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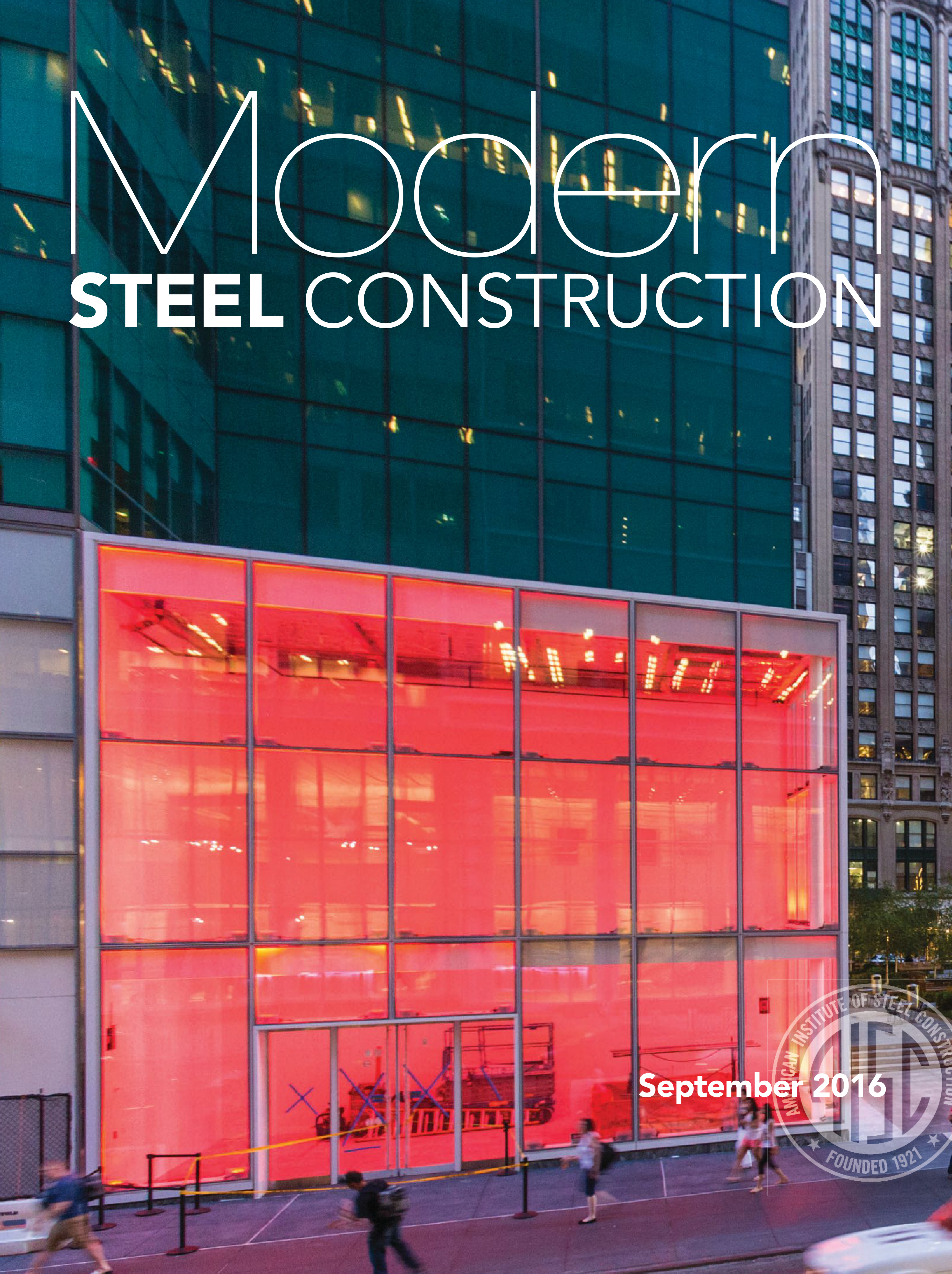

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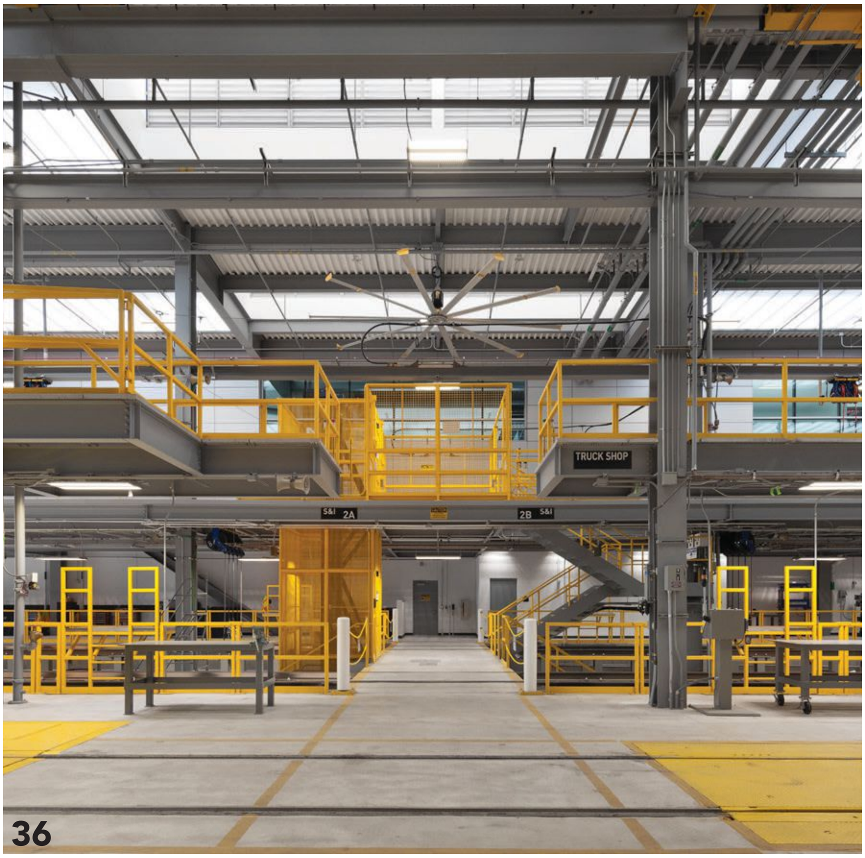

columns

in every issue

features

ON THE COVER: A cubic take on retail space, p. 42. (Photo: Courtesy of MdeAS Architects)

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AS WE CONTINUE SLOGGING THROUGH THIS ELECTION SEASON (WE'RE ALMOST THERE!) AND CONSTANTLY CRINGE AT THE CONTENTIOUS SNIPING BY THE NOMINEES AND THEIR SURROGATES, THERE SEEMS TO BE ONE POINT ON WHICH EVERYONE IS IN AGREEMENT: THE NEED FOR INCREASED INFRASTRUCTURE FUNDING.

While Donald Trump is, as usual, light on specifics, one of his stated goals is repairing America's aging infrastructure. In a CNBC interview, he said, "Maybe my greatest strength is the economy, jobs and building. We do have to rebuild our infrastructure." And in his most recent book, *Crippled America: How to Make America Great Again*, he explained, "Fixing our infrastructure will be one of the biggest projects this country has ever undertaken. There isn't going to be a second chance to get it right." His price tag for the work is in the "trillions," but he also expects it to add 13 million jobs. "If we do what we have to do correctly, we can create the biggest economic boom in this country since the New Deal, when our vast infrastructure was first put into place," he continued. "It's a no-brainer." Trump also ties construction with trade issues and has named Dan DiMicco, former CEO of Nucor, as his senior trade advisor.

And Hillary Clinton also talks extensively and, as would be expected, in great detail about her plans for improving our infrastructure. Recently, she's pledged to enact a $275 billion infrastructure spending plan in her first 100 days in office. She promises "the biggest infrastructure investment since Dwight Eisenhower's Interstate Highway System." The investment will "bankroll upgrades to roads, bridges, airports and public transit. To build a strong economy for our future, we must start by building strong infrastructure today. I want our cities to be in the forefront of cities anywhere in the world. I want our workers to be the most competitive and productive in the world. I want us, once again, to think big and look up, beyond the horizon of what is possible in America."

Of course, during his 2008 campaign, Barack Obama promised to create a $60 billion bank to fund roads and bridges. And during his two campaigns, George W. Bush promised the creation of a Marshall Plan to rebuild America's infrastructure. In 1996, the Republican Platform called for "wise investment" in infrastructure. And in 1992, Bill Clinton promised an additional $20 billion of federal investment in roads, bridges and highways and to create "the world's best transportation, information and environmental protection technologies and networks."

Yet despite these decades of political promises, our infrastructure remains woefully underfunded.

This time, let's hold our politicians to their promises. Whoever wins the election, let's make sure we finally get the investment in our infrastructure that we need.

SCOTT MELNICK
EDITOR

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

steel interchange

Through-bolting HSS

Can through bolts be used to transfer tension at a HSS column? Will the bolts require pretensioning, or can they be installed snug-tight?

Transferring tension with through bolts is not prohibited. However, neither the *Manual* nor the *Specification* provide guidance, so you must design such conditions based on your own engineering judgment and knowledge. Example 3.2 in AISC Design Guide 24: *Hollow Structural Section Connections* (a free download for members at **www.aisc.org/dg**) provides a similar example; it addresses threaded studs but may also be useful in evaluating your condition.

Through bolts can be neither pretensioned nor snug-tightened. Trying to produce the required pretension in the bolts will crush the walls of the HSS, something that seems to be more common than I would have thought until I began to see pictures of crushed HSS sent to the AISC Steel Solutions Center. Even the snug-tightened condition requires the plies to be brought into firm contact and this cannot be done for the condition you described. You'll have to specify the installation you want in the contract documents.

Long story short, a different approach might be better.

Larry S. Muir, PE

Web Openings

I am designing a lightly loaded steel beam with web penetrations exceeding the limits provided in AISC Design Guide 2: *Design of Steel and Composite Beams with Web Openings* (www.aisc.org/dg). The beam is part of a moment frame. Although I understand that the procedures provided in the design guide are not applicable, if these procedures are used to evaluate the condition, then the shear and flexural strength of the beam are significantly greater than the required loads. Is there no way to allow the larger opening?

Let me start off by saying that Design Guide 2 is simply a guide and not a mandatory document. As such, there may be times when you, as the engineer of record, choose to exercise your own judgment when interpreting the information presented in the guide—or you may choose to use a different method entirely for analysis of your condition. If your beam is not highly stressed and you do not believe the "larger" opening will adversely affect the beam performance, then the design may be perfectly adequate.

For instance, let's assume that your condition meets the recommended a_o/h_o limit but does not meet the recommended limit for p_o. The opening parameter, p_o, presented in design guide equation 3-24 is provided as a conservative means to ensure you will not have issues with web buckling localized around the opening or with the member shear strength. There is some discussion regarding the origin and intent of this parameter in Section 5.7, on page 48 of the design guide, which I suggest you review if you haven't already. The parameters in design guide equation 3-24 are all based on physical characteristics of the beam and do not consider the actual stress in the member. However, we can recognize that the likelihood of web buckling occurring in a member is greater when the stresses are greater. If your beam is lightly loaded or your opening occurs in an area of low stress, then it is reasonable to assume you could exceed the limit of p_o, or any of the other proportioning limits and not create a buckling condition. What is low stress and by how much can you exceed the recommended limit are matters of judgment that you'll need to assess for yourself.

As another example, the minimum tee dimensions indicated in Section 3.7.b.1, which were developed as "practical" guidelines due to a lack of test data for shallow tees, do not need to be strictly adhered to as long as you are exercising your engineering judgment. This is briefly explained in Section 5.7.b of the design guide (see page 49). The general intent was to limit the maximum opening size to less than 0.7*d*, leaving 0.3*d* intact. This was split to provide 0.15*d* top and bottom, which is where the 0.15*d* comes from. Again, as the author indicates these are "feel good" limits, and you have some leeway in how strictly you want to adhere to them.

Each condition needs to be evaluated on a case-by-case basis and resolved based on your personal engineering judgment relative to the anticipated loads.

Susan Burmeister, PE

Ungrouted Base Plates

I work in an industry that uses un-grouted baseplates for steel structures—electric substations, for example. The guidance provided in AISC Design Guide 1: *Base Plate and Anchor Rod Design* (www.aisc.org/dg) is directed toward the building industry. Although it is a well-written document, it does not address the situation where the base plate is ungrouted. Generally speaking, ungrouted base plates experience higher weak-axis bending stress as compared to a grouted base plate.

It seems there is much confusion regarding the location of the critical, theoretical bend line relative to the anchors as well as which sections of the current AISC *Code* apply. Are you aware of any published guidance to address this issue?

According to the scope, defined in Section A1, the 2010 AISC *Specification* (a free download at **www.aisc.org/2010spec**) applies to buildings and building-like structures. Therefore, substation structures are not addressed, and there are no plans to address them in the future. AISC Design Guide 1 is focused on typical building and building-like details, but AISC Design Guide 10: *Erection Bracing of Low-Rise Structural Steel Frames* (**www.aisc.org/dg**) has extensive information that you may find useful for these connections. The design recommendations therein are intended to address erection design, but the same principles can be used for permanently non-grouted base plates supported by leveling nuts. The following publications also contain design requirements and recommendations for non-grouted base plate connections:

- AASHTO *Standard Specifications for Structural Supports for Highway Signs, Luminaires, and Traffic Signals*
- ASCE *Substation Structure Design Guide*
- ASCE *Design of Steel Transmission Pole Structures*, ASCE/SEI 48

Base plate strength is typically limited by the flexural strength. The flexural strength of rectangular bars is addressed in *Specification* Section F11. The yielding limit state according to Equation F11-1 is applicable to plates bent about their weak-axis.

Bo Dowswell, PE, PhD

Shear Lag in Compression Members

Shear lag is addressed in Chapter D of the *Specification*, which addresses the design of a member for tension. It is usually not considered in Chapter E, which addresses the design of a member for compression. I understand that compression strength is generally governed by either flexural buckling or torsional flexural buckling; and also that stress levels are far below $0.9F_y$; hence shear lag will generally not need to be considered. However, should shear lag be considered for short compression members, connected only at the web, with high compression forces?

The effect of uneven stress distribution should be considered but can often be neglected. In steel design, shear lag is almost always associated with the rupture of tension members.

Generally, shear lag is used to describe non-uniform stress conditions caused by localized load-transfer deformations. Such non-uniform stress can occur in elements subjected to both tension and compression. For example, the effective slab width for composite beams is often less than the spacing between beams due to the effect of shear lag at the compression flange.

In extreme cases, it is conceivable that the strength of a compression member could be affected by shear lag. However, I'm not aware of any research indicating that shear lag should be considered in the design of compression members. In practice, the connection detail typically restrains buckling and provides a ductile condition where the stresses can redistribute adequately without failure. Any deformation caused by compression yielding due to shear lag is likely to be negligible.

Hopefully, this will provide enough information for you to use your own judgment to determine what is appropriate for your situation.

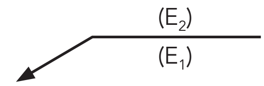
Bo Dowswell, PE, PhD

Flare-bevel Groove Welds

It is common to see flare groove welds shown in the contract documents without the throat provided in the weld symbol. I am under the impression that the welder must build up the weld at least flush and that the throats shown in Table J2.2 of the *Specification* can be assumed. Is this correct, or must the throat always be provided in the weld symbol?

Table J2.2 shows the effective throat of a flare groove weld that is sized to fill flush to the surface. Not all flare groove welds need do so, however.

Section 2.3.5.3 of AWS D1.1 addresses this and states the following:

> The contract documents shall show CJP or PJP groove weld requirements. Contract documents do not need to show groove type or groove dimensions. The welding symbol without dimensions and with "CJP" in the tail designates a CJP weld as follows:
>
> 
>
>
> The welding symbol without dimension and without CJP in the tail designates a weld that will develop the adjacent base metal strength in tension and shear. A welding symbol for a PJP groove weld shall show dimensions enclosed in parentheses below "(E_1)" and/or above "(E_2)" the reference line to indicate the groove weld sizes on the arrow and other sides of the weld joint, respectively, as shown below:
>
> 
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Based on this requirement, the effective throat should be provided when calling out a flare-bevel groove weld.

Carlo Lini, PE

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 and Carlo Lini is staff engineer—technical assistance, both with AISC. Bo Dowswell and Susan Burmeister are consultants to AISC.

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If you have a question or problem that your fellow readers might help you solve, please forward it to us. At the same time, feel free to respond to any of the questions that you have read here. Contact Steel Interchange via AISC's Steel Solutions Center:

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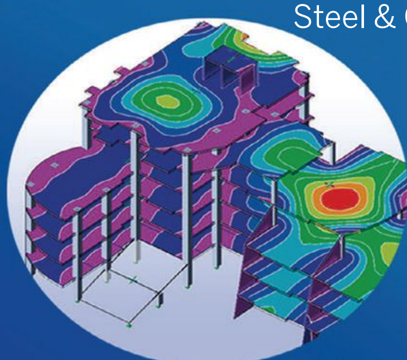
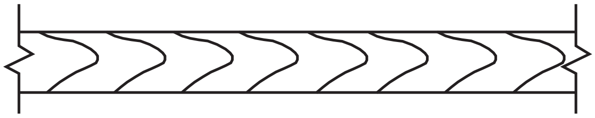


steel quiz

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 ASTM A325 and A490 provisions include head dimensions that are larger than those for other bolt grades. Why?

2 Was the fillet weld shown in Figure 1 deposited from A to B or from B to A?



3 When steel is specified to be painted without indication of required surface preparation method, what surface preparation is used?

4 An ASTM A325 bolt is subjected to a tension load that is gradually increased until failure. Which of the following descriptions best fits the failed bolt?

a. The threads have stripped, causing the bolt and nut to separate

b. The unthreaded bolt shank is necked-down and fractured near its mid-length

c. The threaded portion of the shank between the nut and thread runout is elongated and fractured

d. The unthreaded bot shank is fractured near the juncture of the bolt head and shank

5 A welder is observed and is not wearing a welding helmet. Which of the following welding processes is most likely being used?

a. Flux-cored arc welding (FCAW)

b. Submerged arc welding (SAW)

c. Gas metal arc welding (GMAW)

d. Shielded metal arc welding (SMAW)

e. None of the above

6 Name three methods for setting a column base to proper elevation.

7 **True or False:** In the AISC *Specification*, beams and their connections are designed to have equivalent reliability.

8 Give two examples each of common structural shapes that have: a. only unstiffened elements; b. both unstiffened and stiffened elements; and c. only stiffened elements.

9 In seismic moment frame design, a strong-column/weak-beam design requirement is sometimes imposed. What does this mean?

10 There are at least six methods that are used to cut steel. How many can you name?

TURN TO PAGE 14 FOR ANSWERS

steel quiz | ANSWERS

1 The head size specified in ASTM A325 and A490 is dimensionally equivalent to that for the matching ASTM A563 nut. Therefore, installation is simplified because the same socket or wrench size can be used for both the bolt head and nut. Kudos if you already knew that ASTM F3125 is the new home for grades A325 and A490 bolts; see "Six into One" in the November 2015 issue of *Modern Steel* (available at **www.modernsteel.com**) if you didn't.

2 It was deposited from B to A. The molten weld metal cools faster at the toes because the base metal draws heat away. The ripple pattern results when the slower-cooling weld metal is drawn back by surface tension as the weld is deposited.

3 From the AISC *Code of Standard Practice* Section 6.5.2: "Unless otherwise specified in the contract documents, the fabricator shall, as a minimum, hand clean the structural steel of loose rust, loose mill scale, dirt and other foreign matter, prior to painting, by means of wire brushing or by other methods elected by the fabricator, to meet the requirements of SSPC-SP2."

4 **c.** This is illustrated in *Guide to Design Criteria for Bolted and Riveted Joints* (a free download at **www.boltcouncil.org**). High-strength bolts subjected to tension fail in the threaded portion of the shank. Accordingly, a reduction for threading is incorporated into the tension design strength listed in the AISC *Specification*, which is then used with the nominal bolt area.

5 **b.** In the SAW process, the arc and molten weld metal are submerged beneath a layer of flux. Therefore, a welding helmet (eye protection from the arc) is not required.

6 The use of a leveling plate, leveling nuts and shim stacks are three alternatives. These are discussed in greater detail in the AISC *Steel Construction Manual* beginning on page 14-6.

7 **False.** While the *Specification* does not explicitly state the target reliability index, the Commentary states: "As might be expected, there was a considerable variation in the range of β-values. For example, compact rolled beams (flexure) and tension members (yielding) had β-values that decreased from about 3.1 at L/D = 0.50 to 2.4 at L/D = 4. This decrease is a result of ASD applying the same factor to dead load, which is relatively predictable, and live load, which is more variable. For bolted or welded connections, β was in the range of 4 to 5."

8 Angles and tees have only unstiffened elements, I-shapes and channels have both unstiffened and stiffened elements and round and rectangular HSS have only stiffened elements.

9 The selection of a strong column and weak beam means that the nominal flexural strength of the column is greater than expected flexural strengths of the beams. The Commentary to Section E3.4a of the *Seismic Provisions* explains the intent of this requirement.

10 The six possible answers are: friction sawing, cold sawing (rotary, hack and band), flame cutting, plasma cutting, laser cutting and shearing.

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

steelwise

ADDRESSING ANCHORS

A look at some field-fix options for column anchor rods.

BY ERIC BOLIN

THE BEST-LAID SCHEMES of mice and engineers go often askew.

Even with thoughtful planning in the design phase, mistakes happen and you can be faced with a situation that requires repair or modification in the field. The difficulty in handling these types of problems is that you can't always predict what's going to go wrong or when it's going to happen—and anchor rods are no exception.

However, you can better prepare yourself to deal with these problems by determining what types of errors are more common than others and considering the solutions others have used in the past. Here, we've provided several practical fixes for the most commonly occurring anchor rod problems in the field.

Finding an Issue

When an issue is discovered in the field that requires fixing or modifying column anchor rods, OSHA 1926.75 requires that the engineer of record (EOR) must approve any changes that are made Even if the problems are created by others, it is important for the EOR to be involved with determining the fix. While the EOR is ultimately responsible for the final design, the erector, fabricator, general contractor and other involved parties should contribute to finding the solution to the problem. A simple phone call early on between these parties can facilitate a timely and efficient solution.

Since, like any other field problem, anchor bolt issues can throw a project off schedule, it is important that the solution is identified and approved in a timely manner. Following the repair or fix, the contractor is required to provide written documentation of all field work that was completed. Any fees for additional services performed by the EOR should be discussed early in the process with the owner.

Even Needed?

When looking at potential fixes, a good place to start is to analyze the as-built conditions to determine if a fix is even necessary. Sometimes, a deviation may need only minor or no corrective actions. An example of a problem needing only minor corrective action is a damaged or misplaced anchor rod on a gravity-only column. In this case, it has been provided only for erection to satisfy the OSHA requirement for the minimum number of anchor rods and erection loading. It may be possible to permanently remove the problem anchor rod if the column is temporarily braced during erection.

Another possible example is a column found to be out of plumb. If the analysis indicates that the column, in its as-built condition, and structure around it are acceptable—and there is no other reason the out-of-plumb condition cannot be accepted—then no fix is needed.

If there is a bona fide error—and it's discovered early enough—it may be possible to fix a problem before the affected materials leave the shop. Consider, for example, when a survey finds an improperly located anchor rod. Some fix options that can be performed in the shop are as follows:

- If the base plate has not yet been fabricated, anchor rod holes can still be relocated. If this change necessitates increasing the base plate thickness, you should first confirm with the fabricator if new plate material can be procured, especially if very thick plate is required
- Existing holes can be slotted, or new holes added, to match up with the as-built anchor rod layout
- The base plate can be offset by removing and re-welding it to the column. If needed, the base plate can be flipped over to provide a clean surface to re-weld to the column

Table 14-2 in the AISC *Steel Construction Manual* lists the minimum washer sizes for typical anchor rod diameters. When a base plate hole is enlarged, the washer plate size will also need to be increased to bridge over the enlargement. It should be noted that washer plates may be need to transfer forces from the column into the foundation. If this is the case, the washer plate size and necessary welding will need to be designed by the EOR.

Eric Bolin (bolin@aisc.org) is a staff engineer with AISC.

When a base plate is relocated, or when a new hole is added, you may end up with an interference between the anchor rod and the cross section of the column. In this case, it may be possible to cut access holes in the column flanges or web to allow enough clearance to install the column. Reinforcement may need to be added to the column around the access cuts to replace the strength lost from removing material. If interference exists between the washer plate and the weld at the column base, it may be an option to omit the weld in this location or trim the washer to clear any encroachment.

Fixed in the Field

It is more common that anchor rod fixes need to be performed in the field. When this is the case, you'll need to determine what options the contractor is able to perform and what constraints exist for the redesign. For instance, you may have to exclude the option of field welding if the rods are not made from a weldable grade of material. The most commonly specified anchor rod material type, ASTM F1554, permits welding of some but not all grades. As shown in Table 1, welding is possible with ASTM F1554 Grades 36 and 55 with supplement 1 but not for Grade 55 without supplement 1 or for Grade 105. If a different rod material is specified, its weldability should be confirmed prior to considering a welded fix option.

Table 1. ASTM 1554 Anchor Rod Identification

Grade	Color	Die Stamp Identification	Weldable Material?
36	Blue	AB36	Yes
55	Yellow	AB55	No
55–weldable*	Yellow–at projecting end White–at encased end	AB55	Yes
105	Red	AB105	No

*Supplement 1, weldable Grade 55 rods

A commonly used field fix is to cut off a problem anchor rod and replace it with a post-installed anchor. A downside to using this method is that the base plate likely will need to use a modified hole pattern since the new post-installed anchor often cannot be placed where the abandoned embedded rod is located. Either cutting a new base plate hole in the field or relocating the base plate may allow the fabricated base plate to be used with a revised anchor pattern. Otherwise, a new base plate will need to be fabricated and installed.

Encountering concrete reinforcement can be a problem when drilling holes for post-installed anchors. If the location of the reinforcement in the concrete is known, it may be possible to provide a design with the exact number and placement of the post-installed anchors. However, it's a good idea to design a base plate that has more holes than needed. This way, if reinforcement is encountered when drilling a hole, then the hole can be abandoned and an alternative hole position drilled for the anchor. The engineer will need to specify the total number of anchors that are required to be installed in their design.

Too Short or Tall

Several fix options are available when the threaded portion of the anchor rod is set in a position that is either too short or too tall to allow for the nut to be tight and at least flush with the point/top end of the anchor rod. Note that when an anchor rod is too tall, the rod's embedded length should be verified since the extra length above the concrete may have come from the rod being set too shallow.

One option for an anchor rod that is set too tall is to stack plates or washers above the base plate to give an elevated surface to tighten the nut against (see Figure 1). Another option for a rod that's too tall is to increase the length of the threaded portion using a die.

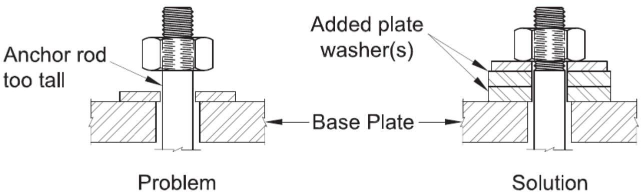


Figure 1. Plate washers for a too-long anchor rod.

If the anchor rod is made from a weldable grade of material, directly welding the rod to the base plate may be a good field fix as shown in Figure 2. This option can be used for both a too-tall condition and a too-short condition. Access for welding a too-short rod may be an issue when the top of the anchor rod is recessed below the top of the base plate.

The gaps between the anchor rod and edges of the base plate hole must be considered when designing a field-welded fix since the length spanning the gap does not contribute to the strength of the weld. The weld size needed for strength will need to be increased by the gap dimension. Large gaps, such as with slotted or oversized holes, may require multiple weld passes, which may not end up being the optimal solution. A washer plate with a smaller hole can be used to make this option work as well.

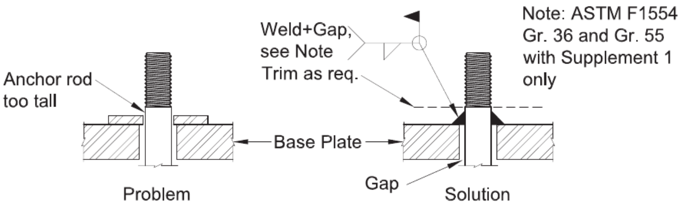


Figure 2. Directly welded anchor rod.

For a rod that's short relative to the base plate, one option is to weld an additional length of threaded rod to the embedded rod. As shown in Figure 3 (page 20), an additional section of threaded rod can be prepared with a double-V-type groove weld. This is generally preferred over a "pencil point" shaped bevel.

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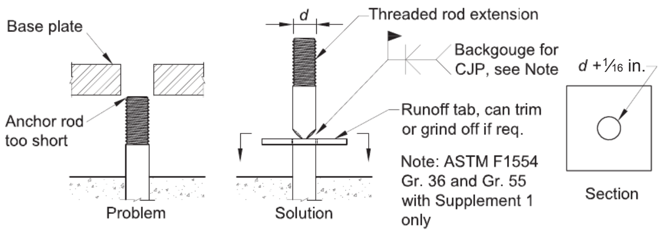


Figure 3. Welded anchor rod extension.

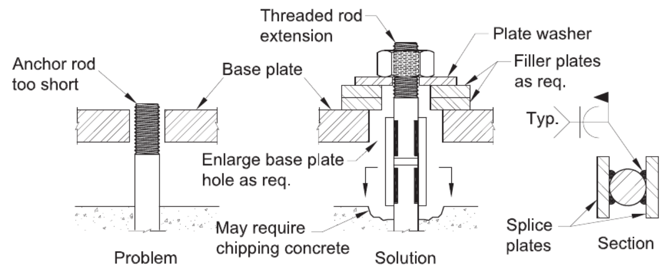
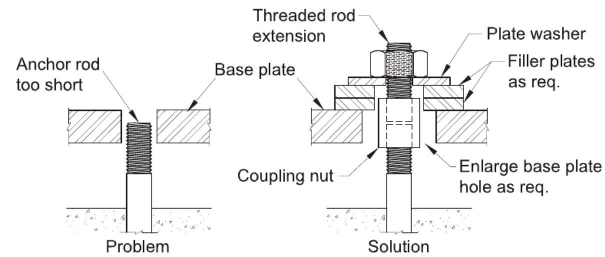


Figure 4. Welded anchor rod splice.

Figure 5. Anchor rod extension using coupling nut.



An alternative to directly welding the rods together is to join the extra length of threaded rod using lap plates (see Figure 4). The lap plates are joined to the rods using flare bevel groove welds. It may be necessary to chip out the concrete to provide adequate clearance for the bottom of these lap plates. Additionally, clearance may be an issue between the lap plates and base plate. The base plate holes may need to be enlarged and covered with a larger plate washer (as suggested earlier for enlarged holes).

A coupling nut is another possibility for joining an additional threaded section to the embedded rod (see Figure 5). The coupling nut is a larger diameter than the rods, which may require the base plate holes to be enlarged.

Yet another fix option for a rod that's too short is to install an extended nut, such as the Elocone elongated nut produced by Canam. This product features an internally threaded portion that extends below the top surface of the base plate, which can connect to an anchor rod set too low (see Figure 6).

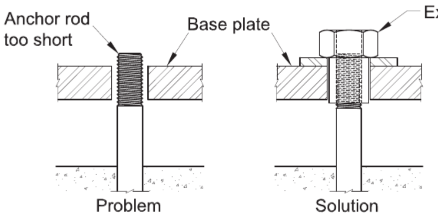


Figure 6. Extended nut option.

The engineer may also investigate using an anchor rod with a partially engaged nut. Information on this option can be found in the second edition of AISC Design Guide 1: *Base Plate and Anchor Rod Design*.

Damaged Rods

When anchor rods are installed in an out-of-plumb position or are bent after being placed, it may be possible to straighten them in the field. In Design Guide 1, the recommendation is that bending a rod in the field should be limited to 36-ksi material and a bend angle no greater than 45°. A rod-bending device called a hickey is also recommended to assist in this process of field straightening rods.

It may be possible to cold bend rods for diameters up to 1 in. For larger-diameter rods, the effort needed to cold bend rods into position increases and can be made easier by applying heat. The maximum temperature allowed for hot bending ASTM F1554 Grade 36 material is 1,300 °F.

If the rod is bent within its threaded portion, the threads may end up being damaged during straightening. If the nut cannot be installed, the rod may need to be trimmed below the damaged portion and, if needed, extended using one of the methods that was previously discussed for a rod that's too short.

Other Column Base Issues

An improperly plumbed column can typically be fixed by adjusting the amount of grout placed under the base plate. When this type of fix is performed, there is a chance that the anchor rod may end up being too tall or short to install the nut. If this happens, the solutions discussed earlier may be workable. This may also affect the elevation at the top of the column and its connections to adjacent members.

Problems can also be caused by grout being installed too late after column erection. If grout is not in place before the column is loaded, the shim stacks or leveling nuts will have to support the column and may be subjected to forces they cannot resist. The base plate is also loaded differently than in the design condition, which can cause problems. This is why the AISC *Code of Standard Practice* requires that grouting be performed promptly after the installation of a column. This provision is intended to prevent a condition where loads in the column cause the base plate to deform unacceptably, leveling nuts to punch through the base plate, rods to punch through the bottom of the concrete foundation or a similar undesirable outcome. It is much less problematic and costly to grout in time than to have to jack a column back up into position to after it's been loaded without grout. ■

This article is based on the 2014 NASCC: The Steel Conference presentation "Field Fixes: Common Problems in Design Fabrication and Erection: Solutions and Prevention" and AISC Design Guide 1. You can watch the full presentation at ***www.aisc.org/2014nascconline****. For more pre-field work tips, see the August 2015 SteelWise article "Field Fixes, Minimizing Fixes in the Field Starts in the Design Phase" at* ***www.modernsteel.com****.*

steelwise

STRENGTH AND ENGAGEMENT

BY JAMES LABELLE, PE, DocE

Notes on thread strength and partial engagement of anchor rod nuts.

EVERY ANCHOR ROD has its limit.

Here, we'll discuss the limit state of thread stripping in threaded steel anchor rods (anchor bolts), used with nuts, for diameters, *D*, from 0.5 in. to 4 in.

Internal threads (nuts) or external threads (threaded rod) could strip under certain conditions. This limit state can usually be avoided by having a suitable type of nut fully engaged with the threaded fastener. A thread's strip strength depends on both its geometry and material. An external unified coarse thread (UNC), whose cross section is approximately triangular, is wrapped as a helix around a solid cylinder. The number of threads that resist load depends on the thread spacing, or pitch, and the engaged length of the nut with the fastener, parallel to the fastener's longitudinal axis.

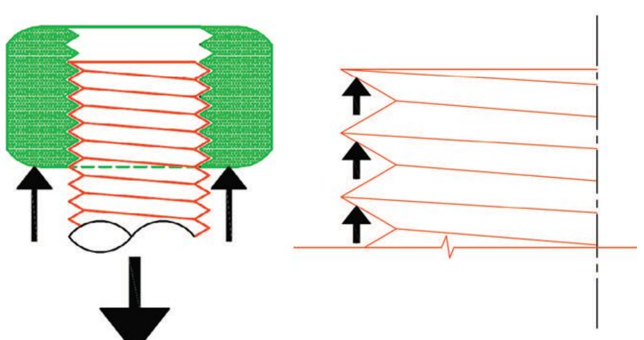
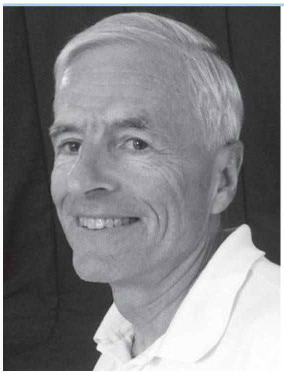
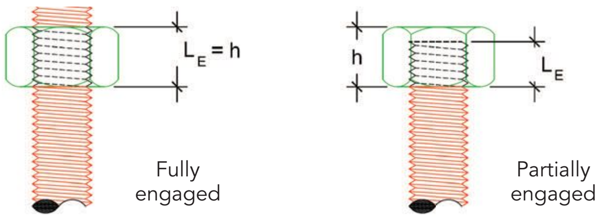


Figure ◄ 1a and ▲ 1b



James LaBelle (jlabelle@csd-eng.com) is a senior associate with CSD Structural Engineers in Milwaukee.



▲ Figure 2. (Note: While protrusion through the nut is shown in the fully engaged example above, it is not necessary for full engagement.)

Load Path

The load path for a tension-loaded threaded fastener with a heavy-hex nut is shown in Figures 1a and 1b. For example, a base plate pushes up against a washer which then pushes against a nut. The nut's threads then push against the corresponding threads of the anchor rod. The anchor threads in turn transmit most of the load into the root diameter portion of the rod—the solid cylinder portion—producing tension stress. However, some of the tension force remains in the threads because they are integral with the root cylinder. For tension, the effective stress area of the anchor rod is its tensile stress area A_T, which is less than the gross area A_G but greater than the root area. See Equation 1, (per references 1, 2, 3 and 6) and Equation 2 (per references 3 and 5). The ratio of A_T to A_G is not a constant, and ranges from 0.72 to 0.88, as shown in Figure 3. Thread spacing *n*, in threads per inch, varies from 13 to 4 for this diameter range (see Table 1).

Table 1

Diam. (in.)	n (threads/in.)	Diam. (in.)	n (threads/in.)	Diam. (in.)	n (threads/in.)
½	13	1¼	7	2¾	4
9⁄16	12	1	6	3	4
5⁄8	11	1½	6	3¼	4
¾	10	1¾	5	3½	4
7⁄8	9	2	4.5	3¾	4
1	8	2¼	4.5	4	4
1⅛	7	2½	4		

$$A_T = (\pi/4)\,(D - [0.9743/n])^2 \quad (1)$$

$$A_G = (\pi/4)D^2 \quad (2)$$

Figure 3. Ratio A_T/A_G vs. Diameter, for UNC Threaded Fasteners

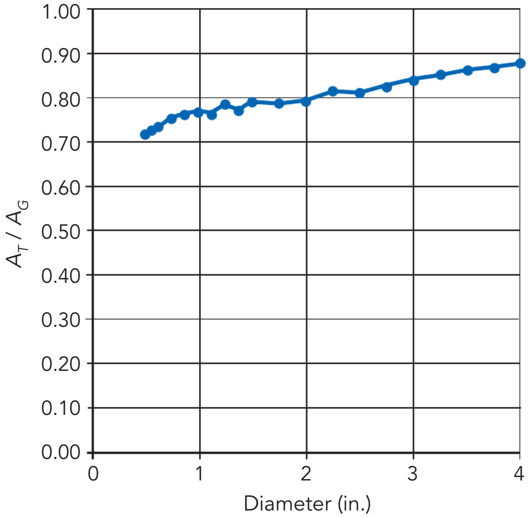


Figure 4. Strip Area per Thread vs. Diameter (UNC Thread)

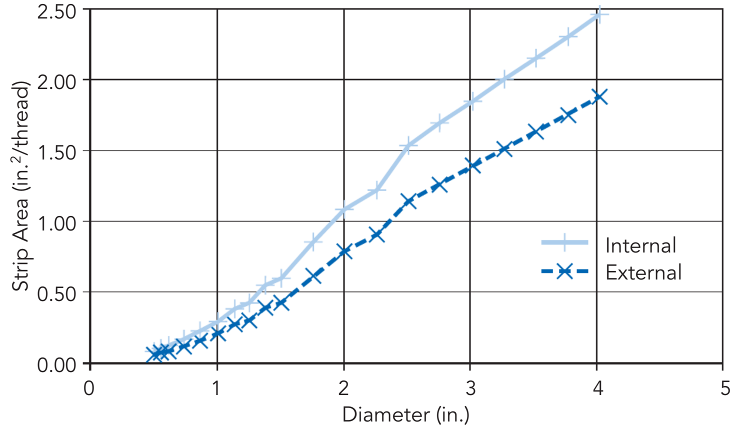


Figure 5. Strip Area per in. vs. Diameter (UNC Thread)

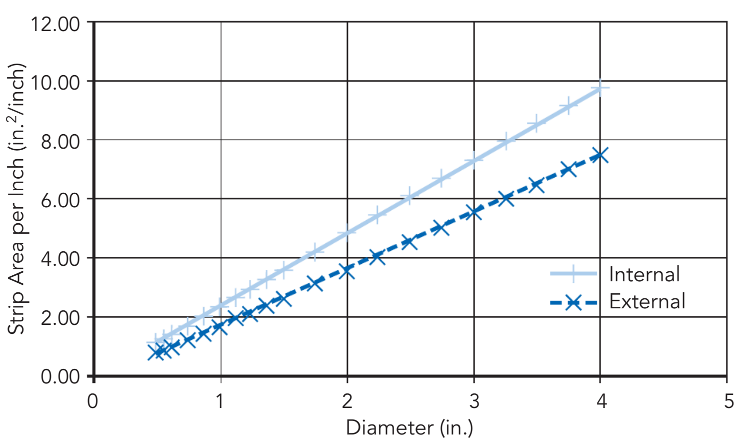
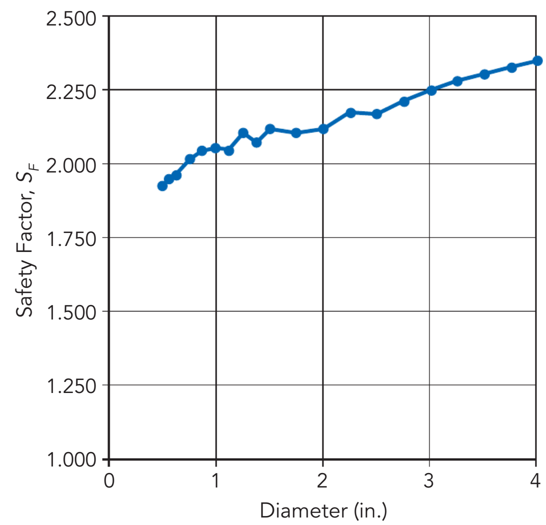


Figure 6. Safety Factor S_F vs. Diameter, for UNC Threaded Fasteners (Tension; Ω = 2.0)



Thread Stripping

The engaged threads of the nut and rod are resisting load via local shear stress along the engaged length. Stripping occurs if the shear stress in the nut or the rod threads reaches the ultimate shear stress. A thread's shear stress depends on the force per thread and the stripping area per thread. Prior to stripping, shear yielding will typically occur. See Eq. 3 and Eq. 4 for stripping areas, per thread, for external and internal threads.

$$A_{TSE} = \pi c\,[(1/(2n)) + (1/\sqrt{3})(b-c)], \text{ ext. thread} \qquad (3)$$

$$A_{TSI} = \pi a\,[(1/(2n)) + (1/\sqrt{3})(a-d)], \text{ int. thread} \qquad (4)$$

where

c = maximum minor diameter of internal thread
b = minimum pitch diameter of external thread
a = minimum major diameter of external thread
d = maximum pitch diameter of internal thread

The preceding variables for bolts and nuts are given in references 1, 2 and 3. Figure 4 is a plot of the strip area per thread, and Figure 5 illustrates the strip area per inch, for external and internal threads.

To better understand thread stripping, it is helpful to know that an external thread's strip area per thread is significantly smaller than that of the corresponding internal thread. Thus as long as the bolt material's tensile ultimate stress F_U does not exceed that of the nut, the bolt threads' strip strength governs the stripping failure mode. The ratio of A_{TSE} to A_{TSI} ranges from 0.70 to 0.77.

In an idealized simple model, engaged threads would contact uniformly along the full length of the helix. The bolt would be rigid and the force on each thread would be the same for a given bolt tension. In reality though, there is variation. Steel's elasticity and ductility, tolerances in fabricated threads and the geometric details of a nut and anchor rod all contribute to variation in the force per thread. For example, the threads closest to the loaded face of the nut resist a disproportionately high fraction of the total load. Within limits, a sufficiently high tension will cause local yielding of some threads and allow for partial redistribution of force among threads.

One aspect of nut behavior is the dilation, or increase in diameter, that occurs as the applied tension force increases. This response is due to the radial component of force per thread that is caused by the sloping contact faces of the triangular cross-section threads. Proper nut design limits this behavior.

Partial Engagement

If a nut is not fully engaged with an anchor rod (see Figure 2) and the required tension is less than the rod's full allowable, then there are design methods that can be used to evaluate structural adequacy.

Method 1 (AISC Design Guide 1: *Base Plate and Anchor Rod Design*, 2nd ed.) conservatively limits the engagement length L_E to a minimum of half of the nut's height h. At this minimum engagement, the reduced allowable rod tension T_{A1} is considered to be half of its full (basic) allowable T_A. Partial-engagement lengths in between 50% and 100% of the nut height result in linear reductions of T_A:

$$T_{A1} = (L_E/h)T_A \quad (5)$$

where $0.5\,h \le L_E \le h$

Method 2 (AAMA *Design Guide for Metal Cladding Fasteners*) involves the use of an approximate equation for allowable bolt tension T_{A2}, which is based on external thread strength and the average load per engaged thread:

$$T_{A2} = F_{SU}A_{TSE}nL_E/S_{F2} = F_{SU}A_{TSEU}L_E/S_{F2} \quad (6)$$

where
F_{SU} = ultimate shear stress for anchor, ksi
A_{TSE} = stripping area per external thread, in.^{2}
S_{F2} = safety factor for Method 2
A_{TSEU} = stripping area per unit length of external thread, in.^{2}/in.

Use $F_{SU} = F_U/\sqrt{3}$ and $S_{F2} = 2.5$ per reference 3.

Heavy-hex Nut

A suitable heavy-hex nut (HHN, fully engaged) will, without thread stripping, allow a matching bolt or anchor to develop its tensile ultimate at the threaded cross-section. By calculation, using the external threads' minimum strip-strength and the average force per bolt thread, a HHN can develop at least 1.5 times the minimum tensile ultimate of the threaded bolt.

Here's an example: UNC thread series, $D = 1.25$ in., $n = 7$ threads/in.; anchor rod is ASTM F1554 Gr. 36 ($F_U = 58$ ksi); heavy-hex nut (Grade A) for which $F_U > 58$ ksi, height $h = 1.25$ in. (A regular-hex nut for this diameter has a height of ⅞ in., which is 70% of the HHN's height. Also, a Grade A ASTM A563 heavy-hex nut must be able to support a proof load due to a fully-engaged threaded fastener stressed in tension to 100 ksi, based on A_T). Eq. 7 from reference 5 gives the basic allowable tension T_A for the anchor rod.

$$\begin{aligned} T_A &= 0.75F_UA_G/\Omega \quad (7) \\ &= 0.75(58\text{ ksi})(1.227\text{ in.}^2)/2.0 \\ &= 26.7\text{ kips, the basic allowable tension of anchor rod} \end{aligned}$$

Method 1. Assume that the nut can be engaged with the rod for only ⅞ in. Use Method 1 to find the reduced allowable tension. Verify that at least half of the nut height is engaged: (⅞ in.)/(1.25 in.) = 70% > 50% OK

$$\begin{aligned} T_{A1} &= (L_E/h)T_A \\ &= (7/8\text{ in.}/1.25\text{ in.})(26.7\text{ k}) \\ &= 18.7\text{ kips; Method 1} \end{aligned}$$

Method 2. In this case, the nut has a total of 8.75 threads (1.25 in. × 7 threads/in.), but only 6.125 threads are engaged. Now use Method 2 to find the reduced allowable tension.

$$\begin{aligned} T_{A2} &= F_{SU}A_{TSE}nL_E/S_{F2} \\ &= (58\text{ ksi}/\sqrt{3})(0.301\text{ in.}^2/\text{thread})(7\text{ threads/in.})(0.875\text{ in.})/2.5 \\ &= 24.7\text{ kips; Method 2} \end{aligned}$$

This value exceeds the reduced value of 18.7 k from Method 1, but in this case is less than the rod's basic allowable of 26.7 k. This illustrates that Method 1 is the more conservative method.

Safety factor and Ω

The design method for allowable tension in a threaded fastener, as given in reference 5, results in a variable value of the actual safety factor S_F against tensile rupture. That is, Ω usually does not equal S_F. This is due to the simplification provided by use of the gross diameter A_G and to the variable ratio A_T/A_G. S_F equals the ratio of the minimum rupture strength (A_TF_U) to the allowable tension (given by Eq. 7):

$$S_F = A_TF_U/(0.75F_UA_G/\Omega) \quad (8)$$

As the diameter increases, both (A_T/A_G) and S_F increase in most cases (see Figures 3 and 6). The safety factor S_F ranges from 1.93 to 2.35. Threaded rods with $D \ge$ ¾ in. each have a minimum tensile ultimate that exceeds 2.0 times the corresponding allowable tension T_A. While conservative for basic tensile strength, this also means that a nut might be subjected to a larger tensile force than would otherwise be the case.

In conclusion, it is recommended that Method 1 be used in the case of a partially engaged nut and anchor rod. In addition to ensuring greater resistance to thread stripping, this will reduce or avoid inelastic shear deformation, at service load, in the most highly stressed threads. ■

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1. *Fastener Standards*, 6th ed. Industrial Fasteners Institute (IFI), 1988
2. *Inch Fastener Standards*, 8th ed., Industrial Fasteners Institute (IFI), 2011
3. *Design Guide for Metal Cladding Fasteners*, TIR A9-14, American Architectural Manufacturers Association (AAMA), 2014
4. Steel Design Guide 1: *Base Plate and Anchor Rod Design*, 2nd ed., American Institute of Steel Construction (AISC), 2006; (section 2.11.3)
5. *Specification for Structural Steel Buildings*, ANSI/AISC 360-10, 2010; (section J3, including Commentary)
6. *Steel Construction Manual*, 14th ed., AISC, 2011; (Part 7, tables 7-17 and 7-19)


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MORE THAN STEEL
JOISTS & DECK

This year's SteelDay continues the spirit of SteelDays past, while also introducing a couple of new elements.

business issues

STEELDAY IS COMING!

BY JOHN CROSS, PE

HERE'S A MULTIPLE-CHOICE QUESTION: Why would the American Institute of Steel Construction purchase 2,805 pizzas?

a. (really) hungry staff
b. Domino's promised to build its next headquarters out of steel
c. to celebrate SteelDay 2015 at engineering and architectural offices around the U.S.
d. to break the *Guinness Book of World Records* for most pizzas ordered in a day

If you answered "c" you are correct. SteelDay 2015 was a great celebration, with over 9,000 participants at 53 events throughout the United States. Structural steel fabricators opened their shops and hosted open houses. Project site tours occurred in several cities. And AISC hosted a luncheon webinar, "Steel and the Phantasmagoria," seen across the country at 673 engineering and architecture offices and presented by AISC vice president and chief structural engineer—and soon-to-be AISC president—Charlie Carter.

But SteelDay 2015 is now a memory and all eyes are focusing on SteelDay 2016, which will be held on September 30th.

SteelDay 2016 will be the eighth annual national celebration of the structural steel industry. And it *will* be a celebration: a celebration of the contributions that structural steel and the thousands of individuals in the design and construction industry working with structural steel have made to the buildings, industrial facilities, bridges and infrastructure of this country.

Once again, many structural steel fabricators will be hosting open houses at their shops. Open houses present an opportunity for engineer, architects and students to look inside the "black box" and experience the process of detailing and fabricating structural steel. And other facility types, such as galvanizing plants, are also scheduling open houses.

Project site tours are also being planned in several cities across the country where signature steel structures are being erected. These events often include presentations by the project's designers, fabricators and erectors on the decisions and approaches used for the project. Site tours are a great means of understanding how other designers and fabricators approach difficult project challenges and address them with innovative steel solutions.

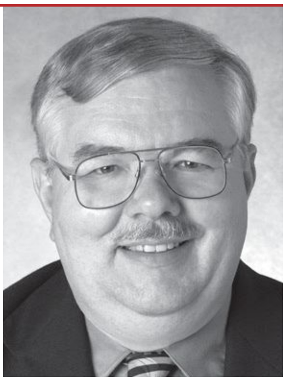
Open houses and site tours, along with registration instructions, are listed on the events page of **www.steelday.org**.

Incorporating Ideas

In addition to the live events, two new features are being added to this year's SteelDay. AISC has a long tradition of recognizing excellence in the design and construction of structural steel-framed buildings through the IDEAS² Awards program (IDEAS² stands for "Innovative Design in Engineering and Architecture with Structural Steel"). In the past, project submissions were due in early January and were judged by a distinguished panel of design and construction professionals with the winning projects announced at NASCC: The Steel Conference in late March or early April. But this year, the competition has been incorporated into SteelDay, and the submission deadline has been moved up to late August in order to provide an opportunity for "People's Choice" input into the judging process.

During the week of SteelDay—starting on Monday, September 26—design and construction professionals can visit the IDEAS² website (**www.aisc.org/ideas2**) to review the projects entered in this year's competition and cast a vote for their favorite project in several different categories.

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



Movie Time

As for the second new feature, while SteelDay has traditionally included a complimentary lunch webinar, this year we have arranged for a series of screenings of a recently released documentary film *Bridging Urban America: The Story of Ralph Modjeski*. So who was Ralph Modjeski and why would AISC (and NSBA, the National Steel Bridge Alliance) be showing a documentary about his life on SteelDay?

In the early 20th century, Ralph Modjeski designed and built many of the bridges that spanned the great and powerful rivers of America. The Mississippi, the Missouri, the Columbia, the Hudson, the Ohio, the Detroit, the Willamette, the Maumee and the Delaware; these rivers and more were bridged through the work of Ralph Modjeski. While Modjeski adhered to the engineer's motto of "stronger, safer, cheaper," he brought an artist's touch inherited from his mother and cultivated by his love of Chopin and the piano to each project.

Modjeski began his career in the late 1800s and quickly learned that teamwork, creativity, improvisation and facing challenges head on were as important as basic engineering principles. In 1896, he was named chief engineer for the Rock Island Arsenal Bridge over the Mississippi River. Faced with the weather-related failure of the crucial center swing span during construction, Modjeski didn't dwell on the fact that he had previously argued that the risk was too great and that construction should be delayed. Rather, he quickly engineered and supervised the construction of a temporary replacement span that minimized interruption of river traffic and allowed rail traffic across the Mississippi River.

Ralph's story is about more than the bridges he built. It is the story of an engineer who was innovative, competent, diligent and internationally recognized, yet was willing to listen to the advice of others and work along aside the men and women building the bridges that continue to serve us today. While other engineers resisted input into their designs and peer review from other bridge engineers, Modjeski actively participated in group design efforts and partnerships, lending his expertise to others while learning from them. His life story is a case study for the practice of engineering.

Please visit **www.steelday.org/webinar** to check the showing times in your area and to register for the webinar. An online quiz will be available following the webinar for those wishing to obtain 1.5 hours of continuing education credit.

Have a Happy SteelDay! ■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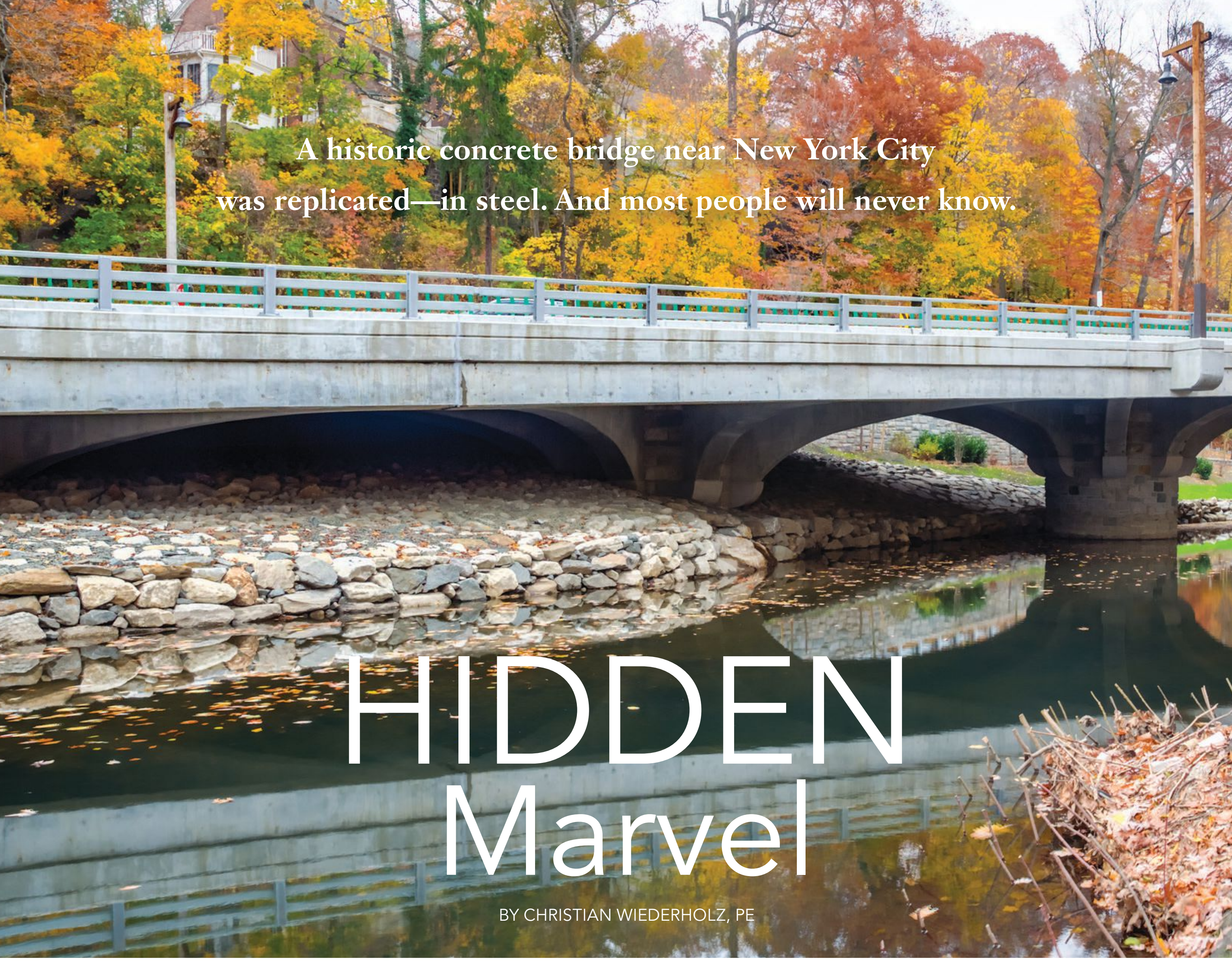
STEEL



A historic concrete bridge near New York City was replicated—in steel. And most people will never know.

HIDDEN Marvel

BY CHRISTIAN WIEDERHOLZ, PE

WHEN YOU HEAR "MUSHROOM BRIDGE," you may very well think of Mario Kart.

But it's also the nickname of a portion of the Crane Road Bridge, a nearly century-old crossing in north suburban New York City.

Comprising two bridges, it carries the Bronx River Parkway through a forest preserve in the Village of Scarsdale and the Town of Greenburgh in Westchester County. The southern bridge is a multi-span concrete bridge (the Mushroom Bridge portion) that crosses the Bronx River, while the northern bridge is a single-span steel through-girder bridge that crosses the two-track Metro-North Railroad Harlem Line (accordingly called the MNR Bridge).

Dating back to 1925, both bridges have been rehabilitated over the years. But when two separate incidents, both of which involved holes punched completely through the concrete deck, resulted in emergency closures and repairs, the Westchester County Department of Public Works and Transportation took immediate action.

An in-depth bridge inspection revealed that the concrete deck slab of the Mushroom Bridge was in a state of advanced deterioration. The reinforcing steel exposed through the spalled concrete had advanced section loss, and the concrete slab around the holes was completely pulverized. The concrete brackets had numerous cracks and spalls, and the overall condition of the deck was rated poor and quickly approaching severe.

Furthermore, traffic safety along this stretch of the Bronx River Parkway continued to be a major concern. Within the project limits, narrow travel lanes with minimum shoulders, sharp curves and limited sight distance had led to an accident rate six times higher than the statewide average. As a result, the County hired a team led by structural engineer Stantec, contractor EE Cruz and construction inspector LKB, Inc., to inspect, repair and design replacement bridges for the aging structures.

Christian Wiederholz (christian.wiederholz@stantec.com) is an associate and structural engineer based in Stantec's Rochelle Park, N.J., office.

Photos: Stantec

▲ Pedestrian use and access to the bridge was improved with the reconstruction.

◄ The new bridge alignment enhances the historic bridge's roadway geometry.

Blending History with Innovation

From the outset, the County and the other agencies involved with funding and approving the project recognized that preserving the unique historic and environmental character of the bridge was a crucial factor. After an exhaustive public screening process and inter-agency coordination, the County selected a replacement alternative of constructing a new bridge that replicated the existing Mushroom Bridge structure.

This alternative provided wider replacement structures immediately south of the existing bridges, allowing for construction phasing such that traffic could continue to use the highway while improving the roadway geometry. The proposed modifications included:

- Replacing the Mushroom Bridge superstructure and substructure with a substantially wider deck
- Replacing the MNR Bridge with a redundant type structure (composite prestressed concrete box beam bridge)
- Replicating the existing Mushroom Bridge piers to maintain the form of the historic pier configuration while relocating them along a similar alignment
- Completing the project's construction within an approximately $39 million budget and three-year schedule

Achieving these vast improvements was no easy task. While the bridge was to be widened, the number and size of the piers were required to remain more or less the same due to flow concerns, which presented obstacles for the structural design. Each existing mushroom superstructure panel was approximately 40 ft by 40 ft, or 1,600 sq. ft. The proposed configuration for each panel was approximately 60 ft by 60 ft, or 3,600 sq. ft, so each panel more than doubled in size. Therefore, the loads that each bracket and pier needed to carry were increased substantially.

The design codes had also changed since the original bridge was built, requiring the replacement structure to carry much heavier traffic loads than the original design. Additionally, each bracket has needed to be significantly longer in order to reach the ends of the enlarged panel. Deflections at the tips of these brackets played a large role in the design of the structure.

The Steel Solution

Most of the Bronx River Parkway bridges are made of concrete, including the existing Mushroom Bridge. Reinforced concrete arch brackets radiated from the central piers, and the center of the deck panel directly over the piers was heavily reinforced with bars from each bracket that converged and overlapped. Since the new brackets are longer and carry more load,

▲ The partially erected Mushroom Bridge, showing steel core and steel brackets.

◄ The bridge's concrete-encased brackets and core.

using reinforced concrete brackets in the new design proved to be impossible due to rebar congestion. In order to address the unique configuration of the superstructure, an innovative steel option was used in which an octagonal core made up of steel plates was fastened to the concrete pier.

The steel core is made up of 1¾-in. steel side plates and 2½-in. top plates. Steel brackets protrude from each face of the core and are spliced to steel ring plates at the top of the core. To provide access for bolting, the top plates were designed as rings, leaving a 3-ft diameter opening in the center. A bottom flange shelf support and web connection, along with with horizontal stiffeners to combat the prying action, complete the bracket connection to the core.

Further complicating the custom steel core were the longitudinal and transverse slopes of the roadway, as well as the curvature of the bridge. As a result, each octagonal core was unique. But while the top of the core was sloped in two directions, the top flanges of the brackets were level, so tapered shims were required to facilitate the bolted connection.

The steel core was secured to the concrete pier via anchor bolts and studs. The

◄ Existing bridge in the background; replicated structure in the foreground.

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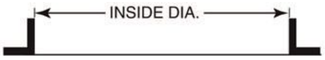
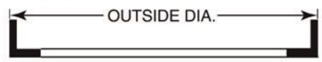


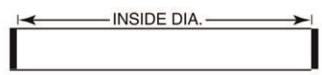
10" x 10" x 1" Angle

2 Angle Leg In


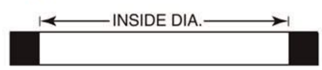
10" x 10" x 1" Angle

3 Flat Bar The Hard Way

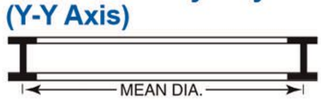

24" x 12" Flat

4 Flat Bar The Easy Way


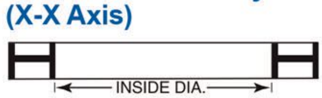
36" x 12" Flat

5 Square Bar


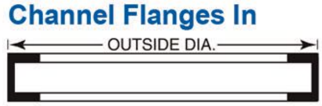
18" Square

6 Beam The Easy Way (Y-Y Axis)


44" x 335#, 36" x 925#

7 Beam The Hard Way (X-X Axis)


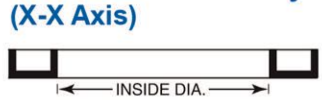
44" x 285#

8 Channel Flanges In


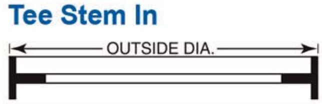
All Sizes

9 Channel Flanges Out

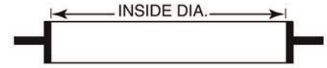

All Sizes

10 Channel The Hard Way (X-X Axis)


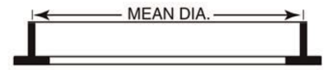
All Sizes

11 Tee Stem In


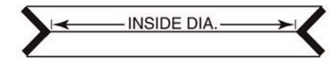
22" x 142 1/2# Tee

12 Tee Stem Out


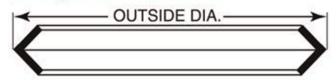
22" x 142 1/2# Tee

13 Tee Stem Up


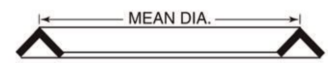
22" x 142 1/2# Tee

14 Angle Heel In


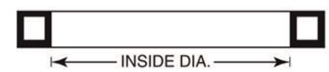
8" x 8" x 1" Angle

15 Angle Heel Out


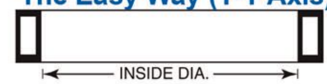
8" x 8" x 1" Angle

16 Angle Heel Up


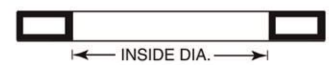
8" x 8"x1" Angle

17 Square Tube


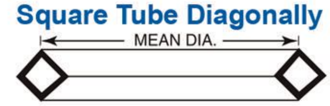
24" x 1/2" Tube

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


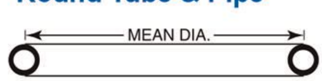
20" x 12" x 5/8" Tube

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


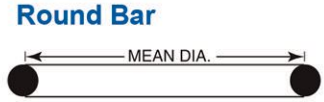
20" x 12" x 5/8" Tube

20 Square Tube Diagonally


12" x 5/8" Square Tube

21 Round Tube & Pipe


24" Sched. 80 Pipe

22 Round Bar


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The bridge's uniquely shaped piers gave it its Mushroom Bridge nickname.

built-up plate brackets were designed with varying depths to decrease the weight and allow replication of the existing curved arch brackets. The perimeter of each 60-ft by 60-ft deck panel was lined with rolled steel edge and fascia beams that connect to the tips of the cantilever built-up steel brackets. The entire steel solution was encased in concrete to maintain the overall aesthetic of the existing bridge.

In order to provide for a redundant structure, the bridge was designed to remain in service even after complete failure of one bracket per panel. Additionally, each panel of the superstructure can behave independently, gaining no necessary support from an adjacent panel.

Built to Last

Despite the tight parameters, the project team designed a replacement structure that has vastly improved the crossing's safety. The entire bridge is wider, including all four travel lanes and shoulders. There are also acceleration/deceleration lanes now, which were virtually nonexistent before. In addition, a merging roadway was raised so that drivers on the Bronx River Parkway and the road can easily see one another and merge safely, and the curved alignment was softened to improve sight distances.

And beneath a facade of salvaged stone facing lies the Crane Road Bridge's most unique and crucial feature: its steel core. While the replacement bridge continues to be a striking and historic fixture of the Bronx River Reservation, the true marvel of its reconstruction will remain hidden from the public eye. ■

Owner
Westchester County Department of Public Works and Transportation

General Contractor
EE Cruz, New York

Structural Engineer
Stantec, Rochelle Park, N.J.

Steel Fabricator
American Bridge, Coraopolis, Pa.

Smooth OPERATOR

L.A. Metro's innovative new operations and maintenance facility is the latest addition to the area's growing transit network.

BY SEAN FEENEY

Photos: RNL and Chang Kim Photography

LOS ANGELES COUNTY Metropolitan Transportation Authority (Metro) keeps a lot of people moving.

The entity serves as the transportation planner, coordinator, designer, builder and operator for one of the country's largest, most populous counties. More than 10 million people live, work and play within its 1,433-sq.-mile service area.

Metro's Expo Light Rail Line is the first passenger rail line to connect downtown Los Angeles and Santa Monica in over 60 years. Designed by architect RNL, industrial design manager MDG and structural engineer Nabih Youssef Associates Structural Engineers (NYASE), the Expo Division 14 Operations and Maintenance Facility is a critical component of the Expo Line. Metro wanted Division 14 to represent innovation, sustainability, functionality and wellness, as well as fit in with a neighboring recording studio and nearby residences. Completed this past May, the facility maximizes the use of natural light and is on track to attain LEED Gold certification.

Sean Feeney (sean.feeney@rnldesign.com) is a senior associate at RNL and was the lead architect and construction administrator on the Expo Division 14 project.

Five in One

The project encompasses over 70,000 sq. ft of building area on a narrow 9.7-acre site. Five major building components make up the facility: main building, secondary building, wash building, cleaning platform and guardhouse. The main building contains the primary train maintenance bays and shops, an operator breakroom, amenities and the yard control and administration offices. The secondary building contains the blowdown bay and wheel-truing bay, and the wash building is a drive-through train wash. The cleaning platform is a double-track platform for daily interior cleaning, and the guardhouse is a 24/7 security hub at the main entrance to the site.

Early design concepts expressed the facility's industrial nature and provided a sculptural aesthetic to the public. On the interior, the structural steel system was exposed and expressed with dark gray paint, and the metal deck ceiling, walls and floors were painted white. Structural steel travels from the maintenance areas to the finished operations areas and is meant to visually bring together the two different personalities of the facility: maintenance and operations.

The typology of a rail maintenance facility requires tall unimpeded bays in the direction of train travel to accommodate the overhead contact system (OCS)—the electric lines that power the trains—and pantograph while still meeting seismic requirements; LA Metro Expo Division 14 resides in a Seismic Design Category D.

NYASE analyzed the site and facility needs and concluded that a structural system with multiple framing schemes proved to be the most economical and functionally viable solution. Open-span moment frames allowing train travel were used in the north-south direction in combination with braced frames in the east-west direction. The braced frames pass through the second-floor soft areas, including offices and hallways, and the steel framing allowed maximum visibility of the yard from the control suite, second-floor offices and operator amenity rooms. The narrowness of the site required a unique solution of overlapping some of the building spaces over the train yard and the maintenance area. The moment frames span 34 ft over two train tracks, and the main hallway cantilevers over a part of the maintenance area.

Maximizing Visibility

The control suite is the heart and brain of the facility and was designed to cantilever out from the north elevation to provide views to both sides of the yard. All train operations in the yard are controlled from within this room, so exceptional visibility of the two lead tracks to the main line and the other remote buildings—and really the site as a whole—is mandatory. A centrally located two-story mega-V brace—each brace spanning 70 ft—allowed two columns to be removed that would otherwise partially block the view out the side windows of the suite, and is visible to commuters riding by the facility on the Expo Line.

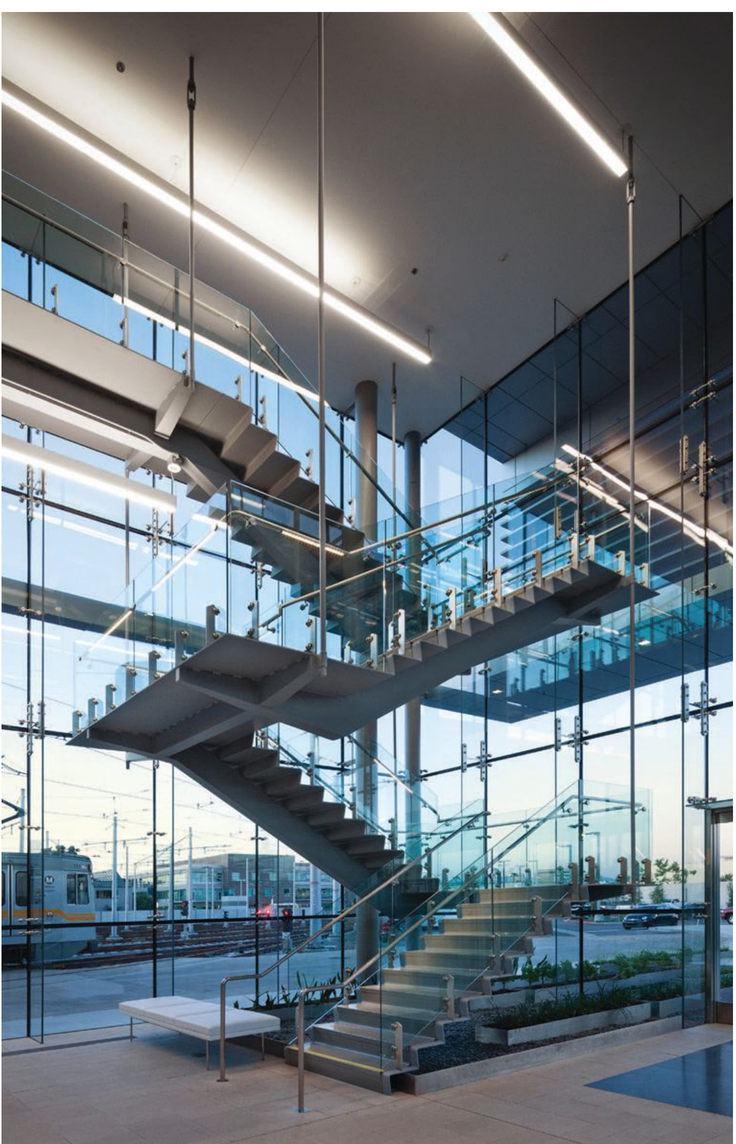
In some locations, the structural steel had to be limited in depth and width in order to fit within the very thin profiles of the building. Subtle tweaks to the structure, including the corner offset transfer columns, allow the glazed curtain wall to wrap around the corners uninterrupted so that the fine detailing of the window mullions and metal panel reveals match up with the underlying 5-ft building grid.

While steel is plentiful throughout the facility, the lobby stairs and associated supporting steel are the only exposed steel members that were required to meet architecturally exposed structural steel (AESS) quality standards. The lobby stair is composed of ½-in. bent steel plate and has multiple landings to ascend to the second floor height of 22 ft. The stair was designed to look monolithic; it literally hangs from the roof structure above via 1½-in.-diameter rods. Glass railings with illuminated handrails were added to further express the steel plate stairs.

In other parts of the facility, the steel takes on a more industrial aesthetic. An insulated precast concrete panel system was used in these spaces, and NYASE coordinated closely with a precast contractor to make sure the structural steel system was robust enough to accept the additional burden of the concrete

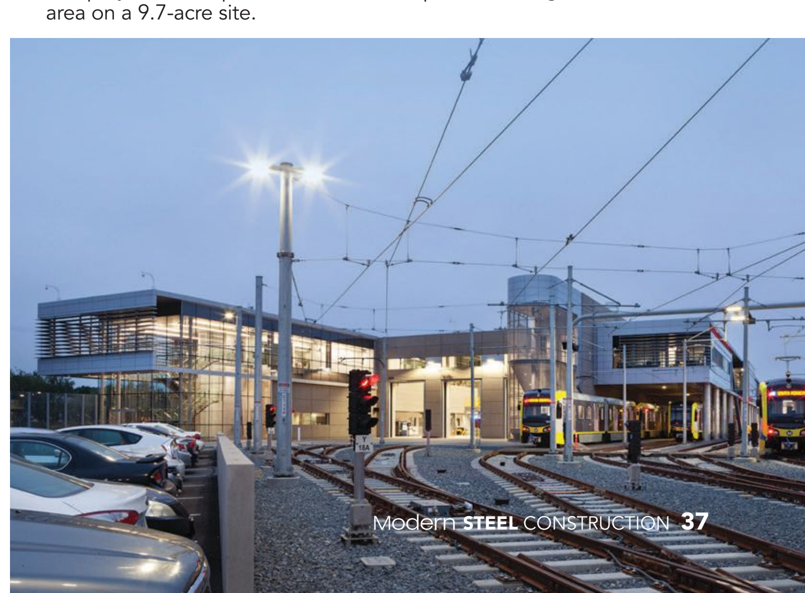
◄ The narrow site created an overlapping program: two rail tracks pass underneath the "north bar."

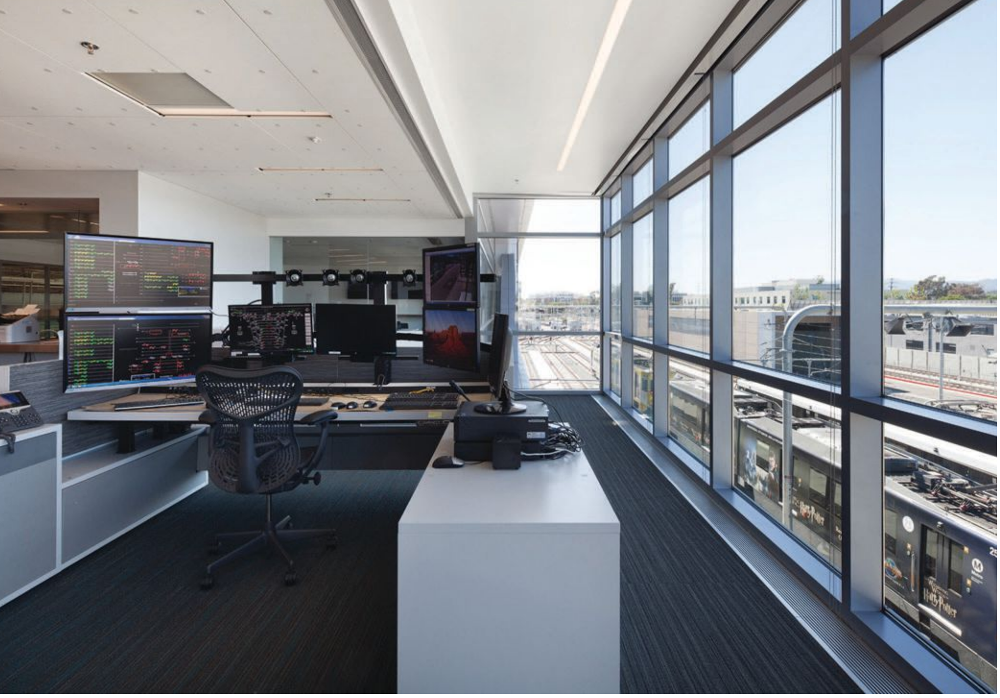
▼ The steel lobby stairs hang from the roof structure.



▲ Long spans are hidden within the metal panel profiles.

▼ The project encompasses over 70,000 sq. ft of building area on a 9.7-acre site.





The control suite has a view of the full length of the yard.

An early rendering of the site.

walls. Precast panels were also used as shear walls for some of the buildings to seismically brace the structural framing.

Healthy Maintenance

The main purpose of the facility is for the maintenance and storage of 45 light rail cars. There are three run-through train bays (no dead ends) that are used for quick service and inspection as well as more time-dependent tasks such as component change-out and truck repair.

The steel-framed bays have a clear height of over 30 ft to accommodate the continuous OCS wire that passes through and the two large bridge cranes that dominate the bay. Train roofs

Large skylights fill the maintenance area with diffused natural daylight.

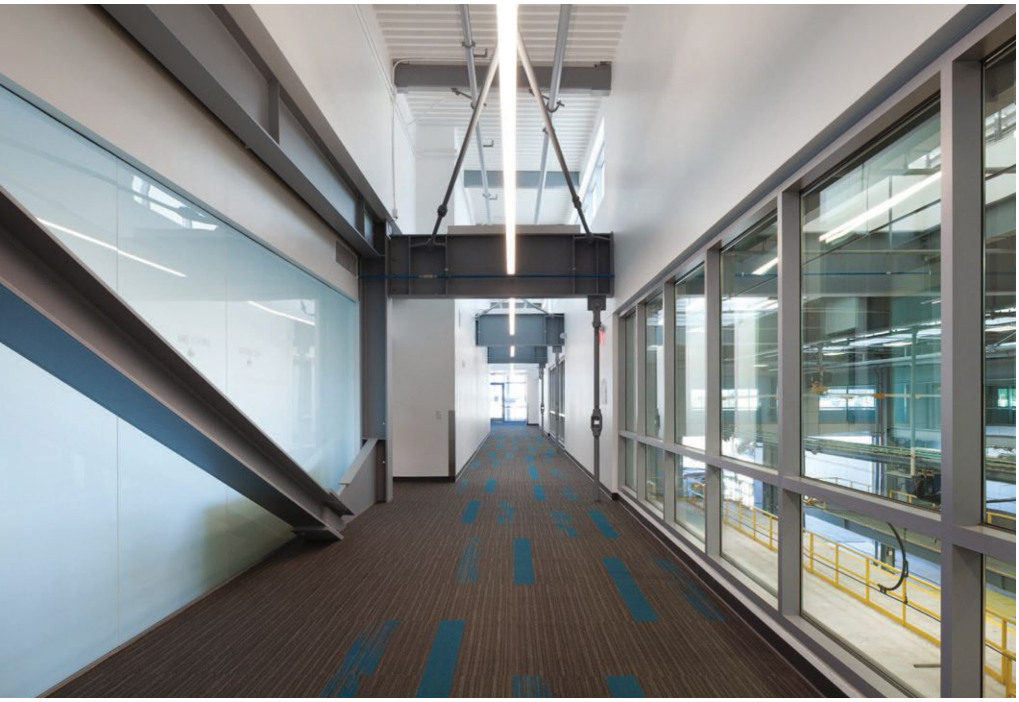
are accessed by an elevated composite deck platform, safety platforms made of metal grating allow the passage of light and serve as fall protection and a recessed pit area provides access to the undercarriage of the trains. The structural steel in this space is painted a dark gray to differentiate from the background of the white ceiling, walls and floors. To enhance safety, much of the miscellaneous steel, such as guardrails, lift cages and platform edges, are painted an obvious yellow.

The north bar of the main building, which contains the operations administrative offices, the control suite and the op-

▲ The large V brace is visible from passing Expo Line light rail trains.

▼ Structural steel expresses itself in the office areas as well as the maintenance areas.

▲ Structural braced frames are expressed sculpturally.



erators room and amenities, provides ample views towards the north through a floor-to-ceiling glazed curtain wall. In order to take advantage of borrowed light, many of the interior partitions are glazed, which gave the design team an additional opportunity to express the industrial nature of the project by ghosting the brace frames behind translucent walls.

The design of Expo Division 14 is industrial and efficient as well as attractive and mindful of its place in the surrounding community. The open, steel-framed facility provides a healthy, naturally lit environment for its employees—as opposed to the dark, grungy spaces typically associated with such facilities—and offers Metro passengers a glimpse, and perhaps better appreciation, into the inner workings of the train system and the structural systems that make it possible. ■

Owner
Los Angeles County Metropolitan Transportation Authority

Design Manager/Industrial Facility Design
MDG

General Contractor
Kiewit Building Group

The maintenance area of the main building.

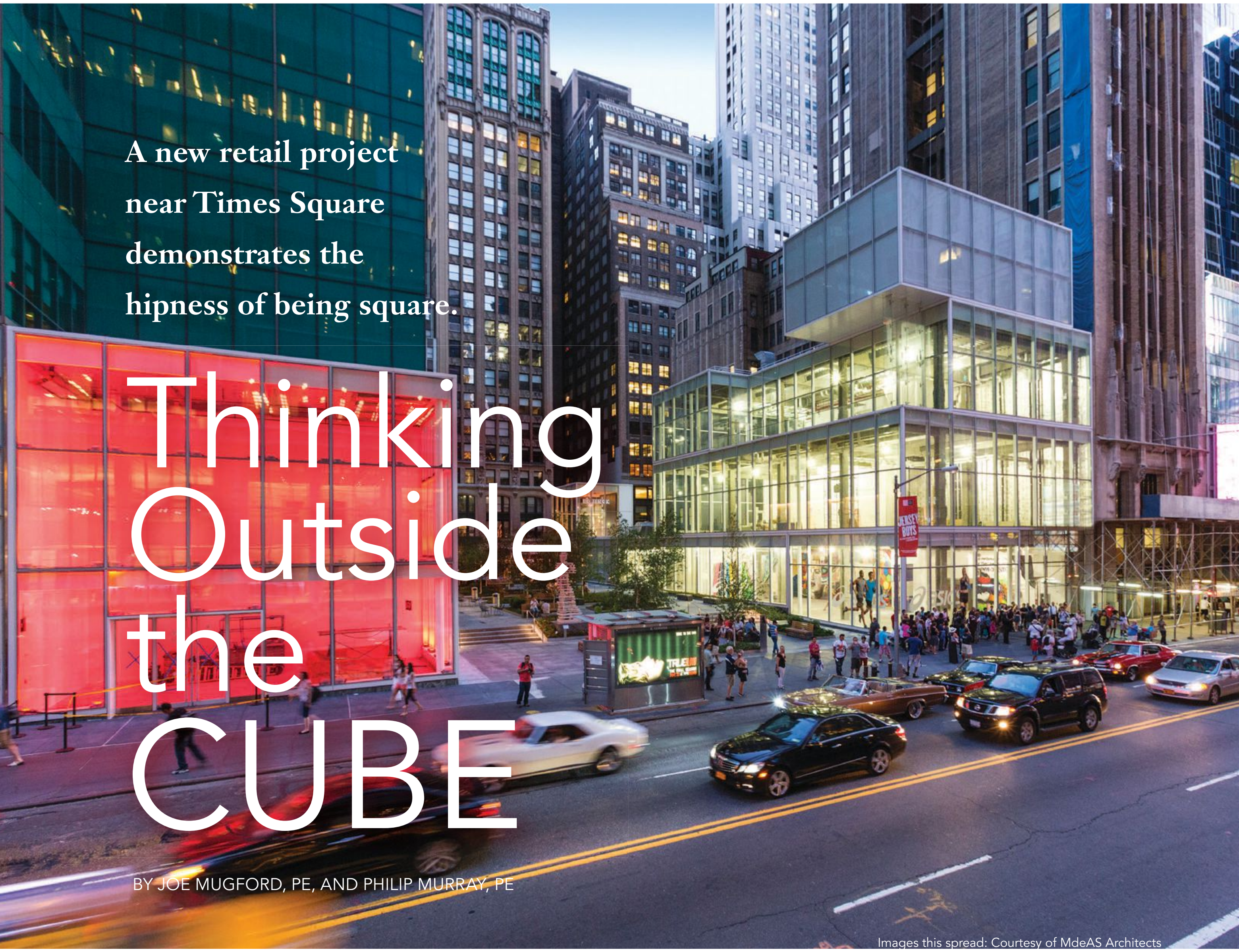
Architect
RNL

Structural Engineer
Nabih Youssef Associates

Steel Team

Fabricator
Beck Steel, Lubbock, Texas

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



A new retail project near Times Square demonstrates the hipness of being square.

Thinking Outside the CUBE

BY JOE MUGFORD, PE, AND PHILIP MURRAY, PE

Images this spread: Courtesy of MdeAS Architects

A DRAMATIC RETAIL NEWCOMER of cubic proportions has come to Manhattan's 42nd Street commercial corridor.

Known as the Cubes, the project flanks the western edge of a through-block plaza at 120 West 42nd Street between Avenue of the Americas and Broadway. Its design employs several distinct boxes shifted in relation to one another while maintaining the uniformity of its grid, and contrasts with the monolithic character of the adjacent 1095 Avenue of the Americas tower (also known as 3 Bryant Park). Framed with 400 tons of structural steel, the 85-ft-tall structure comprises three occupied floors, as well as a fourth-floor mechanical penthouse, and contains approximately 23,000 sq. ft of above-grade retail space and an additional 55,200 sq. ft below grade in the cellar and sub-cellar. The protruding blocks provide an additional 4,300 sq. ft of accessible rooftop exterior space. The design relocated the main entrance to the 1095 tower from the Avenue to the west side of the building (plaza-side) where a new double-height lobby was constructed. Relocating the entrance allowed for additional retail space along the Avenue. The existing subway entrance was repositioned away from the plaza corner to allow prime retail use of that space.

Jewel Box

Glass curtain walls, wide interiors spans and lots of right angles make the interior spaces light-filled and engaging. Across the plaza, this approach is mimicked at the interior of the existing 1095 tower. From the street, the structure looks like two separate buildings, but the two sides are actually united underground.

The ground-up development required demolition of a six-story 1940s building. Additionally, part of an existing annex building was demolished to grade, but its substructure was preserved and engaged by the new superstructure. Drawings for the existing building lacked the appropriate level of details and demanded extensive field verification. The 1970s design of the existing annex building, which was partially demolished, assumed subsequent addition of more floors. Thus, the preserved substructure did not require much reinforcement, as columns were already oversized, and reserve capacity was therefore available to support the new

Setbacks and the mechanical penthouse.

Southwest view from 42nd Street.

Rendering of project components (looking south from 42nd Street).

design. However, the column grid of the new superstructure does not align with the grid of the substructure, so the design employs W30×173 transfer girders at the plaza level that distribute the load to the foundation. The new foundation system consists of spread footings on 20-ton rock. The challenging excavation and foundation work included digging 32 ft below street level adjacent to the operational 42nd Street MTA subway tunnel, with careful attention to earthwork vibration. The dig took place around existing W14 columns, which had to be temporarily supported with drilled piles.

The open layout of the retail floor plates above grade required a long-span column grid, typically 25 ft by 45 ft. With 20-ft floor-to-floor heights, careful consideration of live loads and vibrations demanded stiffer frames. The entire superstructure is designed using moment frames to maintain an open layout for future retail flexibility, and floor vibrations for occupant comfort were taken into consideration in the design of the structure. In accordance with AISC Design Guide 11: *Vibrations of Steel-Framed Structural Systems Due to Human Activity*, these vibrations were limited to a maximum of 1.5% gravity acceleration at

Joe Mugford (joe.mugford@gmsllp.com) is an associate and **Philip Murray** (philip.murray@gmsllp.com) is a partner, both with Gilsanz Murray Steficek.

▲ Substructure. ▼ Superstructure. ➤ A bent girder.

▲ Westward view of plaza.
◀ Northwest view of plaza.
➤ Schematic of frame reinforcement at lobby.

2% damping. (You can read more about the new edition of Design Guide 11 in "Living (Comfortably) with Vibration" on page 58.)

The primary W14×193 and W14×283 moment frame columns are set back 14 ft from the east façade, and round 10-in. hollow structural sections (HSS) were used along the east façade to minimize their visual impact. The floor framing consists of typical W18×35 beams spanning to 30-in. and 36-in. girders, and floor slabs are 3.5-in. lightweight concrete on 3-in. metal deck. The structure is designed to support a 60-ft billboard above the roof as well as a full-span LED display anchored to the north façade, a nod to the Times Square lighting requirements.

Planted Plaza

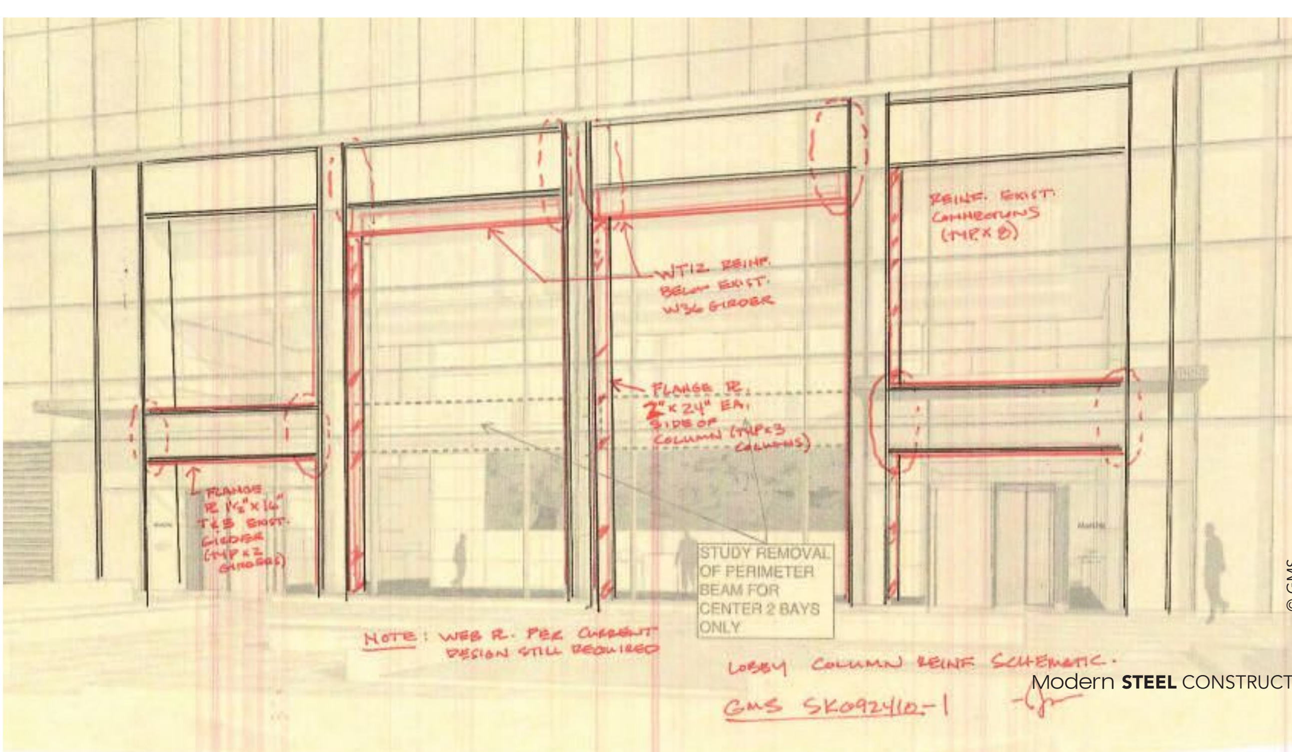
Another design challenge was accommodating the change in grade at the perimeter of the site. The elevation of the northern section of the renovated plaza is 3 ft higher than the ground floor elevation of the Cubes. Structural engineer GMS designed a series of "bent" transfer girders to maximize the retail ceiling heights below. The plaza renovation also demanded careful attention to the design and installation of tree pits so as not to encroach on floor-to-ceiling heights below. The bottom of the 9-in. pit slab is flush with the bottom flange of neighboring W36 and supported by L3 angles welded to either side of HSS9×5×½, which spans in between existing W36 beams at 3 ft, 6-in. on center. This provided adequate support for the weight of the soil and trees, which required a design load of 600 psf.

Approximately 30 ft of the southern portion of the prior plaza was demolished and rebuilt at a lower elevation to match the level of the sidewalk at 41st Street. This generated a more inviting space, similar to the pedestrian approach from the north. Planters, stairs and ramps separate the lower southern portions and raised northern portions of the plaza.

Augmented Atrium

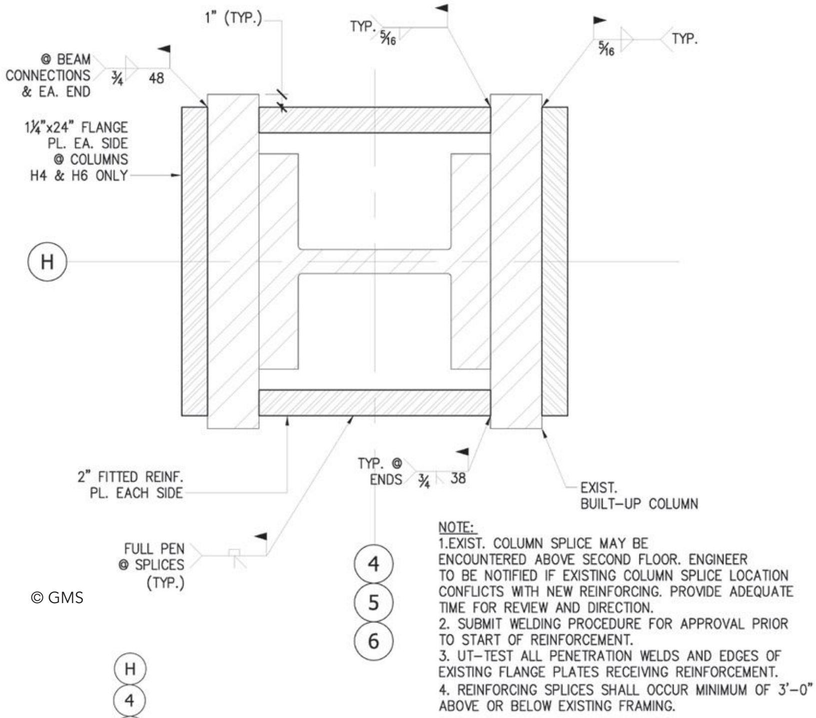
Across the plaza from the Cubes, the existing 1095 Avenue of the Americas is a 40-story steel-framed office building, constructed in 1972, with four moment frames in the north-south direction. The westernmost frame (plaza-side façade) needed to be modified to accommodate the relocation and vertical enlargement of the building's main lobby into a 33-ft-high, two-story atrium. The second floor slab was removed at four north-south bays (25 ft each) by one east-west bay (18 ft, 6 in.). Creating the storefront at the lobby also required removing two wind girders at the second floor, which represented 20% of the floor stiffness at that level. To compensate, the wind girders overhead and in adjacent bays were reinforced, as were the columns that support them. Girders at the second floor are reinforced with 1.125-in. plates at the top and bottom flanges; the third-floor girders are reinforced with WT7×79.5 at bottom flange. Existing built-up columns consist of W14×426 with 6-in. flange cover plates. These were further stiffened with new 2-in. by 18½-in. fitted reinforcing plates added between the flanges, forming a box and providing stiffness necessary to counteract the increased unbraced length. The two end columns that had supported the removed wind girders also have new 1¼-in. flange plates (over the original plates).

▲ The new 1095 Avenue of the Americas lobby from the plaza.



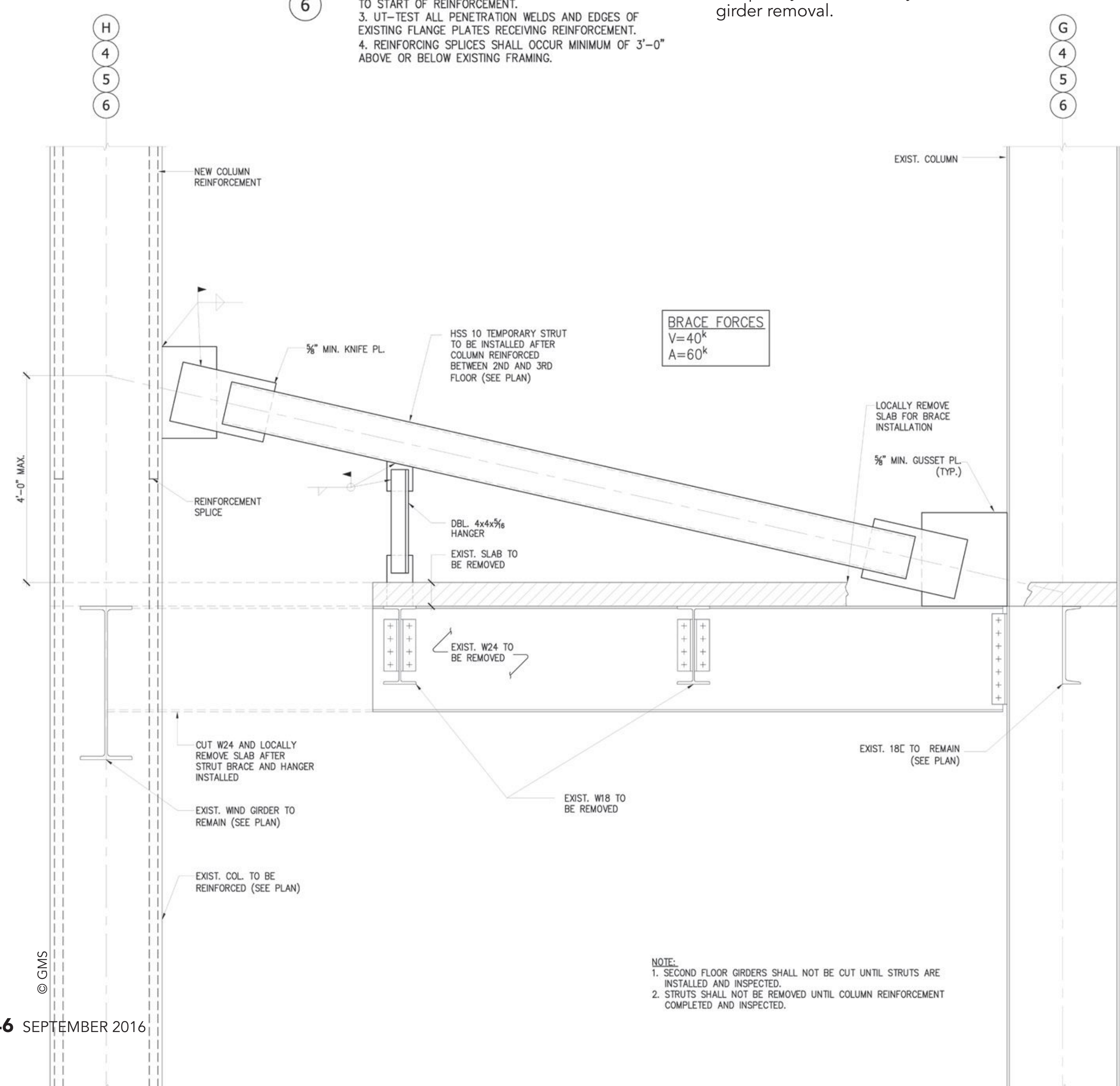
The demolition and installation procedure followed a specific sequence to safeguard the building's ongoing stability during the work:

1. Install column cover plates between the second and third floors
2. Locally remove the slab around the columns and install temporary struts (HSS10)
3. Install a double hanger from temporary struts to the existing east-west beam (W24)
4. Remove a portion of the existing W24 proximate to the western frame
5. Reinforce the perimeter wind girders
6. Complete column reinforcement between first and second floors
7. At the second floor, demolish the remainder of the slab and the W24 beam and temporary strut assemblies



◄ Plate reinforcement of lobby columns.

▼ Temporary strut assembly for slab and girder removal.



A girder before removal...

...and after removal.

Refurbished Retail

The final component of the project was the redevelopment of the 1095 tower's frontage along 42nd Street with a new double-height retail space at the western corner, which connects the street to the concourse beneath the plaza. To the east of this corner space, new stairs and a glass elevator provide access to the subway station beneath the Avenue. However, a moderate elevation difference between where the stairs and elevator land below grade and the entry to the subway station required a ramp structure, which was obstructed by existing framing at the underground concourse level.

Similar to changing the grade between the Cubes and the plaza, a bent beam was installed to support the ramp from a lower elevation. The tops of the existing beams were coped 4 ft from the foundation wall and new 8-ft lengths of beam were added below, bolted to the existing beams' bottom flanges, with a 4-ft overlap. The lower member sits on a channel seat at the foundation wall.

Dramatic Destination

Originally initiated as a plaza restoration, the project was reconceived into a $22 million white box development (the Cubes) and $14 million reconstruction (plaza and 1095 tower). In 2015, the entire property consisting of the Cubes and 1095 Avenue of the Americas tower was sold by Blackstone to Ivanhoe-Callahan Capital joint-venture for $2.2 billion—at that time the largest transaction for a U.S. office building since 2008.

"There is a high demand for new retail space away from the traditional Fifth Avenue shopping district as more brands begin to scout locations lower on Fifth Avenue or closer to Times Square," said William Pisani, vice president of Shawmut Design and Construction. Whole Foods is taking two floors of the 1095 tower at the Avenue and Pandora occupies the plaza-side retail corner.

The glass and steel structure solidifies the plaza's prominence as an active destination by surrounding the plaza above and below grade with retail spaces. One of the Cubes' first retail tenants was an Asics store, which incorporated a 7-ton NYC subway car into its space—a unique retail experience for a unique structure. ■

The authors would like to thank Petr Vancura for his help in writing this article.

Developer
Equity Office, New York

Architect
MdeAS Architects, New York

Structural Engineer
Gilsanz Murray Steficek, New York

General Contractors
Shawmut Design and Construction, New York
Structure Tone (plaza), New York

Steel Fabricators, Erectors and Detailers
United Structural Works, Congers, N.Y.
Burgess Steel, Englewood, N.J.

Designed and built nearly simultaneously, a new office building enhances a Cedar Rapids Growth corridor, turning a vacant lot into premium office space and facilitating expansion.

Rapid RISE

BY MATT BARRON, PE, AARON DAVIS AND MARK SEABOLD

Mike Fager/Fisheye Photography

CEDAR RAPIDS' NORTHWEST QUADRANT is ripe for growth.

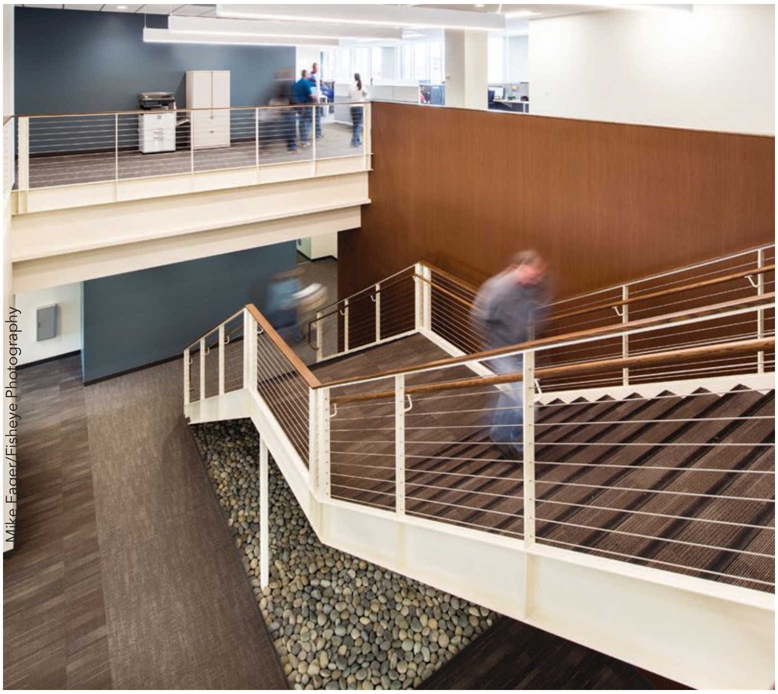
The area features the national headquarters for Transamerica Life Insurance and many other office-commercial complexes and is near the growing Edgewood neighborhood. Owner/developer Hunter Companies recognized the potential for the area and decided to build a $12 million, 67,000-sq.-ft, multistory office building with first-floor retail and restaurant space.

The anchor tenant for the building was quickly secured: Berthel Fisher, a financial services company that employs 85 full-time staff members who serve approximately 700 representatives nationwide. Named for its anchor tenant, the Berthel Fisher Financial Center is an L-shaped building split in two using an expansion joint at the corner. Half of the building—36,000 sq. ft—is Berthel Fisher's three-story office, including an adjacent, limestone-clad single-story restaurant; the other half is a low-slung, two-story brick-clad mixed-use space with retail on the first floor and additional office space on the second floor. The building's design can accommodate an expansion of up to 15,000 sq. ft in the future as Berthel Fisher continues to grow.

Staying On Pace

Berthel Fisher had wanted to move its national headquarters back to Cedar Rapids from nearby Marion, Iowa, for more than two years, and the company's desire to get into the space as quickly as possible fast-tracked the construction project and mandated a tight deadline of less than one year from design to occupancy. With speed playing such a factor, the structure had to be designed before the rest of the building. A rough version of the frame was designed, followed by a detailed version of the foundation. After construction was under way, the frame was modified to include floor and roof framing.

Rooftop mechanical units were selected and laid out after the building's structural steel was fabricated and built, creating a working atmosphere similar to an existing building—i.e., the ability to make changes was very limited. But the flexibility provided by 23 steel KCS joists above the three-story office space and an additional seven KCS joists over the restaurant allowed for mechanical unit location flexibility so the project could move forward without delays—despite the fact that design and construction were happening concurrently. In situations like these, where exact locations of point loads aren't yet available


Mike Fager/Fisheye Photography


Shive-Hattery

▲ The three-story portion, under construction.

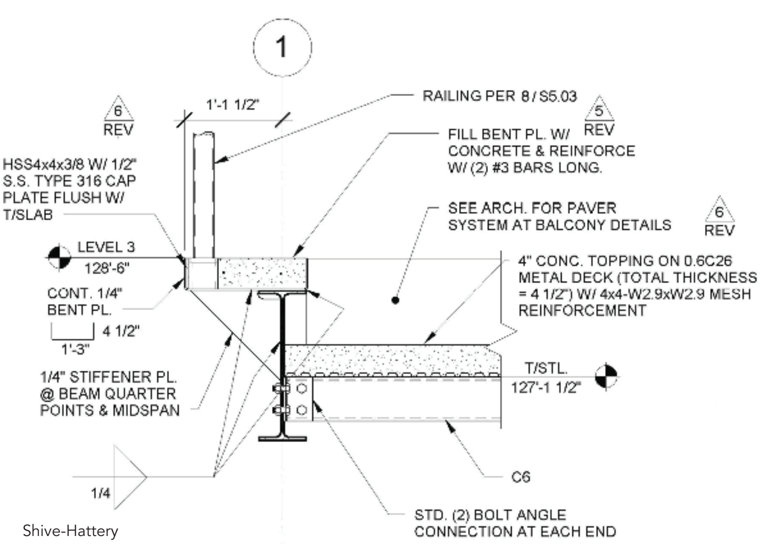
▼ The stair uses exposed structural steel.


Mike Fager/Fisheye Photography

▲ The 67,000-sq.-ft building mixes office, retail and restaurant space.

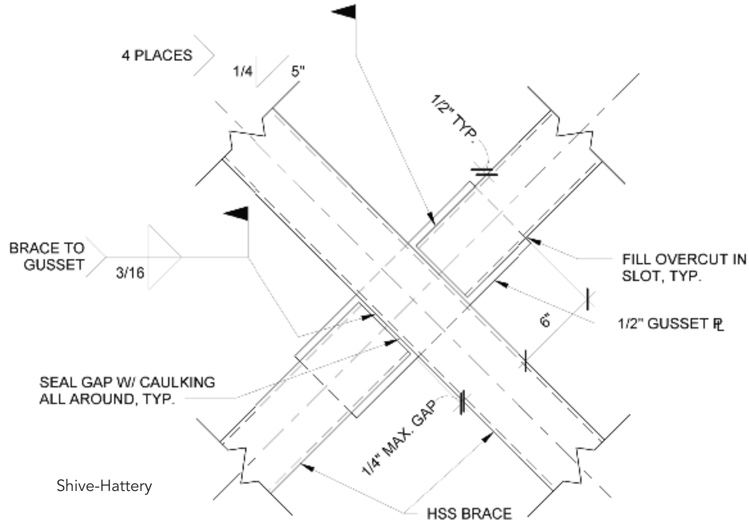
◀ Roughly half of the building—36,000 sq. ft—is Berthel Fisher's office.

▼ Balcony framing at the north wall.



Shive-Hattery

Matt Barron (**mbarron@shive-hattery.com**) is a structural engineer and **Aaron Davis** (**adavis@shive-hattery.com**) and **Mark Seabold** (**mseabold@shive-hattery.com**) are architects, all with Shive-Hattery.



Shive-Hattery

A detail of an X-brace intersection.

Shive-Hattery

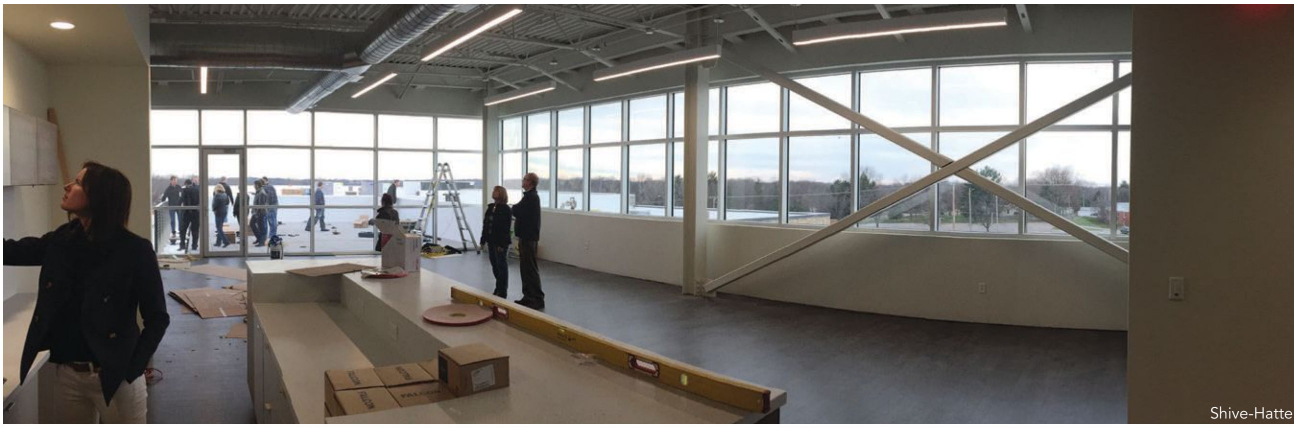
The X-bracing was typically HSS5×5×3⁄8.

or known, the joists provide the flexibility necessary to keep construction progressing with limited information.

Open-Office Design

To maintain maximum building flexibility, Hunter Companies originally hoped for a rigid frame design: a system of columns and beams connected through fully and/or partially restrained moment connections. Using this design, columns are attached to beams with no releases at the joint, and flexure, which induces shears and moments into the beams, columns and their moment-connected joints, helps resist loads. However, after Shive-Hattery completed a cost analysis, it was determined that using steel X-bracing would save between 40% and 50% as compared to a pinned base rigid frame. In addition to saving money, this decision allowed the project team to leave the structural steel exposed, specifically in Berthel Fisher's space.

Exposed lateral X-bracing in the breakroom, four exposed painted columns and even exposed beams were all left untouched to communicate an open feel that matched the company's personality. Use of the braced frames meant sleeker exposed structural members, an aesthetic that could then be echoed in building elements like the stair and handrail designs as well as other finishes. Additionally, the increased stiffness of the system allows for increased energy performance of the glass curtain wall system, ultimately lowering utility bills. The braced frames are all exterior bays, directly behind the full-height glass curtain wall system, which allowed the team to incorporate large amounts of glass on all levels of the building, offering tenants sweeping views of a nearby golf course and the surrounding Cedar Rapids area.



Shive-Hattery

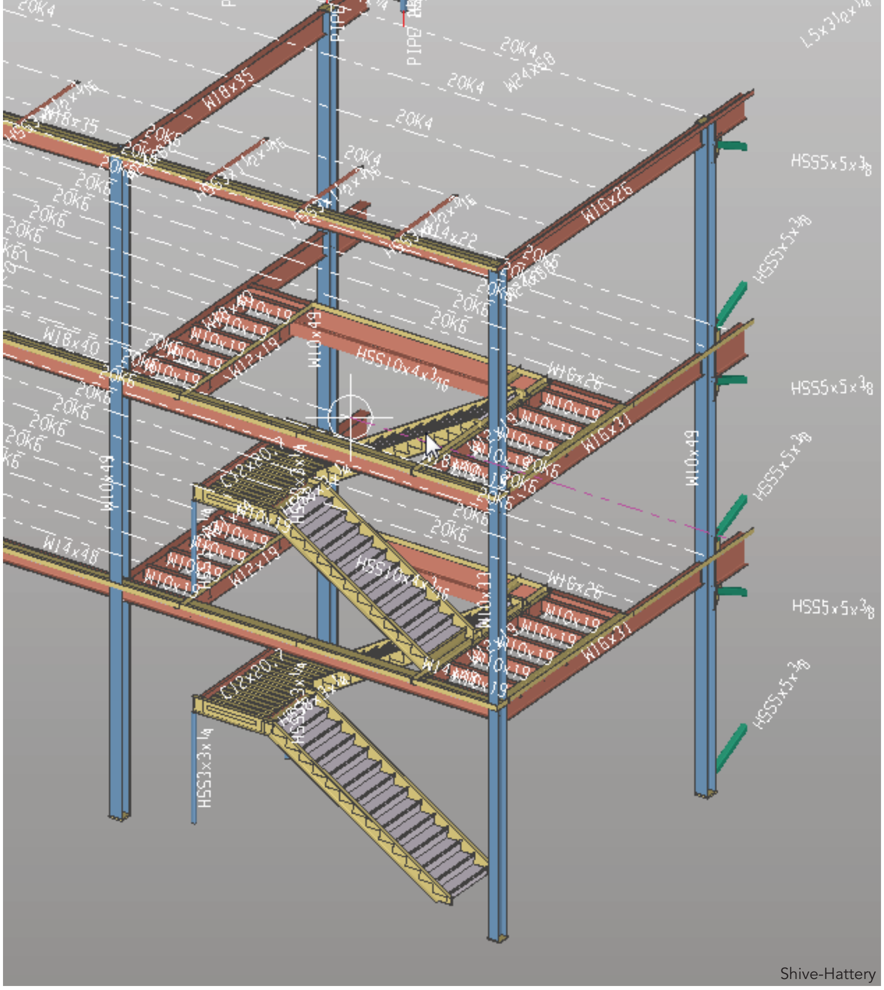
The X-bracing in the breakroom during construction.

The X-bracing was typically HSS5×5×3⁄8 and columns were mostly W10, ranging from W10×33 to W10×68. Some W12×65 columns were used in the two-story portion where rigid frames were necessary. Beams were W18 to W24 depending on location, and there were also 44-in. and 48-in. joist girders used at spans over 35 ft. The braced bays were typically 26 ft in length with a 15-ft first-floor height and a 13.5-ft height for the second and third floors.

The building's two asymmetrical sections are separated by an expansion joint to reduce torsion and twisting, which eliminated the need for larger member sizes, and the long-span open bays of 35 ft and 40 ft incorporate nine joists. One particular span carries an elevated gym space, which required extra structural damping in terms of stiffness and mass. The framing system also allowed for easy incorporation of a high-end paver system—essentially elevated concrete blocks that sit on pedestals—into the patio areas. As the flooring underneath the pavers is sloped for drainage, the flooring needed to be recessed in order to maintain a level walking surface, and the steel framing allowed the project team to easily and cleanly create recessed floors and establish level transitions from inside the building to the outdoor patio areas.

Planning for the Future

Berthel Fisher requested that its space be designed with the ability to add a sizable addition to the east side of the building in the future, and structural steel made it feasible (and economical) to design the framing so that the east wall's curtain wall and architectural elements can be removed for expansion. A similar forward-thinking process was used when planning the single-story restaurant roof, which is designed to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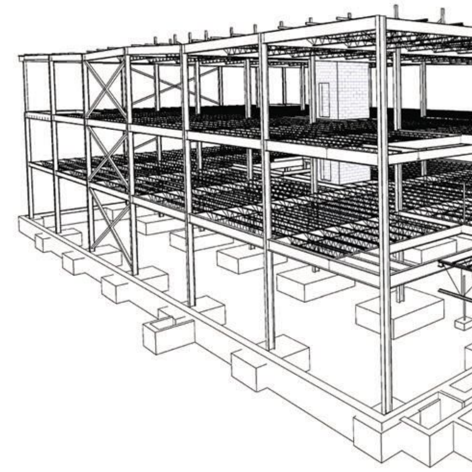
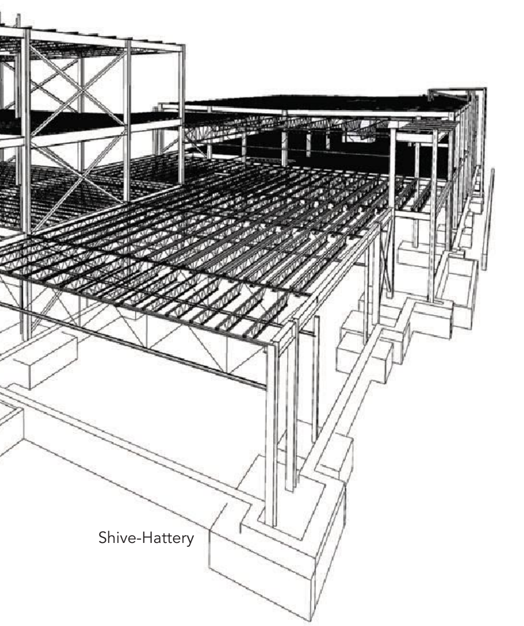


A structural model of the building.

A model of the stair in Berthel Fisher's space.

Bolted connections for the X-bracing.



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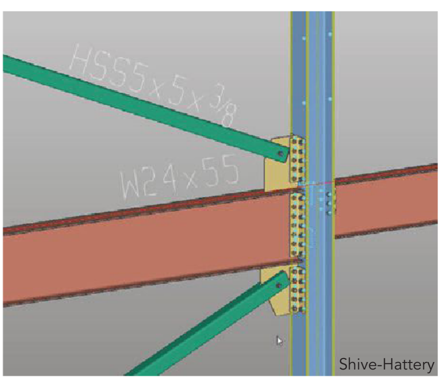


Shive-Hattery

function as a rooftop patio in the future and would require another means of egress. The steel joists were laid out so that the roof can easily be cut and a section of steel can be removed, thus allowing for easy installation of an extra stairway when needed.

With its new headquarters, Berthel Fisher hopes to continue recruiting top-notch employees and offer them a high-quality work environment that's close to high-end shopping and restaurants and just a few minutes from several residential neighborhoods—all in a wide-open office space that offers plenty of exposure to its structure and tenants. ■

Owner, Developer and General Contractor
Hunter Companies, Cedar Rapids, Iowa

Architect and Structural Engineer
Shive-Hattery, Cedar Rapids and Iowa City, Iowa

Steel Fabricator and Detailer
Design Build Structures, Peosta, Iowa

BUILT to Last

AISC full member steel fabricators that have reached the century mark share some of their secrets to success.

BY GEOFF WEISENBERGER

▲ Michelmann Steel Construction's shop. The company was started in 1865 by current president Laura Gerdes Ehrhart's great-great-grandfather.

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

ONE HUNDRED YEARS is a long time.

Well, actually, it depends on your perspective. In the grand scheme of existence, it's merely a blip.

But for an American company—especially one that rides the ups and downs of the construction industry—staying in business that long is quite the achievement.

In fact, of AISC's 926 current member fabricators, only 20—two percent—have been in business for a century or longer.

Evolution

So how did they do it? Adaptability and diversification are the names of the game, note representatives from a handful of these 100-plus-year-old shops.

"Our corporate structure doesn't just represent a steel fabricator that works in several different markets, but also includes steel service centers, a powder coat facility and a manufactured products division," says Tyler Owen, executive vice president of Paxton and Vierling Steel Company, which was established in 1885. "We're also committed to exploration of new markets for growth potential. For example, when the local commercial fabrication markets ran dry, we explored industrial markets with success—and in turn when the nuclear market presented itself, we pursued projects of that nature, and so on."

Thomas Latona, president and CEO of Buffalo Structural Steel Construction Corporation, credits similar characteristics for his company's success. "The secret to our longevity has been to continually monitor the marketplace and adjust to the customer's needs, while at the same time providing clients with quality products at competitive prices," he says.

"Our ability to adapt to the needs of our customers has allowed us to be one step ahead of our competition and grow as a leader in the metals industry," concurs Andy Galinsky, CEO of Sioux City Foundry. "By diversifying our company, we are able to make our customers' products better."

But a little luck also doesn't hurt, notes Laura Gerdes Ehrhart, president of Michelmann Steel Construction Company.

"A lot of hard work, a little luck, five generations of a caring and committed family and some wonderful, talented managers and employees," she offers. "Plus, some loyal and long-term customers and some great vendors. We also live in a small, supportive community."

And sometimes, it's about belt-tightening.

"The business always comes first," notes Philip Stupp, executive vice president of Stupp Brothers. "While we are a family business and recognize the importance of taking care of all shareholders, retaining profits and building capital reserves for future growth or surviving downturns are more important than distributing profits."

Hard Times

Of course, it's not always easy. Part of staying in business for so long means dealing with the general ebb and flow of the building industry, as well as challenging economic cycles.

For example, Owen explains that just before the bank holiday during the early years of the Great Depression, Fred Owen, the facility manager for Paxton and Vierling at the time, withdrew enough cash to cover payroll during the bank closure.

"Putting employees first has always been a cultural strength of the organization," he says.

Going back even further, Stupp notes that the Panic of 1873 caused severe hardship to the first and second generations of Stupps. "We were in a growth mode and had an outstanding loan with an unscrupulous lender that took advantage of our founder's lack of business acumen," he notes. "When the loan was called, the business was lost and we had to start over. Never again would we be in such a position."

And there's no doubt that more recent downturns have also challenged the fabrication business, specifically the Great Recession of 2008. But firms with a long history of weathering storms are in a better position to handle tumultuous times.

"We got through it by changing the way we operate to adapt to the times," explains Ehrhart. "We didn't let anybody go, but we didn't replace anybody who left either. And we worked hard on our customer relationships, which allowed us to do more contract work and less bid work. We learned to do more with less and to make the most of what we had."

Making a Mark

The concept of steel fabrication as a local business really gelled back in late 19th and early 20th centuries. Of course now, the geographic ranges are farther, but many of the oldest member fabricators started off almost exclusively with projects in their hometowns. Early projects, marquee and otherwise, have allowed these companies to make a name for themselves—and being associated with other well-recognized names doesn't hurt.

"We were bigger than Anheuser-Busch at one point and did most of their work in the last quarter of the 19th century," notes Stupp. "Of course, the gates for Lafayette Square Park in St. Louis were our big break in the earlier 1870s, and they still stand today. And we won second place for our exhibit at the 1904 World's Fair in St. Louis. In addition, we developed a relationship with International Paper in the 1920s and designed and fabricated over 100,000 tons for their Southern Craft division over the next 60 years."

Michelmann ironworkers on the job.

For Buffalo Structural Steel, most of its largest early projects are in, you guessed it, Buffalo: the Statler Hotel, the Lafayette Hotel, the Touraine Hotel, the Larkin Soap Company, the Buffalo Pottery Co., the Buffalo Leather Co., the United States Government Building at the Pan-American Exposition, the Pratt and Letchworth Co., the Buffalo Smelting Works, the International Railway Company in Buffalo, the Historical Society Building, the Albright-Knox Art Gallery and the Prudential Building, to name a few. Over the first few decades of the 20th century, Buffalo Structural Steel broadened its geographic scope as well as its project types, even building landing barges for the Navy during World War II. And in the late 1950s and early 1960s, the expansion of the New York State Thruway presented a new opportunity for the organization, which fabricated and erected over 70% of all the bridges carrying the Thruway from New York City to the Pennsylvania border, as well as many of the secondary bridges crossing over the Thruway system.

In Paxton and Vierling's case, it was the little things. "Many of the oldest structures in the city still bear some evidence of our involvement, be it through step plates or manhole covers," says Owen. "As a foundry, we made light poles that, to this day, line many of the older Omaha neighborhoods. Perhaps our most interesting project in the early days was the development and fabrication of the world's first ski lift, which was installed in Sun Valley, Idaho, in the 1930s. The Union Pacific Railroad owned Sun Valley and needed a way to move skiers up the mountain."

Origins

Like comic book superheroes, each fabricator has its own origin story.

"Our company was founded by my great-great-grandfather, J.H. Michelmann, in 1865," says Ehrhart. "A Prussian immigrant, he worked as a boilermaker under another man in Evansville, Ind. When his boss moved his business to Quincy, Ill., J.H. came with him. In time, he bought a small boiler and tank shop from his boss and started his own company, the Michelmann Boiler Company, and his son Henry L. Michelmann went into business with him." Around 1900, the company changed its emphasis to fabricated structural steel, incorporated and moved to its current location, and the modern-day Michelmann Steel Construction Company was born.

A recent fire in Quincy helped unearth relics from the company's past. The fire claimed a building that had originally housed the Newcomb Hotel. "From the wreckage, we were able to claim pieces of the two original Michelmann boilers that had been in the basement," Ehrhart explains. "The talented welders and shop workers in our plant were able to assemble one complete set of boiler doors from the pieces, which we now proudly display in our sales office."

West of Quincy, all the way across Iowa, Paxton and Vierling Iron Works was established in 1885 through a partnership with Vierling Iron Works (Chicago) and local businessman William Paxton. It started as a foundry that specialized in storefronts and miscellaneous items, then branched out to fabrication shortly thereafter. "Its original office wasn't on the wrong side of the tracks, but rather between the tracks—literally," says Tyler Owen. "The shop was located between active Union Pacific rail lines, eventually moving to Carter Lake, Iowa, just outside of Omaha. Fred Owen, patriarch of the current line of ownership, got his start as a draftsman in the Chicago office of Vierling Iron Works and began his career at Paxton and Vierling by running payroll on the train from Chicago to Omaha in the early 1920s. The guns he carried to protect himself on the train are on display at our offices."

Buffalo Structural Steel Construction Corporation was founded in 1894 by another German immigrant, Casper Teiper, who came to the U.S. at the age of six in 1852. According to Latona, Teiper's connection with steel bridge building and similar operations dated from the infancy of the use of steel for structural purposes. From constant study and practical experience, he gained knowledge in engineering, railroad and bridge construction, iron and steel manufacturing and metallurgy.

In 1891, Teiper moved to Buffalo and with his partner, Carl Meyer, he started the Buffalo Bridge and Iron Works, whose plant was situated on Perry Street. Shortly afterwards, the partners sold the business, and in 1892 Teiper purchased land at Bailey and Seneca Streets. In 1894, he sold the enterprise to John Wilson and that same year purchased the property at the corner of Dart and Letchworth Streets in the Black Rock District of Buffalo, erecting the Plant of Buffalo Structural Steel Works. The business grew rapidly and steadily. In 1899, it was organized into a stock company as the Buffalo Structural Steel Company, with Teiper as president, a position he held until his death in 1906.

Back to Iowa, Sioux City Foundry and Machine Works was established in Sioux City, Iowa, to produce engines, gristmills,

The early days at Michelmann, when boilers and tanks were the company's bread and butter.

Said the *Sioux City Journal* of Sioux City Foundry's opening: "Sioux City is now in the possession of an institution... of which the people of this section may well be proud."

Work Rules

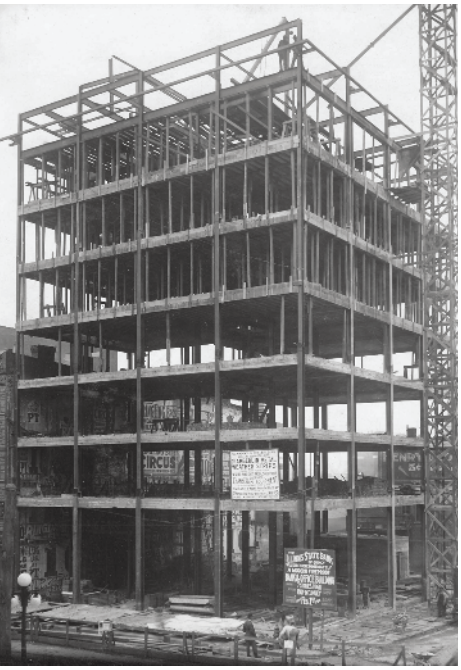
How times have changed. Early in the 20th century, employees of Michelmann Steel Construction Company in Quincy, Ill., had to abide by a posted list of "Work Rules" created and ostensibly enforced by the company's founder, J.H. Michelmann. Here are some of them:

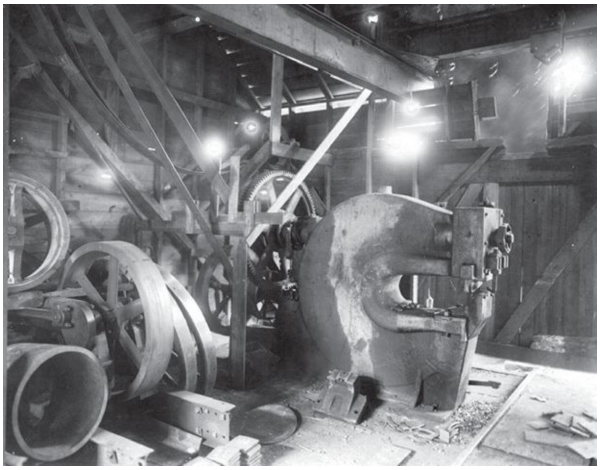
1. Office employees will sweep the floor and dust the furniture, shelves and show cases daily.
2. Each day, fill the lamps, clean the chimneys and trim the wicks. Wash the windows once a week.
3. Each clerk will bring a bucket of water and a scuttle of coal for the day's business.
4. Make your pens carefully. You may whittle your nibs to your individual taste.
5. Male employees will be given an evening off each week for courting purposes—or two evenings if they go regularly to church.
6. After an employee has spent 13 hours of labor in the office, he should spend time reading the Bible and other books.
7. Every employee should lay aside from each pay a goodly sum of his earnings for his benefit during his declining years, so that he will not become a burden upon the charity of his betters.
8. Any employee who smokes cigars, uses liquor in any form, gets shaved at a barber shop or frequents pool and public halls will give me good reason to suspect his worth, intentions, integrity and honesty.
9. The employee who has performed his labors faithfully and without fail for a period of five years in my service—and who has been thrifty and attentive to his religious duties and is looked upon by his fellow men as a substantial and law-abiding citizen—will be given an increase of five cents per day in his pay, provided that a just return in profits from the business permits it.

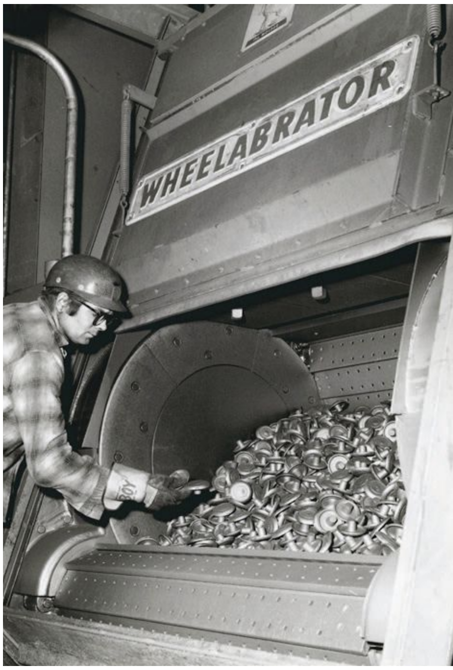
Century Club

These AISC member fabricators have been in business for 100 or more years. As other member fabricators reach the 100-year mark, AISC will recognize their achievement. And if you happen to know of another 100-year-old fabricator, let us know by emailing Carly Hurd at **hurd@aisc.org**.

A Lucas and Sons, Peoria, Ill.
Art Iron, Inc., Toledo, Ohio
Buffalo Structural Steel Construction Corp., Amherst, N.Y.
Central Texas Iron Works, Waco, Texas
Geiger and Peters, Inc., Indianapolis, Ind.
Huntington Steel and Supply, Huntington, W.V.
LB Foster Fabricated Bridge Products, Pittsburgh, Pa.
Michelmann Steel Construction Co., Quincy, Ill.
Paxton and Vierling Steel Co., Carter Lake, Iowa
Ralph H. Simpson Co., Elmhurst, Ill.
Reno Iron Works, Reno, Nev.
Romak Iron Works, Benicia, Calif.
Salem Steel, Winston-Salem, N.C.
Sioux City Foundry Co., Sioux City, Iowa
Standard Iron Works, Scranton, Pa.
Stupp Bros., Inc., St. Louis, Mo.
The Berlin Steel Construction Co., Kensington, Conn.
Woerner Wire Works, Omaha, Neb.
Wyatt Resources, Inc., Fulshear, Texas
Zalk Josephs Fabricators, LLC, Stoughton, Wis.







▲ Old machinery at Sioux City Foundry, which opened in 1871.

◄ The Illinois State Bank building in Quincy, Ill., in 1915.

► Working the Wheelabrator at Sioux City Foundry.

sawmills and building columns, as well as to provide general repair work of machinery and iron. The November 26, 1871 issue of the *Sioux City Journal* commemorated the company's opening, saying, "Sioux City is now in the possession of an institution, the want of which has been long felt in northwestern Iowa—an institution of which the people of this section may well be proud." Now that the town had secured a foundry and machine shop, it "no longer will be obliged to [travel] 200 or 300 miles for iron work and machinery." In 1890, the company moved to its present location, producing boiler parts as well as one of the earliest steam-driven tractors.

Huntington Steel in Huntington, W.V., is another fabricator that has stayed in the family. "The year was 1904, and my great-grandfather, Jim Diddle, and my uncle, Pete Diddle, started Huntington Boiler Works after being employed by the C&O Railroad Company," says R. Sterling Hall, former head of Huntington and father-in-law of current president and CEO, Michael Emerson. The company began its operation in a riverbank facility, and its business was boiler repair and manufacturing small 20-hp boilers that were mainly used in the dry-cleaning business. It evolved to provide more fabrication of plate, miscellaneous steel and structural shapes, and the name was changed to Huntington Boiler and Supply Company.

"By the time I entered in the business in 1955, boiler work was much a thing of the past, and we had moved in the direction of steel supply and miscellaneous fabrication," Hall notes. "The goal for the company was moving more into steel processing and structural steel fabrication. At this time, the name was changed to its current name, Huntington Steel and Supply Company. Since then, we have expanded in Huntington multiple times and now operate several sites in West Virginia and one in Kentucky."

The patterns of German origin and family involvement for an entire company history are also embodied by Stupp Brothers. "Johann Stupp was a blacksmith in Cologne, Germany," explains Philip Stupp. "The guild system was in place, and as a journeyman then an apprentice, he traveled to Moscow and then to Vienna. Some of his peers had immigrated to St. Louis and repeatedly tried to get him to join them. He finally said yes and was in business for himself a very short time after getting settled in St. Louis."

Business acumen, adaptability and luck—or a combination thereof—have kept each of the Century Club members afloat for 100 years, and they are poised for the next 100. ■

Living (Comfortably) with VIBRATION

Vibration due to human activity is a major design consideration.

But it doesn't have to be a problem.

BY THOMAS M. MURRAY, PE, PHD

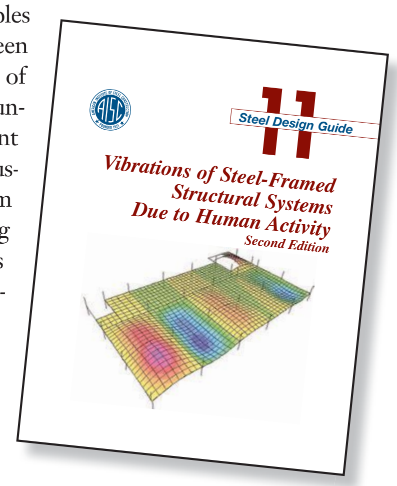
VIBRATION HAPPENS.

In all building types and materials, vibration due to human activity has become an increasingly significant serviceability concern. Modern design specifications, coupled with today's stronger materials, allow for lighter sections when strength considerations govern. Monumental stairs and pedestrian bridges are longer and more slender than ever before. Balconies and grandstands in stadiums have increasingly longer cantilevers and lighter seating areas. There are a lot of opportunities for vibration, to be sure!

But don't fret. The second edition of AISC Design Guide 11: *Vibrations of Steel-Framed Structural Systems Due to Human Activity* provides the design engineer with the resources necessary to solve these vibration concerns in steel structures.

The first edition of Design Guide 11 was published in 1997 and revised in 2003. Since that time, a large amount of new information has become available, and much new literature now exists on the response of steel-framed structural systems, including floors, monumental stairs and balconies. In addition, some human tolerance and sensitive equipment tolerance limits have been modified, and updated methods to evaluate high-frequency systems have been proposed. Finally, the use of the finite element method for analysis of structural systems has been refined, and new techniques for evaluating problem floors have been proposed. This second edition of the guide updates design practice in all of these areas. It is organized to move from basic principles of occupant-caused vibration and the associated terminology in Chapter 1, to serviceability criteria for evaluation and design in Chapter 2, to estimation of natural frequency in Chapter 3, to applications of the criteria in Chapters 4, 5, 6 and 7 and finally to possible remedial measures in Chapter 8. A brief overview of each chapter follows.

Chapter 1 includes a greatly expanded list of basic terminology. Terminology required to understand sensitive equipment manufacturer's tolerance limits is provided, as well as terminology associated with finite element analysis techniques. A section on structural response principles related to human activity has been expanded from the first edition of the guide to help the reader understand basic concepts. Resonant response due to walking is illustrated using measured data from an actual floor. Walking, running and rhythmic forcing functions taken from a number of publications are presented. The chapter ends with a brief discussion of the use of finite element analysis to assess structural systems supporting human activity.



Tom Murray (thmurray@vt.edu) is a professor emeritus at Virginia Tech and the president of Structural Engineers, Inc., in Radford, Va.

Chapter 2 describes the development of the evaluation criteria for human comfort that are implemented in Chapter 4 (Design for Walking Excitation) and Chapter 5 (Design for Rhythmic Excitation). It includes evaluation criteria for walking on high-frequency floors and running on a level surface and describes the development of criteria for monumental stairs and rhythmic excitation.

Chapter 3 gives guidance for estimating the natural frequency (the most important vibration property) of steel beam- and steel joist-supported floors and pedestrian bridges, including the effects of continuity and shear deformation of trusses and open web joists.

Chapter 4 presents a criterion for the evaluation of concrete slab/steel framed structural systems supporting offices, residences, churches, schools and other quiet spaces, as well as shopping malls, pedestrian bridges and (in a modified form) monumental stairs. Six design examples demonstrate application of the criterion.

Chapter 5 provides design guidance for floors supporting dancing, lively crowd movement and aerobics. The primary concern is the tolerance of occupants to floor motion near rhythmic activities. The recommended criterion is based on acceleration limits and is more direct and easier to apply than in the first edition.

Chapter 6 provides guidance for evaluation of vibrations of floors supporting sensitive equipment such as precision imaging, measurement and manufacturing instruments, and also of floors supporting sensitive occupancies such as hospital patient rooms and operating rooms. New assessment procedures developed at the University of Kentucky through an AISC-sponsored research project are presented. Assessments can be made in relation to widely used generic tolerance limits or equipment manufacturers' tolerance limits stated in terms of peak velocity or acceleration, narrow-band spectral velocity or acceleration or one-third-octave-band spectral velocity or acceleration.

Chapter 7 is entirely new and presents recommendations for finite element analysis of floors, pedestrian bridges and stairs subject to walking or running, floors and balconies subject to rhythmic activities and floors supporting sensitive equipment, based on research by Brad Davis. Design examples are included of the analysis of structural systems that are outside the scope of the methods presented in Chapters 4, 5 and 6.

Chapter 8 provides guidance on experimental evaluation and on remedial measures to resolve floor vibration problems that can arise in existing buildings. The recommended vibration measurement approach requires minimal equipment.

Vibration happens, and the second edition of Design Guide 11 provides an abundance of practical knowledge from the experts that can eliminate it as a design concern. AISC members can download the guide for free at **www.aisc.org/dg**. ■

About the Authors

The second edition of AISC Design Guide 11 is dedicated to David Allen, PhD, who made seminal contributions to the first edition but was unable to contribute to the second edition because of health issues. Brad Davis, SE, PhD, an assistant professor with the University of Kentucky's College of Engineering, is a new coauthor, and Eric E. Ungar, PhD, Acentech's chief engineering scientist, and Professor Davis provided significant new information regarding floor systems supporting sensitive equipment.

PEDDINGHAUS PEDDI XDM-630 DRILL/SAW COMBINATION

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For more information, visit **www.peddinghaus.com** or call 815.937.3800.

SJI DESIGN TOOLS

The Steel Joist Institute (SJI) offers seven Design Tools to assist in designing with steel joists and Joist Girders. New to the toolbox are Moment Connection Design Tools for Joist Girder to Column, and Floor and Roof Bay Analysis Tools. Previously available tools include Joist Investigation Form, Virtual Joist and Virtual Joist Girder Tables. All tools offered by SJI are available at no charge and can be downloaded at **www.steeljoist.org/design-tools**.

For more information, visit **www.steeljoist.org** or call 843.407.4091.

COMBILIFT COMBI-SC

The Combilift Straddle Carrier (Combi-SC) range was developed as a more cost-effective and flexible solution for steel-handling companies. A typical column, beam, truss or joist is handled three times: first to a storage yard, then to a staging area and finally to the trailer. Instead of moving one item at a time, the Combi-SC lifts and moves a complete load a time, cutting trailer-loading time considerably. The Combi-SC is much more economical option compared to heavy-handling forklifts, reach stackers or mobile cranes and offers complete independence when moving oversized loads onto trailers and around sites.

For more information, visit **www.combilift.com** or call 877.COMBI.56.

IN MEMORIAM

Arthur P. Arndt, Steel Bridge Expert, Dies at 91

Arthur P. Arndt, former vice president for AISC member/AISC certified erector American Bridge Company, passed away earlier this summer in Dublin, Ohio, at the age of 91.

Born and raised in Texas, Arndt served in the U.S. Navy and the Naval Reserves before graduating from the University of Texas with a degree in civil engineering. He worked for American Bridge—which at the time was a subsidiary of US Steel Corporation—for more than 40 years, starting out as a civil engineer and moving up to vice president until his retirement. He was the recipient of many awards for excellence in engineering and in 2001 he received AISC's Lifetime Achievement Award for his contributions to the structural steel industry. He also served as an auditor for Quality Auditing Company, Inc., the precursor to Quality Management Company, LLC, which currently operates under the auspices of AISC's certification programs.

Mike Flowers, who recently retired as president and CEO of American Bridge, recalled, "I worked directly for Art briefly back in the 1980s and got to know him fairly well. He was a no-nonsense kind of guy, an engineer's engineer. I'll never forget when he pulled me aside at the end of a particular AISC audit and told me how proud he was that we were building American Bridge back to its former glory and doing a very fine job of it. Compliments from Art were not easily earned, and it was pretty meaningful in giving perspective to what we were building here at American Bridge."

Arndt was preceded in death by his wife, Aileen.

STEELDAY

Show Us Your School's Steel Sculpture!

This fall marks 30 years since the installment of the original AISC Steel Sculpture on the University of Florida's campus. Today, there are more than 170 of these teaching sculptures across the U.S. and around the world. In celebration of the sculpture's 30th anniversary and to honor its creator, Duane Ellifritt, professor emeritus of civil engineering at Florida, AISC is holding a contest for students to show off their university's steel sculpture.

Students have until Friday, September 16, to submit a creative photo (or photos) of their school's AISC Steel Sculpture. All eligible entries will be posted to AISC's Facebook page (**www.facebook.com/AISCdotORG**) during the week of September 26, and anyone with a Facebook account can vote for their favorite photo. The final day of online voting will be on SteelDay, Friday, September 30. Students whose photos receive the most likes will win prizes.

To enter the contest, students are required to submit a photo of their school's AISC Steel Sculpture to **socialmedia@aisc.org** and must include their full name and university name with each photo entry. They can enter as many photos as they wish but may win only one prize. Creativity and personality are important. Props and/or people are encouraged in the photos.

For full contest details, visit **www.aisc.org/studentsteeldaycontest**. For more information on the AISC Steel Sculpture, including a full school listing, photo gallery and a link to download the Steel Sculpture plans, visit **www.aisc.org/steelsculpture**. And for more on SteelDay, see "SteelDay is Coming!" on page 27.

People and Firms

- AISC member **Alro Steel** has opened an 80,000-sq.-ft service center facility in Tulsa, Okla. The building replaces a 9,000-sq.-ft facility that Alro operated in Tulsa since 1999. The larger footprint will allow Alro to process additional grades and sizes of steel.
- The **New York State Steel Fabricators Association** is hosting its 75th Anniversary Fall Meeting September 14-15 at the 1000 Islands Harbor Hotel in Clayton, N.Y. Visit **www.nyssfa.org** for information.
- **Vulcraft/Verco Group**, a division of AISC member **Nucor Corporation**, is accepting entries for its fourth annual NuHeights Design Awards competition. The program recognizes excellence and quality in steel building design and construction. If you've recently completed a building project using Vulcraft Joists or Steel Decking, Verco Decking or Ecospan Composite Floor System products, you're eligible to enter. Entries will be accepted until October 31. For more information, visit **www.vulcraft.com/nuheights**.
- **McLaren Engineering Group**, a full-service engineering firm with eight divisions, is opening its newest office in Allentown, Pa., to expand its roster of public and private sector clients in the Lehigh Valley. The new office will provide services in vertical structures and the steel industry and will help develop the company's other divisions, including transportation and entertainment. (See "River View" in August's "What's Cool in Steel" feature, available at **www.modernsteel.com**, for a McLaren-designed project.)

letters to the editor

Human Touch

Thanks for the excellent coverage of the National Student Steel Bridge Competition in the August issue ("Proven in Provo"). Your article effectively melds human interest and technical detail, with great photos to illustrate both.

—Frank Hatfield, PE, PhD
Professor Emeritus, Michigan State University Dept. of Civil and Environmental Engineering

TRADE NEWS

U.S. Steel Industry Associations Release China Subsidies Report

Five of the leading American steel trade associations have released a report documenting that rapid growth of China's steel industry has been fueled by government subsidies and other market-distorting policies. The report was released by the American Iron and Steel Institute (AISI), the Steel Manufacturers Association (SMA), the Committee on Pipe and Tube Imports (CPTI), the Specialty Steel Industry of North America (SSINA) and AISC.

The report analyzed each of the 25 largest steel companies in China and detailed the amount and types of government subsidies each company received in recent years. The analysis also found that these subsidies and policies have led to tremendous overcapacity and created a highly fragmented domestic steel sector in China made up of many inefficient and heavily polluting companies.

The report states: "The Chinese government has supported the country's steel industry primarily through cash grants, equity infusions, government-mandated mergers and acquisitions, preferential loans and directed credit, land use subsidies, subsidies for utilities, raw material price controls, tax policies and benefits, currency policies and lax enforcement of environmental regulation. The Chinese government maintains a majority share in the top-producing (by 2014 tonnage) Chinese steel producers. Domestic steel producers are not competing with private enterprises but with sovereign governments that do not need to use free-market principles to operate."

According to the report, China produced over 822 million tons of steel in 2014, which accounted for half of the world's steel production. However, the Chinese steel industry is facing weakening demand for steel both globally and domestically. But despite these trends and increasingly challenging market conditions for China's steel producers, steel capacity is expected to continue expanding in the short term as new production under construction comes online.

In releasing the report, the associations said that the investigation serves as additional corroboration that China should not be granted market economy status by the World Trade Organization in December. The group also emphasized that the results of this study will be used to further advance the global dialogue among nations on the elimination of excess steel capacity throughout the world.

"WTO Members expected China—consistent with its commitments during accession negotiations—to transition to a full-market economy; however, the evidence and experience is that many significant aspects of the Chinese economy remain under significant government control or influence," the groups concluded.

ERECTION

Steel Erection Projects Win SEAA Awards

The Steel Erectors Association of America (SEAA) has announced the winners of its annual Project of the Year competition. Projects are recognized for their complexity, and companies are awarded for overcoming challenges while maintaining safe work standards. The award-winning projects, which all topped out last year, are: the I-225 Florida Pedestrian Bridge, Aurora, Colo., erected by AISC member LPR Construction; 625 West 57th St., Manhattan, N.Y.; the Liberty University Fine Arts School of Music, Lynchburg, Va., erected by AISC member/AISC certified erector CSE, Inc.; and the University of Mississippi Basketball Arena, Oxford, Miss., erected by AISC member/AISC certified erector Bracken Construction Co. Project information and photos can be found at **www.seaa.net**.

SEAA is now accepting nominations from its members for projects topped out this year. Submissions must be received by February 3, 2017. For more about entering the competition, visit **www.seaa.net**.

EVENTS

Future Leaders Ideas Lab Prepares Next Generation of Fabricators

If you work for an AISC-member fabricator and have recently moved into or anticipate moving into a senior management position during the next few years, the Future Leaders Ideas Lab is the event for you! Attendees will learn valuable leadership tools specific to the fabrication industry and have the opportunity to network and exchange ideas with their peers. Now in its third consecutive year, the event will take place October 20–21 in Philadelphia.

"Leaders generally have very few peers within their own environment to interact with," said past attendee Rick Russel of Future Fabricating. "The opportunity to meet, network, share and validate means and methods of leadership is a priceless value that can be captured by participating in this AISC-sponsored event."

Sessions will cover a wide range of topics including legal issues (with a focus on contracts), negotiation skills and new developments in fabrication software. New this year is a special session for attendees to meet in small groups with experienced industry leaders to explore real-life case studies and gain insight into critical management issues and how to deal with them.

For more information and to register, go to **www.aisc.org/ideaslab**.

structurally sound

TUBULAR TRANSFORMATION

A NEW SCULPTURAL pavilion is undergoing a metamorphosis in Merriweather Park at Symphony Woods in Columbia, Md.

Initially conceived as a pure compression shell of shingled steel or aluminum plate, the project stayed true to its name—the Chrysalis—as its design was transformed to include a ribcage of structural steel.

On behalf of the Inner Arbor Trust, Michael McCall, president of developer Strategic Leisure, tasked designer Marc Fornes/TheVeryMany with creating this one-of-a-kind park pavilion; Living Design Lab functioned as the architect of record for the project. The steel frame, designed by Arup in Washington D.C., is doubly curved, like the skin it supports, and follows the pleats of the distinctive ridged cladding (the steel was curved by AISC member Kubes Steel, Inc.). Each warped arch is tied together by secondary members to help redistribute loads and increase the stability of the overall frame. The largest arch frames the main performance stage and has an approximate span of 65 ft, with a corresponding max height of 50 ft. The arches are composed of 1,000 linear ft of 10-in.-diameter hollow structural sections (HSS), with 675 ft of straight 8-in.-diameter HSS being used for the secondary framing.

The frame will ultimately be clad in 12,000 sq. ft of anodized aluminum shingles made and installed by Zahner. The cladding system uses an additional layer of framing to help achieve the peaks and valleys of the skin. This frame is composed of ribbed purlins, arrayed at 30-in. centers, that attach directly to the primary steel frame. Due to the structure's complex form, BMT Fluid Mechanics performed a wind tunnel test to attain the appropriate design loads on both the structure and cladding.

In addition, robust analysis was performed to validate the overall stability of the frame, with flanged, bolted moment connections providing continuity across the whole system. The arches were spliced to both aid in erection and help achieve the required curvature of the sculpture. A tertiary layer of steel sits below the primary frame to provide a grid of strong points that can support up to 20 tons of theater equipment. In total, the structure shelters a footprint of 5,000 sq. ft, providing an ample amount of stage space for a variety of performance events, as well as an open-air pavilion for public gatherings. ■