—was built with funds from a $4.5 million local bond measure.

Lindenthal was hired to redesign the Sellwood Bridge as a result of cost overruns on the Burnside Bridge. The result was a unique and efficient four-span continuous steel truss costing a mere $541,000. At 32 ft wide, the bridge was extremely narrow: two lanes, no shoulders or median and one 4-ft-wide sidewalk. It was Portland's first "fixed span" bridge across the Willamette and the first to not be designed for streetcars.

The NBI rating of 2 for the old bridge reflected a number of critical issues ranging from movement of an ancient landslide on the west bank of the Willamette to general deterioration of the 90-year old concrete approach structures.

The County began the NEPA (National Environmental Policy Act) process in 2006, and an engineering team of CH2M and T.Y. Lin International (TYLI) was retained to perform the engineering studies and develop alternatives for a new crossing. The evaluations included rehabilitation and replacement options for the main bridge, a dozen structure types for the main crossing and various

Ian Cannon (**ian.b.cannon@multco.us**) is Multnomah County's transportation director and program manager of the Sellwood Bridge project, **Eric Rau** (**eric.rau@tylin.com**) is a bridge engineer with TYLI and **David Goodyear** (**david.goodyear@tylin.com**) is TYLI's chief bridge engineer and the lead bridge engineer for the Sellwood Bridge project.

The new Sellwood Bridge over the Willamette River near downtown Portland, Ore., replaces a more-than-90-year-old span that had become unusable.

alignments and project configurations. The recommendation was replacement on the same alignment, and through an active and meaningful public outreach process, the Community Advisory Committee's (CAC) preferred alternative—a steel deck arch—was approved by the County Board of Commissioners.

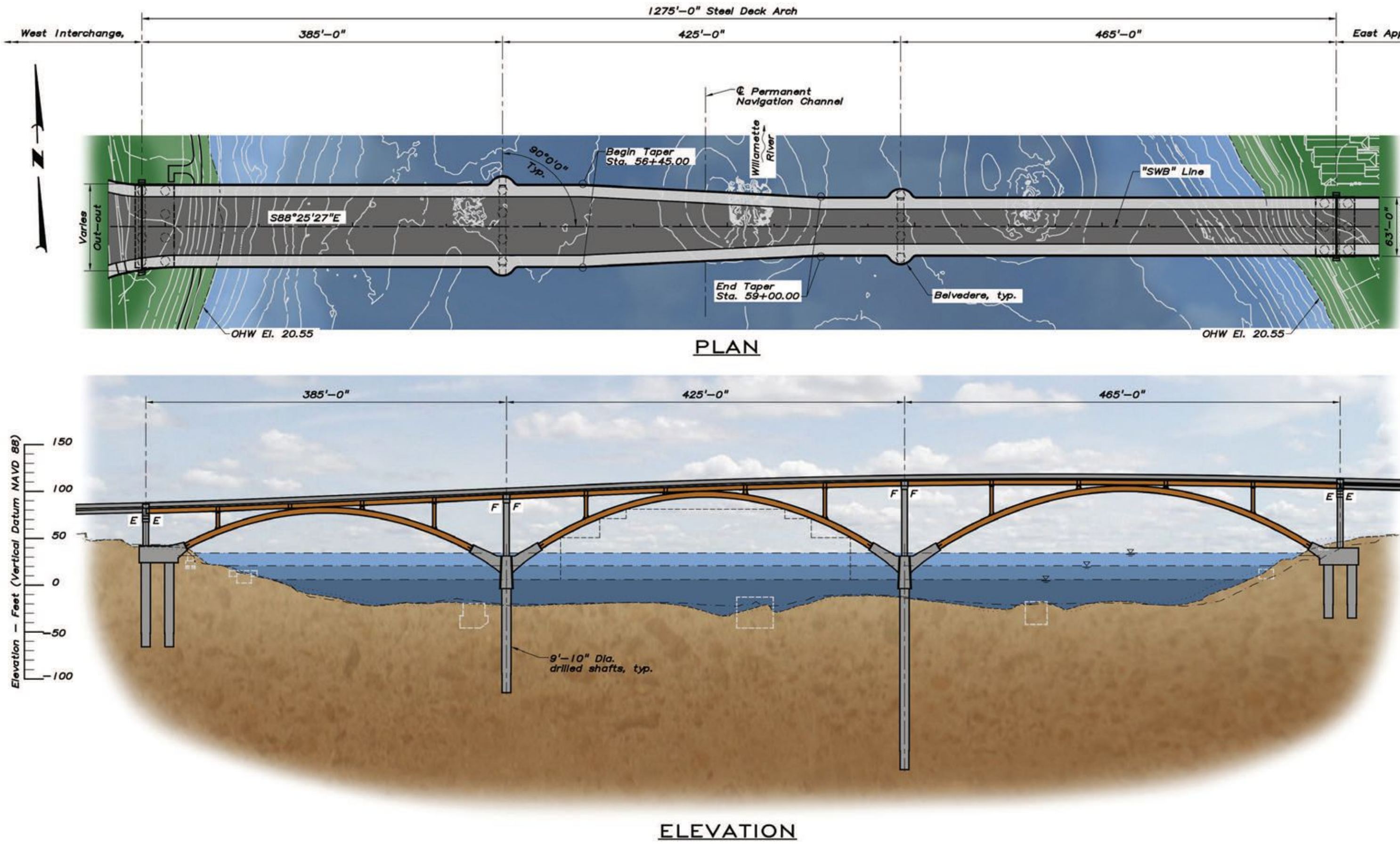
Forming a Team

Multnomah County elected to use the construction manager/general contractor (CM/GC) method of project delivery. A primary advantage of this method is that the contractor, in the role of construction manager, provides direct input to the owner and design team regarding constructability, pricing, scheduling and phasing of the work throughout the design process. In 2009, Multnomah County selected SSJV, a joint venture between Sundt Construction and Slayden Construction, as the CM/GC for the bridge based on a competitive qualification based proposal. In 2010, TYLI and CH2M were selected to develop the final design. To facilitate the CM/GC process, Multnomah County established a collocated project office with full-time staff from the owner, owner's representative David Evans and Associates, the engineering design team and the CM/GC.

The 1,275-ft main structure over the river is flanked on the east by a five-span concrete approach structure extending 500 ft from the riverbank into the adjacent Sellwood neighborhood. On the west side, the structure terminates with a significant interchange connection to Oregon Highway 43, which is composed of approximately 3,600 ft of bridge and retaining wall ramp structures.

The west side of the project site is located within an ancient landslide, which had moved about 4 ft since the original bridge opened in 1925. To prevent movement during construction and stop chronic seasonal movements in the long term, an anchored shear pile system that spanned the full 500-ft width of the landslide was employed. Consisting of 40 6-ft-diameter drilled shafts connected by a grade beam and 70 ground anchors with loads up to 850 kips per anchor, the system is designed to limit seismic deformation to under 4 in. during a moment magnitude scale (MMS) 9.0 Cascadia Subduction Zone earthquake. The landslide mitigation was bid at a construction cost of $14 million.

Both the original truss bridge and new arch bridge have only two through-traffic lanes. This was the recommended configuration from the environmental impact statement (EIS) stage, driven by the request from the Sellwood neighborhood to restrict traffic to two lanes to match the capacity of Tacoma Street to the east. While the existing bridge had an overall structure width of 32 ft, the new structure provides 6-ft, 6-in. shoulders, designated bike lanes and raised 12-ft sidewalks on each side of the bridge. The result is a pedestrian-friendly structure that has a nominal width of 63 ft. The structure width increases on the western half of the bridge to 90 ft, allowing for additional turn



Plan and elevation drawings of the new bridge.

lanes to and from Highway 43. Using 5,000 tons of structural steel, the bridge opened earlier this year.

Steel Deck Arch Structure

The 1,275-ft-long three-span steel deck arch has a span arrangement of 385 ft-425 ft-465 ft, with two arch ribs per span. The progression of span lengths generally follows the rise of the bridge in grade from west to east.

A reinforced concrete Y-arm extends from the pier and footing substructure to meet the steel arch rib at the springing connection in order to keep the steel ribs above the 100-year flood stage. These extensions are up to 36 ft in length at the river piers and follow the curved geometry of the arch.

The solid-ribbed arches are welded box sections with a constant web depth of 70 in., a flange width of 54 in. and a smooth parabolic curve profile (all steel curving was performed in-house by the project's fabricator, Thompson Metal Fab). Each of the three arch spans has four spandrel columns, which coincide with the location of the portal bracing between the two ribs. Each spandrel column supports a transverse steel cap beam, with longitudinal girders spanning between them.

Both the girders and cap beams have an overall steel depth of 60 in. and are composite with the reinforced concrete deck. The girder system is 15-span continuous over the 1,275-ft arch structure, with five to seven girder lines spaced up to 14 ft, 6 in. Based on pricing feedback from the CM/GC, plate transition splices were eliminated and flange and web plate thickness were held constant for the entire girder system. Flange plate width varied based on structural demand but was held constant within a spandrel span.

Top and bottom girder flanges are connected across the cap beams with a continuity connection plate while the girder web is connected with traditional clip angles. The cap beam has an internal diaphragm at the girder line, and the entire connection is bolted. The CM/GC requested slotted holes at specific girder locations to increase tolerances for fit-up during erection.

The transverse cap beams are built-up box-shape members composed of two welded I-girders with top and bottom cover plates. The entire assembly is bolted to eliminate the possibility of crack propagation across the entire section and is designed for the loss of either I-shape or cover plate.

The spandrel columns are welded box sections with dimensions of 42 in. × 36 in. and plate thicknesses varying between 1.25 in. and 2 in. The connection of the spandrel columns to the arch rib is a bolted end-plated moment connection.

Establishing the articulation of the spandrel columns was an important aspect of the design. Design iterations evaluated various configurations of "pinned," "fixed," and "free" boundary conditions at the 12 column locations, with the primary challenge being to balance structure stiffness and load path during seismic and thermal response.

The final articulation uses unidirectional bearings at the top of spandrel columns in the flanking spans 3 and 5 and fixed end-plate moment connections for the columns in the center span 4 (the middle arch span). These fixed columns function similarly to a closed arch crown, while the deck structure is free to move at the ends.

➤ The shallow nature of the bridge's fixed arches led to increased bending demands.

Nick Garibbo/Nick's Photo Design

Engineering Development

Like many replacement projects, local site conditions and the associated built environment imposed a number of engineering challenges. The structural system of the new Sellwood Bridge had to meet the following constraints:

- ➤ Provide a horizontal and vertical navigational opening that meets or exceeds that of the existing bridge.
- ➤ Provide a span layout that, when combined with the existing bridge, would allow continued navigation throughout construction
- ➤ Limit the amount of structure constructed in the waterway to comply with no-net-river-level-rise criteria.
- ➤ Provide a similar roadway profile as the existing bridge in order to limit project extents and facilitate construction staging

Meeting the profile grade requirement resulted in limited rise in the west arch. The three arches have a rise-to-span ratio that varies from 1:7.7 (0.13) to 1:6.4 (0.16). The shallow nature of the fixed arches led to increased bending demands compared to the more efficient arching action that could be attained with more ideal geometry.

In order to limit the effects of flexural demands on the size of the arch section, the springing connections were left in a pinned condition during construction from initial rib placement through concrete deck placement. The two-hinged arch freely rotated during construction loading, resulting in "simple span" bending, with zero negative moment at the springing support and increased positive moment at the crown. After deck placement the springing connection was fixed, shifting the flexural response toward "fixed-fixed" beam action for subsequent loading.

The springing connection consists of ten 4-in.-diameter ASTM A354 Gr. BC high-strength steel rods that are embedded up to 15 ft into the concrete substructure. In the temporary hinged condition, the rods are not tightened to the end of the arch ribs. A high-strength (15-ksi) UHMW pin plate was placed at the springing connection to transfer axial thrust while allowing rotation, and was coupled with an external frame support for vertical loads. Upon completion of staged construction, the fixed connection was completed by

Oregon Department of Transportation

Nick Garibbo/Nick's Photo Design

Steel was transported to the site on barges and placed with cranes operating from work bridges and barges.

There are three segments per rib span, with lengths up to 148 ft.

grouting the pin plate gap and prestressing the anchor rods for service level moments.

Thompson Metal Fab proposed piece-by-piece stick erection, with arch ribs placed on shoring towers instead of a float-in system originally considered for arch erection. Each rib span contained two bolted field splices to match the optimum weights chosen by the CM/GC for fabrication and erection, resulting in three segments per span with lengths up to 148 ft and weights up to 146 tons each. Steel was transported to the site on barges and placed with cranes operating from work bridges and barges.

When the bridge opened to traffic, the crossing immediately jumped to a sufficiency rating of 100. ■

Owner

Multnomah County, Ore.

General Contractor

Slayden/Sundt Joint Venture

Slayden Construction Group, Stayton, Ore.

Sundt Construction, Tempe, Ariz.

Structural Engineer

T.Y. Lin International, Beaverton, Ore.

Architect

Safdie Rabines Architects, San Diego

Steel Team

Fabricator

Thompson Metal Fab, Vancouver, Wash.

Detailer

Candraft Detailing, Inc., New Westminster, B.C., Canada

Nick Garibbo/Nick's Photo Design

The 1,275-ft-long three-span steel deck arch has a span arrangement of 385 ft-425 ft-465 ft, with two arch ribs per span.

Leo Neves

An attractive new transit station in Chicago provides enhanced access to the city's McCormick Place convention center and surrounding areas.

TUBULAR Solution

BY DOUGLAS M. JAKALSKI, PE, AND ANNA DUKES, SE, PE

CHICAGO'S NEWEST "L" STATION kills two birds with one stone.

The new $50 million Chicago Transit Authority (CTA) Cermak-McCormick Place Elevated Green Line Station fills what was a two-mile gap in service on the train line and now provides much-needed access to rapid transit for neighborhood residents and businesses. It also brings an L station a few blocks closer to McCormick Place, the largest convention center in North America, than the previous closest station in nearby Chinatown. (A former station in the same location as the new one opened in 1892 but ceased operations in 1977.) And CTA rail service was maintained during construction of the new station, which was built around live tracks.

The station is comprised of three entrances at street level and two elevators and two stairwells that access a center boarding platform located along the abandoned center track. The station buildings, stairs and elevator towers were built using exposed galvanized steel with glass, polycarbonate and perforated stainless steel cladding to maximize visibility and natural light in the interior spaces.

When it came to design, the largest complication was the tight site constraints. Because the property lines run very close to the elevated structure south of Cermak Road, a center platform design—with both north- and southbound trains sharing a common boarding area—became necessary. Track realignment was not an option, so the existing conditions would only allow for a platform width of approximately 15 ft, much less than CTA's pre-

◄ The new Cermak station revives the original, which opened in 1892 but closed in 1977.

▲▼ The new station's weather-protecting tube stretches over Cermak Road, where the CTA right-of-way is both widest and most visible to the public.

ferred center platform width of 26 ft. The challenge was to maximize the usable space of the narrow platform to serve a community with anticipated population growth and transit use. The design had to keep the platform as free from obstructions as possible. Ultimately, this translated to canopy columns, the boarding area wind break and signage—all of which traditionally occupy platform space—being pushed to the outside to allow for an obstruction-free platform.

The result is an iconic weather-protecting tube covering the platform, providing

Douglas M. Jakalski is a vice president with T.Y. Lin International and was the project manager for the Cermak-McCormick Place Green Line Station. **Anna Dukes** is a senior associate with T.Y. Lin and the project's lead structural engineer.

The tube structure consists of a series of steel ribs, spaced 8 ft apart on center and laced together with diagonal and horizontal bracing; the ribs and bracing are constructed from round HSS.

an attractive yet functional experience for riders and passersby. The enclosed tube stretches over Cermak Road, where CTA right-of-way is both widest and most visible to the public. Due to the age of the existing elevated track structure, CTA wanted to avoid placing any additional loads on the steel track stringers and steel cross bents. Therefore, a completely separate structural support system, including foundations, was designed for the tube structure.

The tube consists of a series of steel ribs, spaced 8 ft apart on center and laced together with diagonal and horizontal bracing; the ribs and bracing are constructed from round HSS. The tube structure sits on an elevated concrete girder system supported by columns and cross beams, and the outer skin of the tube is a series of 4-ft × 8-ft perforated stainless steel panels in a staggered formation to control exposure to wind and light. The panels were arranged as louvers to allow air flow in and out, and thorough research determined the best perforation patterns that would be closed enough to keep the wind, rain and snow out while permitting natural ventilation and visual transparency.

To develop the panel connection to the round HSS, the team developed a stainless steel clip that could be bolted to the structural members and support the panels under wind and snow loads, as well as accommodate thermal movements.

Since heavy lifting was restricted to a limited number of weekend shutdowns, the tube was initially built on the ground in six preassembled sections, then lifted into place and bolted to the elevated concrete girder system running parallel to the tracks.

The general contractor was able to lease land from an adjacent empty lot to use as a lay-down and assembly area for the tube structure. The tube arches were shipped in pairs of two half-arches, with a field splice located at the top of each arch. The heaviest section weighed 33 tons. A 350-ton crane was required to place the sections, and an elaborate rigging system was used to lift the tube sections up at multiple points so that they could be picked up evenly and set down on anchor bolts already cast into the concrete girder.

In keeping with the open platform layout, lighting, cables and signage were suspended

The tube arches were shipped in pairs of two half-arches, with a field splice located at the top of each arch. Up to six arches were assembled at a time on the ground, then lifted into place.

Leo Neves

▲▼ The station provides easier access between Chicago's massive McCormick Place convention center and the city's central business district (known as the Loop) and beyond.

Leo Neves

▼ The station is comprised of three entrances at street level and two elevators and two stairwells that access a center boarding platform located along the abandoned center track.

Ross Barney Architects

from the HSS structure. Light fixtures and cables were enclosed in two steel trays clad with stainless steel. Signage, including digital message displays and advertising screens, was supported by steel cross beams, and stainless steel cables were used to support the entire cable tray and sign system.

Beyond the boarding areas, a steel canopy cantilevering approximately 13 ft was implemented. The canopy columns were placed on one side of the platform and followed the shape of the CTA rapid transit train clearance envelope to maximize the clearance on the platform. The unique shape was fabricated out of steel plate welded together at intermittent locations.

Using 550 tons of structural steel, the station accommodates an average of nearly 1,100 passengers a day, filling a gap on the Green Line, providing more convenient access to Chicago's massive convention center and adding a modern icon to the city's already iconic train system. ■

Owner
Chicago Department of Transportation

General Contractor
F.H. Paschen, S.N. Nielsen, Chicago

Architect
Ross Barney Architects, Chicago

Structural Engineer
T.Y. Lin International, Chicago

Steel Team

Steel Fabricator
Munster Steel Company, Inc., Hammond, Ind.

Steel Detailer
Dowco Consultants, Ltd., Surrey, B.C., Canada

Steel Bender-Roller
Chicago Metal Rolled Products, Chicago

"Zinc Protects Steel" ®

WWW.HOTDIPGALVANIZING.COM

Protecting our Infrastructure...
"One Dip at a Time"

The Pyramid Residential Building erected in NYC was constructed with the use of all exterior steel frame work being Hot Dip Galvanized. Fabricator, **Orange County Ironworks** and Architect, **Bjarke Ingels Group**, worked with V&S team members, **V&S Amboy** and **V&S Lebanon** to complete the 467-foot, maintenance-free pyramid. See our web site for more about this project and others.

Let V&S help with your next award-winning Steel Fabrication! Every project made up of Galvanized Steel, regardless of size or significance, is given Award-Winning effort by all V&S Galvanizing locations. Help us in saving all of our future Infrastructure **"ONE DIP AT A TIME."**

V&S Amboy Galvanizing LLC
Perth Amboy, New Jersey

V&S Columbus Galvanizing LLC
Columbus, Ohio

V&S Delaware Galvanizing LLC
New Castle, Delaware

V&S Detroit Galvanizing LLC
Detroit, Michigan

V&S Lebanon Galvanizing LLC
Jonestown, Pennsylvania

"Zinc Protects Steel" ®

V&S Memphis Galvanizing LLC
Millington, Tennessee

V&S Taunton Galvanizing LLC
Taunton, Massachusetts

800-801-3648

Some things to consider when selecting the right hard hat.

Topped OUT

BY DONALD GARVEY

THE ONE PIECE of personal protective equipment (PPE) most associated with construction and heavy industry is the hard hat.

On first glance, it appears to be a simple, one-size-fits-all accessory. But there are multiple factors that any safety director should consider during the selection process, and several critical items the wearer must be aware of and follow, in order to ensure that the hard hat provides expected protection.

Selection

Per OSHA (Occupation Safety and Health Administration) regulations, hard hats used in the United States must meet the design requirements of the ANSI/ISEA Z89.1 standard *Industrial Head Protection*. Hard hats that meet this requirement will have a sticker or other marking showing "ANSI/ISEA Z89.1" and the standard revision year the hard hat was designed to.

Hard hats come in two main styles: ball cap and full brim. For the most part, the choice is up to the individual or employer. For outdoor work, however, the full brim may provide additional shade protection from the sun—and some industries (oil and gas extraction, for example) tend to use the full brim style almost exclusively. Conditions on the work site may also dictate one style over the other—but again, in most cases it is a personal or employer choice.

▲ Hard hats, Type I and Type II.

ANSI Z89.1 specifies two types of hard hat:

- Type I: designed to reduce impact to the top of the head
- Type II: designed to reduce impact to the top and side of the head

Employer safety professionals working with project management and workers will need to assess the specific work site and tasks to determine which type is more appropriate for their situation.

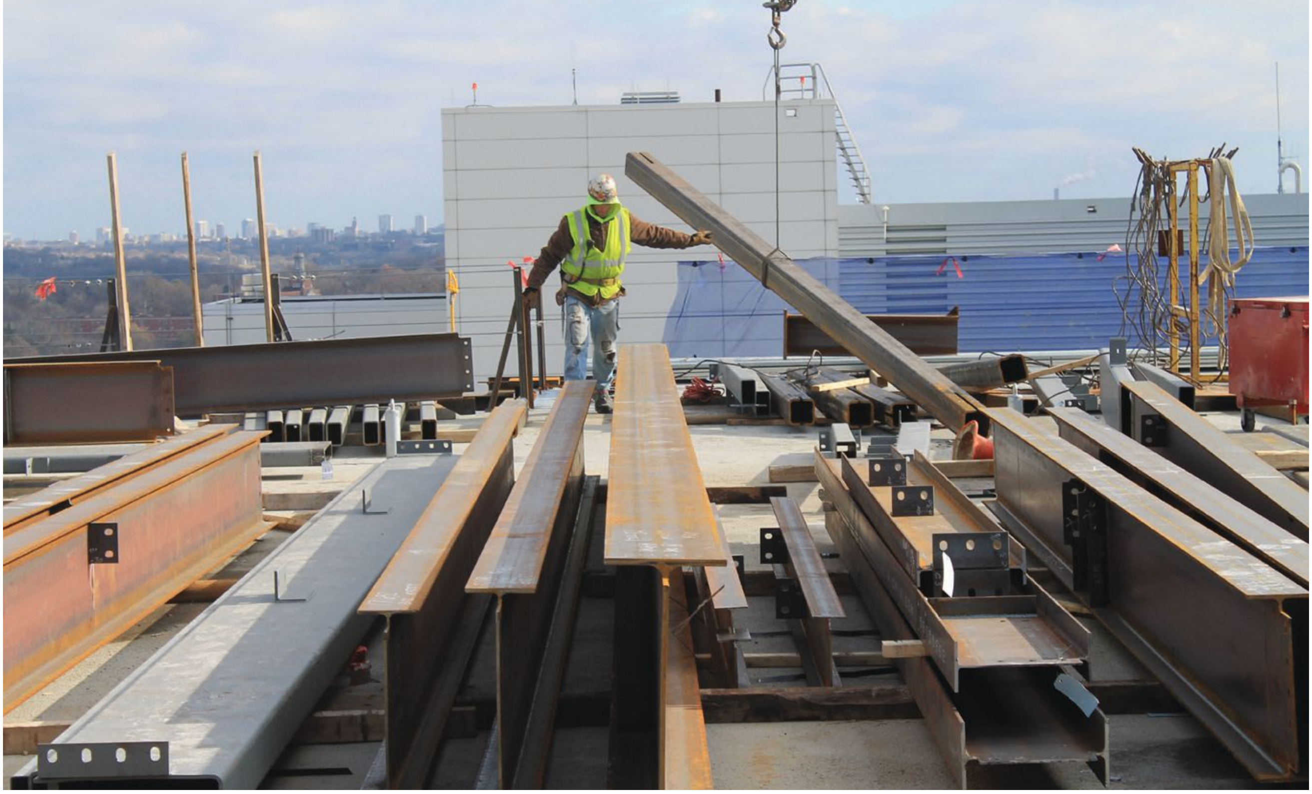
Hard hats are rated for one of three levels of electrical protection:

- C – Conductive: helmet offers no protection against contact with electrical conductors
- G – General: designed to reduce the danger to contact with low-voltage sources. Proof tested to 2,200 volts
- E – Electrical: designed to reduce the danger to contact with high-voltage sources. Proof tested to 20,000 volts

Again, the safety professional, along with management and workers, will need to assess the specific job site and tasks to determine if electrical contact hazards exist and what level of protection may be required.

Color, in most cases, is at the discretion of the company. However, on some work sites color may be used to distinguish different trades or work qualifications. In underground mining, rookie miners must wear a distinctly different color of

Donald Garvey (djgarvey@mmm.com) provides construction technical service in 3M's Personal Safety Division.



hard hat (typically red) for their first year underground. Safety professionals may want to ask the general contractor or construction manager if color-coding hard hats will be used on a particular job site.

Optional Features

Once the above features have been selected, the safety professional should review potential optional ANSI Z89.1 features that may enhance worker safety and comfort. These include:

High visibility. Hard hats can meet specifications for high visibility colors and luminescence. "Struck By" and "Caught Between/In" are two of the biggest sources of fatalities on work sites. Enhancing visibility of the worker can help prevent these from occurring.

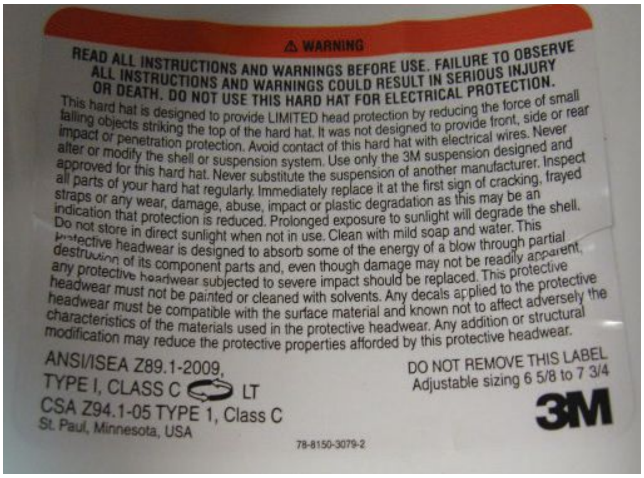
Temperature extremes. Hard hats can meet specifications for use in hot or cold environments. High Temp (HT) means the hard hat has been preconditioned at 140 ºF and still meets all Z89.1 criteria. Low Temp (LT) means that the hard hat has been preconditioned to -22 ºF and has still passed the required ANSI Z89.1 tests. This may be a valuable feature when working outdoors in, say, North Dakota in January.

Reversing shell. Many workers like to wear their hard hat backwards (for various reasons). Hard hats with the reversing arrows marking can be worn with the shell backwards and still meet Z89.1 criteria. It is critical to note that the reversing arrows marking only allows the *shell* to be backwards. The head suspension must still be worn in the proper manner. This means the suspension must be reversed from its normal position in the hard hat for a reversed shell orientation.

Each hard hat will have a sticker or other marking that will show: that the hat meets Z89.1, the type of hat, the electrical rating and any of the four optional features mentioned above. The photo at right shows a hard hat that meets the Z89.1 standard for a Type I hard hat; Class C – no electrical protection; can be worn with the shell reversed (reversing arrows); and meets the ANSI Z89.1 requirements for low temperature (LT). Note that the sticker will also list important warnings regarding use and limitations that the user must be aware of and follow.

Other non-ANSI optional features include ventilation slots, which may help address potential heat stress conditions, and ultraviolet (UV) indicators. Regarding the latter, most hard hats are made of high-density polyethylene. Age, chemical exposure, impacts and repeated/prolonged exposure to sunlight can eventually degrade the hard hat shell and necessitate replacement. UV indictors can be one part of an overall hard hat replacement scheduling program, particularly for workers who work outdoors in UV-intensive areas.

And as a reminder of why hard hats are so important in the first place, head injuries accounted for 5,730 (approximately 8%) of non-fatal construction injuries in 2014, according to the Bureau of Labor Statistics. Proper selection and use of hard hats based on the specific work site situation is important in helping reduce that number. But remember that hard hats are designed to provide only limited head protection by reducing the force of small, falling objects striking the helmet. So while they are indeed useful and necessary, they should be seen as one component of a comprehensive safety program. ■



A sticker indicating that a hard had meets the requirements of the ANSI/ISEA Z89.1 standard, including the revision year.

Achieving CLARITY

BY JOHN CROSS, PE

Transparency can be rather cloudy when it comes to evaluating the sustainability of building materials.

TRANSPARENT. ANALYTICAL.

If any two words could describe the major focus of building sustainability in 2016, it would be these two.

In response to a call for transparency by advocates of green construction, a large number of environmental product declarations (EPDs) documenting the environmental impacts of construction products have been published this year (and AISC has now published EPDs for fabricated structural steel products). At the same time, the growing availability of EPDs and the life-cycle inventory data behind them have fueled a greater push to evaluate project alternatives from an analytical through whole-building life-cycle assessments (WBLCAs) rather than attributional basis.

But the availability of EPDs and a push toward WBLCAs doesn't equate to full transparency and analytical decision-making. Let's look at those two items separately.

Transparency

There is more to an EPD than initially meets the eye. It would be nice to think that every EPD published by every product manufacturer is directly comparable to every other EPD in the marketplace. But that is not the case.

Different EPDs are often based on different declared units. Some product manufacturers may choose to state the environmental impacts of their products based on volume (tons of CO_2 per cubic yard of material) while others go with a square-feet-of-constructed-area basis (tons of CO_2 per square foot) and yet others a per-square-foot-of-material (tons of CO_2 per board-foot) basis. In the case of structural steel, the EPDs published by AISC document impacts on a tonnage basis (tons of CO_2 per ton).

John Cross (cross@aisc.org) is an AISC vice president.

Within a particular product family, such as steel, a product category rule (PCR) is established to assure that all product category EPDs are based on the same declared units and report the environmental impacts in a consistent manner. The PCR for steel requires that all steel EPDs report impacts based on a declared unit of "one metric ton of steel construction product" (sorry, EPDs are governed by an ISO standard that requires the use of metric units). But even a common declared unit does not guarantee comparability. A ton of cold-formed steel sections does not have the same engineering and load bearing properties that a ton of hot-rolled structural steel has, and it is therefore impossible to do a direct comparison between different steel products even if they are all covered by the same PCR.

And it is not just the unit type used to determine environmental impacts that limits comparability. The scope of the EPD can also vary. Different EPDs may track impacts up to and through different product stages. Some EPDs are only consider impacts through the manufacturing stage of the base material, others include impacts through offsite fabrication, some include the construction stage and others calculate impacts during the use stage of the product and some attempt to achieve a full cradle-to-cradle perspective and include the end-of-life stage. Which approach is correct? All of them and none of them. The fact is that to compare EPDs, the product stages being compared must be consistent.

This is particularly tricky for products that are fabricated offsite like structural steel. There are EPDs based on the material produced at the mill—i.e. "hot-rolled structural steel" and there are EPDs for the fabricated product as delivered to the project site—i.e. "fabricated hot rolled structural steel." To satisfy the requirements of rating systems like LEED, the EPD that is submitted for a project must be for the product as delivered to the project site. So in the case of steel, this means fabricated hot-rolled structural sections, plate or hollow structural sections (HSS).

But even that isn't a fair comparison to other materials that are assembled or built on-site. Why should the fabrication impacts for structural steel be included when the on-site construction activity required for concrete and wood are not? The bottom line is that EPDs are good information that is required for project documentation by rating systems like LEED, but they should not be used to compare products or materials.

At this point, there may be a question floating around in your mind… If AISC has published EPDs for fabricated structural steel products, why isn't there a table in this article listing what the impacts are for a ton of fabricated hot-rolled shapes, a ton of fabricated HSS and a ton of fabricated plate? Well, no such table exists, nor will it. The data is there and the EPDs are published, but if a table was included in this article, most readers would immediately go to the table and conclude that the environmental impacts of fabricated hot-rolled structural sections are less than the impacts for fabricated plate or fabricated HSS. And they would be wrong. A ton of hot-rolled sections is not the same as a ton of plate or a ton of HSS. You cannot make a comparison on an impact-per-ton basis. If you want to see the impacts, you can go to **www.aisc.org/epd** and download the appropriate EPD and look at it only the context of that product.

Analytical

So what is the solution?

The green community has long dreamed of an analytical approach for comparing the overall environmental impacts of a building. That dream has been captured under the label of WBLCAs, which look at the quantities of all the products used in the construction of a building then add them up to determine the overall environmental impact of the building. The goal is then to compare the final building design to that of the same building designed using an alternative approach and show improvement in the level of the impacts. Such a process is now memorialized in ASTM Standard E-2921.

This is great in theory, but for accurate comparisons to be made in a WBLCA, certain factors must be in place:

- Accurate environmental impact data must be available for all products
- The methodology for determining the impacts must be consistent
- All environmental impact categories must be considered, not just a select subset of categories
- The product stages of the impact data must be consistent
- Product quantities for both the final design and the comparative structure must be accurate, not rough parametric estimates

The fact is that in most cases, WBLCAs currently fail on all counts.

Accurate environmental impact data is often not available for the products being used for the project. While many EPDs have been published and the background data from these EPDs has been entered in impact databases, the impact data remains suspicious. For example, EPDs issued by the wood industry are based on the assumption of sustainable forest management and harvesting practices, yet less than 20% of the timber harvested in the United States meets those requirements.

Different products may follow different methodologies for the calculation of the impacts. For example, the concrete industry ignores the environmental impacts of mill slag used as a cement substitute while the steel industry takes a credit because the material is a co-product being used in another process. Who's right? Both of us and neither of us.

And what impact categories are being considered? The push toward environmental impact categories was based on the argument that categories provide an analytical view of overall product impacts rather than simple identifying a single product attribute. Steel is a highly recycled product, concrete is regionally produced and wood is bio-based—all of which are attractive attributes—but it was argued that products should not be chosen based on a single attribute. Instead, a product should be evaluated on its overall environmental impacts. Yet the wood industry has resisted any attempts to include a wide range of impacts such as land use, resource consumption and biodiversity in WBLCA criteria, limiting the analysis to only those categories that would be associated with a bio-based product. This sleight-of-hand transforms what is intended to be a comprehensive view of environmental impacts into a disguised single-attribute evaluation.

Comparisons that are made without considering the use stage of the product also miss the mark. Structural steel framing systems do not require replacement or rehabilitation during their life, yet wood and concrete systems may require a greater level of maintenance during the same building lifespan. Accurate WBLCAs must take these differences into account.

And finally, any accurate WBLCA comparing two structures must have accurate material quantities for each alternative. Estimates don't work when it comes to structural quantities. Steel tonnage and concrete quantities are not calculated in the same way as carpet square footage. Load requirements must be known, span lengths optimized, seismic conditions taken into account.

Does this mean that the structural system for both buildings (the proposed building and the alternative to which it is being compared) be fully designed? The simple answer is yes—while probably not to the level of construction drawings, certainly well beyond concept or schematic drawings. An immediate objection is raised that this will be a costly process and that project budgets will not be adequate to cover this cost. That is certainly a concern, but the solution isn't to dumb down WBLCAs to the point where they produce meaningless results, but rather to treat them as a critical decision-making tool in the design process.

Most rating systems and standards require that the chosen alternative demonstrate a minimum of a 5% improvement in several impact categories compared to the building alternate. But parametric and early design estimates of materials typically vary by as much as 20%. What level of confidence can exist in the results of a WBLCA if the basis of the calculations varies by 20%? Certainly not enough to justify a decision based on a 5% improvement in impacts.

So…

So do we throw up our hands, give up and declare both transparency and WBLCAs a fool's errand? No. Environmental-impact transparency and WBLCAs should be critical decision-making tools in the design process. But the design industry is faced with a dilemma. Are EPDs and WBLCAs dumbed down by accepting incomplete, inconsistent and inaccurate input data, or are they elevated to serious science? Or will project owners and design professionals demand rigorous transparency and WBLCAs, recognizing the costs associated with them? In one case it is garbage in, garbage out. In the other case a meaningful approach to addressing the environmental challenges of the 21st century is to do so by seeing clearly and knowingly. ■

AISC Certification is rolling out a new process for managing audit findings, corrective action requests and evidence.

The New (Inter) Face of AISC Certification

BY ART BUSTOS

ONLINE IS WHERE IT'S AT.

During the fourth quarter, all AISC Certification site audit findings, corrective action requests (CARs) issued by auditors and evidence submitted by participants will be managed by a new online interface.

Note that the site audit process itself is not changing, nor is the criteria (program requirements, standards, etc.). The CAR process is merely moving online, including the current CAR and evidence response forms. This new, streamlined process will keep participants more informed about their certification status and reduce the overall review time.

Within 24 hours of a site audit's conclusion, participants will receive two emails for the CARs issued by the auditor:

- The certification contact (individual who receives correspondence from AISC) will receive an email containing individual links for each CAR issued during the audit.
- The principal contact (highest-ranking officer at the fabrication facility/erection company) will receive the same email, but it will not contain links to the CARs.

The certification contact will open the individual link for each CAR issued, which will take them to the online interface where they will be able to review the CAR. The next step is to click "Next" located at the bottom of the page, which will link to a second page where the required evidence—including Immediate Correction, Root Cause Analysis, Corrective Action to Prevent Recurrence and any supporting exhibits—will be submitted. When submitting evidence, the user should keep the following in mind:

- Files must be submitted as PDFs only
- Only five files per CAR may be uploaded
- Each file may not exceed 5 MB
- If you wish to share a video, you must include a link to it in the PDF as opposed to submitting the video itself

At the bottom of the second page, there are two options: "Save" or "Finalize." Save allows the user to save evidence and return at a later time to edit or upload more evidence. Finalize will submit all evidence to the audit agency for review; once that has been done, the user will no longer be able to edit or change the evidence.

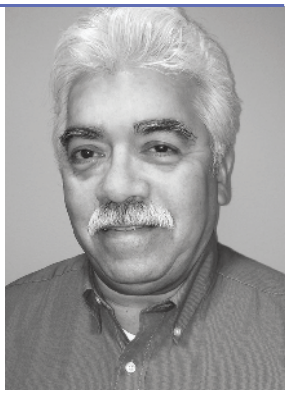
What's a CAR? (Hint: It's not something you drive.)
In the world of AISC Certification, a CAR is a "request" that the fabricator or erector issue their own corrective action, which is defined as the action or actions undertaken to identify and eliminate the root cause of a product or process nonconformance to prevent its recurrence. CARs are a core element of the Certification Programs and also a valuable opportunity for our participants.

Why are they important? Because their effective implementation can prevent recurring issues, save time and money and help focus the management team on using their quality management system (QMS) to drive improvements across the organization.

This process will need to be repeated for each CAR. Once all evidence has been submitted and finalized, the review process can begin. The time frame for submitting evidence for review has not changed; all evidence must still be submitted within 30 days of the site audit.

If you have questions on this new process or other items related to AISC Certification, please contact us at **certification@aisc.org**. ■

Art Bustos (**bustos@aisc.org**) is a certification program analyst for AISC.



IN MEMORIAM

Dorothy Owen, First Female AISC Board Member, Dies at 81

Dorothy "Dottie" Anne Greene Owen of Columbia, S.C., passed away recently at the age of 81. She served in leadership roles on various industry boards, including Colonial Cos., Inc., the state and national boards of BB&T, Commercial Metals Co. and South Carolina State Ports Authority. She was the first woman to serve on AISC's Board of Directors (from 1982 to 1986).

Owen was born on December 16, 1934, in Blowing Rock, N.C. An alumna of Furman University, she went on to earn a master's degree from Appalachian State University. Early in her career, she worked in higher education, teaching at both Anderson College and Wake Forest University. Later, her career path led to administration roles in the regional steel industry. She met her husband, Franklyn Deming Owen, Jr., the second generation of leadership for Owen Steel Co., Inc. (an AISC member and certified fabricator), while working for U.S. Steel.

When Franklyn died in 1982, Dorothy became the company's chairwoman of the board—including its 10 subsidiaries in South Carolina, Georgia, Florida and Virginia—and served in this role until 1994. She also served on many community and higher education boards and received several honors, including Life Membership-University of South Carolina Alumni Association, Woman of Valor from the Diabetes Association, the Girl Scouts Women of Distinction award and the YWCA 1994 Tribute to Women in Industry Award, and was twice recognized in *Working Woman* magazine as one of the "Top 50 U.S. Women in Business."

She is survived by three children and four grandchildren.

IN MEMORIAM

Robert Beauchamp, Past NISD President, Dies

Robert Beauchamp, a prolific contributor to AISC and a past president of the National Institute of Steel Detailing (NISD), passed away this summer at the age of 65.

Beauchamp was born in Montreal, Quebec, Canada, where he lived his entire life. After graduating from high school in the late 1960s, he found his way into the world of steel detailing, attending a trade school where he studied architectural and structural detailing. He gained most of his experience working for steel fabrication shops in the Montreal area, until he founded his first company, R.B. Designs, in 1976. He started exploring the U.S. market in 1979 and never stopped. He was most recently president of Datadraft Structural Detailing Systems, Inc., an AISC member.

In addition to AISC, Beauchamp was an enthusiastic supporter of all steel-related organizations, including the New England Steel Detailers Association (NESDA) and the Canadian Institute of Steel Construction (CISC). He served as NISD's president from 2007 to 2011 and previously served as vice president and secretary/treasurer. He was active on NISD's Guidelines and NASCC Committees, founded its Quebec Chapter and conceptualized its website.

He is survived by four children and one grandchild.

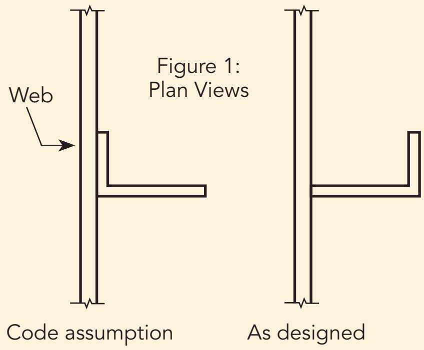
People and Firms

- The **Steel Erectors Association of America (SEAA)** elected four new officers to its Board of Directors this summer. These individuals will serve two-year terms, concluding in 2018. **David Schulz**, president of **Schulz Iron Works, Inc.**, has been elected vice president—industry representative. In 2017, Schulz will become president elect, in line to succeed current SEAA president, **Josh Cilley**. **Carrie Sopuch-Gulajan**, president of **Construction Insurance Agency, Inc.**, has been elected vice president, associate representative. Remaining in the position of treasurer is **Geoffrey Kress**, vice president of **Gardner-Watson Decking, Inc.**, and president of **G&G Distributors, Inc.** **Chris Legnon**, a senior sales manager at AISC member **Cooper Steel Fabricators, Inc.**, was named to the position of secretary.
- **McLaren Engineering Group**, a full-service firm with eight engineering divisions, announced the promotion of **Jeremy D. Billig, PE**, to vice president and New York City regional director. With over a decade of experience in structural analysis and design, inspections and renovations, Billig has managed a number of large, complex projects since joining the company and holds a Master of Engineering degree in structural engineering from Cornell University.

letters to the editor

Blind Spot

I was disappointed in the June Steel Interchange response to the engineer in training (EIT) looking for more guidance, so that he is not just blindly plugging numbers into equations (visit **www.modernsteel.com** to see the question and response). While your response was likely driven in part by legal considerations, I believe it sends the wrong message. No, he is not allowed to design without supervision, but that is no excuse for ignorance; even good engineers get it wrong. On one of my first jobs, I was told to design the webs on a large bidirectional plate girder slab (15 ft deep × 240 ft × 240 ft with webs at about 30 ft centers both ways and with angles for the vertical stiffeners) using an equivalent of AASHTO *Bridge Design Code* (the formulae were identical). I did this, but like the EIT, felt uncomfortable as I did not *really* understand what I was doing, despite a plate buckling course at university. Tracking down the background papers, the code formulae were based on the angles being placed with one leg adjacent to the web so it could be riveted, and not the way we were using them with the toe welded to the web, a common ship building practice (Figure 1). Very different cases from a buckling perspective.



This is not an isolated example. We all have blind spots, and we don't always realize they are areas of weakness. Fortunately, two factors have tended to limit the number of failures:

1. Most structures never see their design loads.
2. As one engineer said, "Steel is smarter than most of its designers."

Will this continue? Materials are getting stronger, structures and codes more complex, budgets and schedules more compressed, analysis more sophisticated and designs more automated. Buckling and fatigue, areas where steel tends to be less forgiving and many engineers are weak, are becoming more important than ever.

Writing clear, unambiguous codes and guides is very difficult. There are many trade-offs between accuracy and ease of use. Easy-to-use codes are usually safer because a more conservative approach is commonly taken and misinterpretations tend to be fewer, but they can result in less efficient structures in some cases.

—Ralph Watts, PEng, PE

A Bridge to the Working World

I read your August article on the National Student Bridge Design Competition, "Proven in Provo" (available at **www.modernsteel.com**), and I thought you would find it interesting that two of our young engineers—a project manager and an estimator—were previously captains of the steel bridge team at Université Laval. They now work at Supermétal and are both great assets!

—Sylvie Boulanger, PEng, PhD
Vice President, Technical Marketing
Supermétal Structures, Inc.

SEISMIC NEWS

SMDI and AISC Help Establish Steel Diaphragm Initiative

The Steel Market Development Institute, a business unit of the American Iron and Steel Institute (AISI), and AISC have partnered together with several industry organizations and academic institutions to establish the Steel Diaphragm Innovation Initiative (SDII), a multi-year effort to advance the seismic performance of steel floor and roof diaphragms used in structural steel buildings through better understanding of diaphragm-structure interaction, innovative design approaches and new 3D modeling tools that provide enhanced capabilities to designers.

SDII investors include SMDI, AISC, the Steel Deck Institute (SDI), the Steel Joist Institute (SJI) and the Metal Building Manufacturers Association (MBMA). Additional partners in SDII include the Cold-Formed Steel Research Consortium (CFSRC), which is comprised of researchers and engineers from The Johns Hopkins University, Virginia Tech, Northeastern University, and Walter P. Moore and Associates. The research team was awarded a three-year grant from the National Science Foundation commencing September 2016. SDII will be managed by the Cold-Formed Steel Research Consortium.

Benjamin Schafer, PE, PhD, director of CFSRC, announced that a new website, **www.steeli.org**, has been launched to keep the design community informed of advancements resulting from the research, as well as to provide an educational tool for those interested in learning more about the use and design of steel deck diaphragms.

The new website introduces engineers and other design professionals to the seismic design of steel deck, provides web resources for steel deck diaphragms, discusses the past performance of tested steel deck diaphragms and explores challenges in simplified models for steel deck.

CENTURY CLUB UPDATE

Here are three more AISC member fabricators over 100 years old:

- Drake-Williams Steel, Omaha
- Western Structural Company, Moline, Ill.
- W&W|AFCO Steel, Little Rock, Ark.

If you know of another 100-year-old fabricator, please contact Carly Hurd, AISC's director of membership, at **hurd@aisc.org.**

MEMBER NEWS

High Steel Structures Encourages Kids to Explore Bridge Building

AISC member and certified fabricator High Steel Structures in Lancaster, Pa., recently hosted a five-day camp at the Lancaster Science Factory for kids in grades 4 through 8 to explore bridge design and construction. The event provided hands-on experiences with field-related technologies and activities like welding and bolting, as well as a tour of High Steel's facility.

"I've learned how to make bridges more stable and durable, and how to make arches," said camper Ava Ludewig. "It's really interesting because it's really hands-on, and you're doing a lot of stuff you don't get to do every day."

Ronnie Medlock, vice president of technical services at High Steel Structures, explained, "In order for kids to really get the experience of bridge building they need to see it, touch it and feel it. The technology involved such as welding, the scale of what we do with steel, it's not something you can appreciate in terms of looking at just pictures. Touching the steel, seeing the giant girders and the welding makes them gain an appreciation for those technologies and techniques and also generates interest. Of course, bridges are a part of our community, and we want them to understand and appreciate the bridges in their community."

Watch the story, reported by Blue-Ridge 11, at **https://youtu.be/eVTMh2bxTjY**.

RESEARCH

New Research Aims to Advance Composite Shear Walls

AISC is working with the Charles Pankow Foundation and other academic and industry partners on a three-year research project to advance the state of the art for concrete-filled composite plate shear walls (CF-CPSWs). The collaborative project aims to generate experimental data and numerical models and lead to design guidelines for individual and coupled CF-CPSW core wall structures as a way to optimize the design and speed the construction schedule of high-rise buildings.

The principal investigator for the $600,000 research project is Amit Varma of Purdue University. Additional partners include Ron Klemencic of Magnusson Klemencic Associates, Jim Malley of Degenkolb Engineers, Ron Hamburger of Simpson Gumpertz and Heger and Peter Timler of Supreme Group.

Search employment ads online at **www.modernsteel.com**. To advertise, call 231.228.2274 or e-mail **gurthet@modernsteel.com**.

structurally sound

BIG NUMBERS


A.E. Crane, National Scenic Byways Online

THIS YEAR MARKS the 100th birthday of the National Park Service.

And this month marks the 39th birthday of the New River Gorge Bridge, the structural centerpiece of the New River Gorge National River, a unit of the National Park Service in southern West Virginia. It also marks the 37th annual Bridge Day, a celebration of the bridge that draws tens of thousands of spectators to watch BASE jumpers hurl themselves from the deck 876 ft above the New River, also known as the Kanawha River. (BASE jumping is the practice of parachuting or wingsuit flying from a fixed spot as opposed to an airplane; BASE stands for building, antenna, span—e.g., the New River Gorge Bridge—and earth.)

The bridge is the third-highest in the U.S., one of the 20 highest in the world and the third-longest single-span arch bridge in the world. Completed in 1977 by AISC associate member American Bridge Company (then a division of US Steel) for a total cost of $37 million, the steel structure has a total length of 3,030 ft, with the longest span being 1,700 ft. With a total weight of 44,000 tons, the bridge is made from weathering steel, which saves an estimated $1 million for every time the structure would need to be painted if it hadn't used weathering steel. When it opened, it cut the transit time across the gorge from 45 minutes to under a minute. The bridge was listed on the National Register of Historic Places in 2013.

For more on Bridge Day, which takes place October 15, visit **www.officialbridgeday.com**. ■