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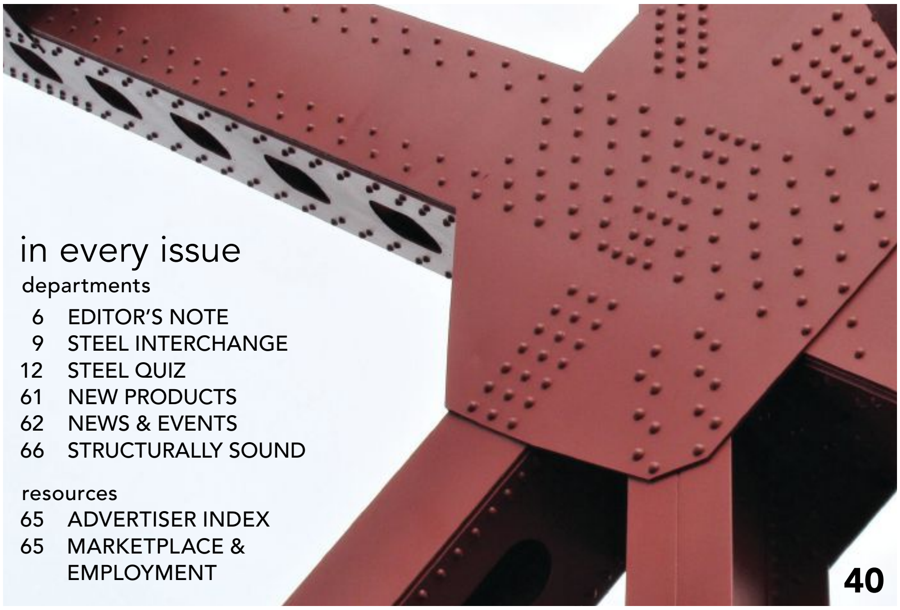

in every issue

columns

features

ON THE COVER: The University of Maryland's new computer science building augments its computing power with an attractive user interface, p. 26. (Photo: Courtesy of Hope Furrer Associates)

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editor's note

Self-driving cars, moon tourism, and robot housekeepers: The promises of my youth are actually getting closer. Whether it's from Tesla or Google, the technology that enables self-driving vehicles is rapidly approaching widespread deployment. Likewise, Elon Musk and Richard Branson are racing to offer trips to orbit the earth and beyond. And, of course, we already have Roombas and Eufys to clean our floors at home.

But the really cool future promise was the opportunity to go anywhere and see anything, all from the comfort of your living room, through enhanced virtual reality systems.

In the 19th century, we had stereoscopic viewers that allowed a kind of three-dimensional view. These morphed into View-Masters in the early 20th century. And beginning in 1960, we started to see true virtual reality systems (though the term wouldn't be actually coined until 1987), though they were large and expensive and the computing power needed to make them really work wasn't available. In the 1990s, some arcade games started offering immersive, stereoscopic 3D visuals, and we saw the idea enter popular culture in 1992 with the movie *The Lawnmower Man*.

Technological advancements were slow but steady. Sega introduced the VR-1 in 1994 and Nintendo offered its Virtual Boy in 1995. And, of course, the concept exploded in 1999 with *The Matrix*.

Google introduced its Street View technology offering 360° maps in 2007 and finally, in 2010, the first Oculus VR viewer was prototyped and a Kickstarter campaign was launched in 2012. By the end of the decade, prices for viewers and cameras had dropped enough for VR to enter the mainstream.

As Morpheus says in *The Matrix*, "No one can be told what the Matrix is. You have to see it for yourself." And now you can see the steel industry's version. If you attend NASCC: The Steel Conference (April 22–24 in Atlanta; visit **aisc.org/nascc** for more information) you'll see VR applications everywhere. Some equipment vendors will let you don a headset and see their equipment in operation. Others will let you experience welding firsthand. Bill Issler and his company, Industry Lift, are in the process of gamifying the construction industry, and visitors to his world can walk out on a beam hundreds of feet in the air (trust me, don't do this if you have a fear of heights!) or operate a forklift or crane.

At AISC's booth, we'll be giving away VR viewing glasses that work with your cell phone. You'll be able to visit **aisc.org/vr** (available to everyone beginning April 22) and download a series of VR experiences, such as touring a steel mill, checking out how HSS is manufactured, and walking through a fabrication shop (we'll also have the videos loaded on Oculus Go headsets for an even more immersive experience). And in the future, we'll release job site tours and other VR experiences.

I hope to see you in Atlanta, where you can experience the world of steel as you've never seen it!

Scott Melnick
Editor

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steel interchange

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

Half-Inch-Diameter Grade A325 Bolts

Table 7-2 in the 15th Edition AISC *Steel Construction Manual* does not provide available strengths for ½-in.-diameter bolts. Am I permitted to use a ½-in.-diameter Grade A325 bolt? I notice that Table J3.1 does include minimum bolt pretension values for these bolt sizes.

Yes, you can use the AISC *Specification for Structural Steel Buildings* (ANSI/AISC 360) to design connections with ½-in.-diameter Grade A325 bolts. Section A3.3 of the *Specification* approves the use of bolts that conform to the ASTM F3125/F3125M standard. ½-in.-diameter Grade A325 bolts are included and can be produced to the F3125 standard. Values for ½-in.-diameter bolts are not included in Table 7-2 because these bolt sizes are not commonly used in building construction. I believe that ¾-in.-, ⅞-in.-, and 1-in.-diameter bolts dominate the structural steel construction market.

Carlo Lini, PE

Weldability of Structural Steel

We are evaluating a building that was constructed before 1940. We have performed a chemical analysis on a representative sample and believe the material used was ASTM A9 and are concerned about weldability. We are wondering what carbon equivalent (CE) formula to use as there seems to be a number of different formulas out there?

The CE value will only provide a rough idea of weldability. AISC Design Guide 21: *Welded Connections—A Primer for Engineers* states: "A variety of CE formulas have been derived over the years, each developed with the intent of quantifying the weldability of a material and prescribing the conditions, such as preheat, heat input level, and hydrogen level that must be maintained in order to fabricate such materials without cracking… When the chemical composition of the base metal is known, the CE can be calculated. This number by itself is of limited value. However, the CE number can be used to determine welding conditions that are conducive to crack-free welding, such as minimum preheat temperatures and required maximum diffusible hydrogen limits."

Also, Clause 8.2.2 in AWS D1.1/D1.1M:2015 states: "The suitability of the base metal for welding shall be established (see Table C-8.1 for guidance)." ASTM A9 structural steel is not addressed in Table C-8.1. For cases where no guidance is provided, AWS D1.1 indicates that welding suitability needs to be established, stating: "Existence of previous satisfactory welding may justify the use of Table 3.2 (Group II) filler metals. If not previously welded, obtain samples and prepare WPS qualification. Conduct in place weld test on safe area of structure if samples are not available."

Additionally, AWS D1.7/D1.7M:2010: *Guide for Strengthening and Repairing Existing Structures* provides the following guidance: "ASTM A7 and ASTM A9 were generally accepted as weldable steel, but both had a wider range of carbon content and fewer limits on other alloys and undesirable elements than permitted by ASTM A36, their eventual successor. ASTM A373 steel, an interim steel specification before the adoption of ASTM A36 in 1962, provided better assurance of good weldability than ASTM A7. Electrodes in the E60 classes were routinely used for ASTM A7 and ASTM A9 steels, and E70 class electrodes came into use in the early 1960s." This standard provides four CE equations along with guidance on the use of each equation.

AISC Design Guide 21 also indicates that a representative chemical composition only provides an indirect indication of weldability and suggests that a simple weld test be run. The design guide discusses a fillet weld break test, where a plate is welded to the material with unknown weldability, as pictured in Figure 1(a). If the weld breaks easily in the first attempt illustrated in Figure 1(b), which puts the weld face in tension, this would be a good indication that the steel has poor weldability. If the first attempt does not result in a break, then the plate is struck from the opposite side, as shown in Figure 1(c). The weld should break since this test places tension on the weld root. If the break occurs in the weld throat area, this indicates better weldability. If the break is in the heat-affected zone (HAZ), the steel can be re-welded using a higher level of preheat.

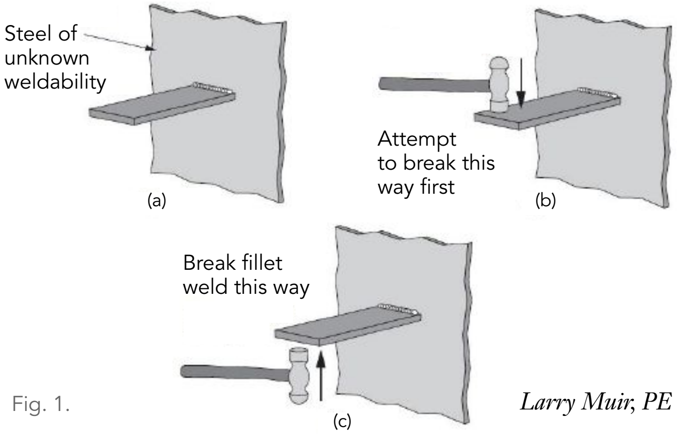

Fig. 1.

Larry Muir, PE

Carlo Lini (**lini@aisc.org**) is AISC's director of technical assistance. **Bo Dowswell**, principal with ARC International, LLC, and **Larry Muir** are both consultants to AISC.

Base Plate Load Distribution

For columns subject to tension loading, when anchor rods are located inside the flange, AISC Design Guide 1: *Base Plate and Anchor Rod Design* recommends in Figure 4.5.2 a 45° distribution for rod loads back to the column web. When anchor rods are located outside the flanges (see Figure 2), can we conservatively assume a 45° dispersion angle considering one-way distribution to the web of the column?

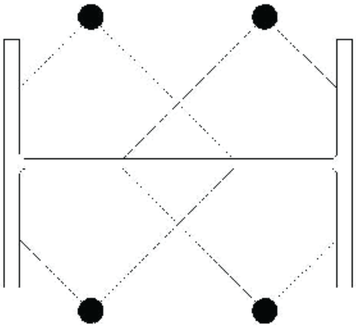

Fig. 2.

Yes. I believe the approach you have suggested, where a dispersion angle of 45°, with a moment arm defined as the distance between the anchor rod and the column web, would be conservative.

A more accurate method will require further analysis. There are certainly other failure patterns that could be selected by the designer. One possible failure pattern would be a linear bend line that could form at the column flange tips. In this case, the moment arm is the distance from the bolt to the column flange tips, L (see Figure 3). Of course, at some point it would no longer make sense to increase the width of the base plate to maintain a thinner plate, so engineering judgment must be exercised.

Figure 4 presents another possible failure pattern depending on where the anchors are located. This pattern is described in AISC Design Guide 10: *Erection Bracing of Low-Rise Structural Steel Buildings*. Note that the design guide recommends not exceeding a maximum width of 5 in.; the intent is to not increase the width of the base plate by an unreasonable amount. The moment arm, in this case, would be L, as shown in Figure 4.

In both examples, you might also want to consider how much of the weld length along the column flange would be appropriate to use, since stiffness may concentrate quite a bit of the load near the column flange tips. AISC Design Guide 10 recommends that an effective width of 2 in. be used to determine the weld strength.

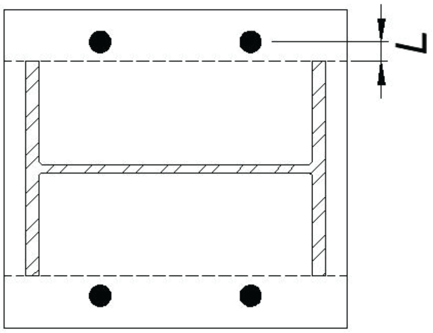

Fig. 3.

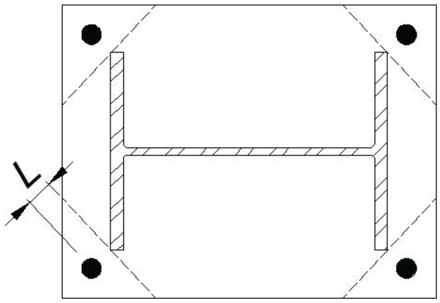

Fig. 4.

Bo Dowswell, PE, PhD

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The complete collection of Steel Interchange questions and answers is available online at **www.modernsteel.com**.

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steel quiz

With the 2020 NASCC: The Steel Conference taking place this month (April 22–24 in Atlanta; visit **aisc.org/nascc** for information) this special installment of Steel Quiz will test your knowledge on steel design and the conference.

There are two parts to the quiz. First, determine the correct answer for each clue. Second, locate the answers in the word search puzzle. Note that multiple-word answers in the word search do not include spaces or hyphens.

E	A	E	B	C	R	E	Z	N	K	W	F	U	Q	X	U	D	O	H	N
P	U	D	L	X	M	U	W	Y	H	H	G	Q	C	A	N	D	G	L	B
A	T	K	O	I	D	R	Z	P	S	I	T	J	R	R	I	Q	C	O	P
C	X	D	C	D	B	N	J	T	H	T	Y	H	Y	A	F	J	S	O	I
I	Z	E	K	H	Q	U	J	I	E	M	T	U	I	D	O	T	E	R	I
R	M	W	S	G	P	G	P	T	A	O	Y	W	B	I	R	D	L	N	H
E	A	E	H	W	P	T	T	H	R	R	F	H	I	O	M	U	I	S	E
M	J	K	E	L	I	O	J	P	L	E	J	L	N	G	F	C	T	U	C
A	V	S	A	Q	I	N	E	J	A	W	Y	M	I	R	O	F	C	V	H
F	E	M	R	R	Q	E	Z	Y	G	K	L	P	A	A	R	S	U	K	E
O	M	E	R	C	E	D	E	S	B	E	N	Z	R	P	C	G	D	V	V
K	N	A	U	E	N	O	B	G	O	D	M	Y	T	H	E	D	O	V	R
N	M	D	P	P	R	O	T	E	C	T	E	D	S	I	I	B	R	B	O
A	K	X	T	D	E	Z	I	S	R	E	V	O	V	C	Y	M	X	K	N
B	Y	S	U	G	N	I	L	K	C	U	B	L	A	R	U	X	E	L	F
N	N	P	R	O	D	T	N	E	E	U	Q	D	N	A	G	N	I	K	R
W	N	P	E	B	G	X	P	Y	E	W	B	K	P	E	C	N	C	W	R
H	V	T	F	L	A	T	I	R	O	N	P	H	M	S	I	U	K	O	V
C	W	Y	E	T	E	L	P	M	O	C	Z	A	W	U	Q	Y	I	G	J
A	N	U	J	L	O	U	I	S	V	I	L	L	E	S	A	F	J	G	U

1 The home stadium of the Atlanta Falcons and also the name of a German Automobile manufacturer.

2 Famous hotel chain and downtown Atlanta steel structure nicknamed the "pregnant building."

3 The 2021 NASCC: The Steel Conference will be held in this city.

4 A historic building in Atlanta. It shares a similar shape to its counterpart in New York City.

5 Twin buildings in Atlanta named after two prominent chess pieces.

6 _____ Plaza is the tallest structure in Atlanta.

7 This design term is used to indicate the portion of the gusset plate that is effective in resisting the tension or compression forces transferred to it by the brace.

8 This type of bracing is advantageous for providing a door opening in the middle of two braces. It shares its name with a well-known petroleum company.

9 _____ holes are permitted for slip-critical connections but not bearing-type connections.

10 The preferred method for determining the forces that exist at gusset interfaces.

11 In seismic construction, the region at the end of the beam or middle of the brace subjected to plastic hinge formation is called the ____ zone.

12 In a reduced beam section (RBS), beam flanges shall be connected to column flanges using ____-joint-penetration welds.

13 This type of NDT (nondestructive testing) includes the use of X-rays or gamma rays to inspect weld defects and repairs.

14 One of the four methods to calculate nominal strength of composite sections: the _____ compatibility method.

15 One of three limit states used to determine nominal compressive strength of members without slender elements.

16 When the width-to-thickness ratio is lower than λ_{hd}, a member is considered to be highly _____.

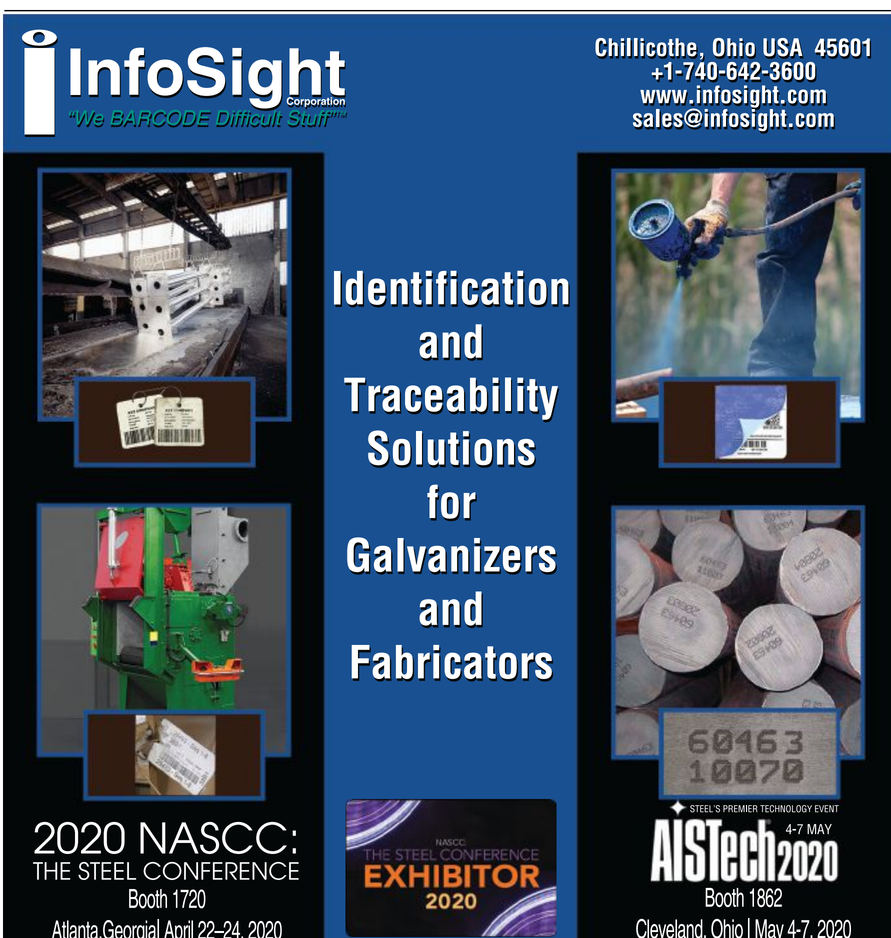
17 This term is used to define the non-uniform tensile stress distribution in a member or connecting element in the vicinity of a connection.

18 Limit state of tension rupture along one path and shear yielding or shear rupture along another path.

19 This kind of retrofit is used to mitigate cracks in steel bridges. Also another name for a reduced beam section (RBS).

20 A beam is said to be ______ when it meets another framing member at an angle other than 90°.

TURN TO PAGE 14 FOR THE ANSWERS



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steel quiz ANSWERS

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A	T	K	O	I	D	R	Z	P	S	I	T	J	R	R	I	Q	C	O	P
C	X	D	C	D	B	N	J	T	H	T	Y	H	Y	A	F	J	S	O	I
I	Z	E	K	H	Q	U	J	I	E	M	T	U	I	D	O	T	E	R	I
R	M	W	S	G	P	G	P	T	A	O	Y	W	B	I	R	D	L	N	H
E	A	E	H	W	P	T	T	H	R	R	F	H	I	O	M	U	I	S	E
M	J	K	E	L	I	O	J	P	L	E	J	L	N	G	F	C	T	U	C
A	V	S	A	Q	I	N	E	J	A	W	Y	M	I	R	O	F	C	V	H
F	E	M	R	R	Q	E	Z	Y	G	K	L	P	A	A	R	S	U	K	E
O	M	E	R	C	E	D	E	S	B	E	N	Z	R	P	C	G	D	V	V
K	N	A	U	E	N	O	B	G	O	D	M	Y	T	H	E	D	O	V	R
N	M	D	P	P	R	O	T	E	C	T	E	D	S	I	I	B	R	B	O
A	K	X	T	D	E	Z	I	S	R	E	V	O	V	C	Y	M	X	K	N
B	Y	S	U	G	N	I	L	K	C	U	B	L	A	R	U	X	E	L	F
N	N	P	R	O	D	T	N	E	E	U	Q	D	N	A	G	N	I	K	R
W	N	P	E	B	G	X	P	Y	E	W	B	K	P	E	C	N	C	W	R
H	V	T	F	L	A	T	I	R	O	N	P	H	M	S	I	U	K	O	V
C	W	Y	E	T	E	L	P	M	O	C	Z	A	W	U	Q	Y	I	G	J
A	N	U	J	L	O	U	I	S	V	I	L	L	E	S	A	F	J	G	U

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14 Strain
15 Flexural buckling
16 Ductile
17 Shear Lag
18 Block shear rupture
19 Dog bone
20 Skewed

The puzzle was developed by **Bhavnoor Dhaliwal**, a current engineering intern at AISC. (Thanks, Bhavnoor!)

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DELEGATING CONNECTION DESIGN

BY CLIFFORD SCHWINGER, PE

Just because you delegate connection design doesn't mean you're not still responsible for it. Here are some tips for getting the most out of your decision to delegate.

Cliff Schwinger (**cschwinger@harmangroup.com**) is a vice president with the Harman Group.

For more on delegating connection design, see "Solving the Puzzle" on page 54.

DELEGATION OF STRUCTURAL STEEL CONNECTION DESIGN is fairly common in many parts of the United States.

Equally common is the misconception that the engineer of record (EOR) is not responsible for connection design when they delegate it to the fabricator's licensed engineer. The AISC *Code of Standard Practice for Steel Buildings and Bridges* (AISC 303-16, **aisc.org/specifications**), in Section 1.9.2, states: "The structural engineer of record shall be responsible for the structural adequacy of the structure in the completed project." Structural adequacy includes the ability of both members and connections to support applied loads. Likewise, Section 4.4 states: "The owner's designated representative for design is the final authority in the event of a disagreement between parties regarding the design of connections to be incorporated into the overall structural steel frame." That the EOR is identified as the "final authority" indicates their ultimate responsibility for ensuring that connections are properly designed. And this responsibility is not new to the latest (2016) version of the *Code*. As the Commentary to Section 4.4.1 notes, "The owner's designated representative for design has thus retained responsibility for the adequacy and safety of the entire structure since at least the 1927 edition of the *Code*."

Connection Options

Now that we've established where the responsibility lies, let's take a quick look at how EORs can deal with connection design. Section 3.1 of the *Code* provides three options.

Option 1 requires the EOR to design all connections and provide details for those connections on the contract documents.

Option 2 requires the EOR to provide connection details on the contract documents in sufficient detail such that experienced steel detailers can select or complete the connection details (without the need to perform engineering calculations).

Option 3, the focus of this article, permits the EOR to delegate connection design to a licensed engineer working for the fabricator.

The EOR is required to indicate, on the contract documents, which of the three options was used on the project. The use of more than option is permitted, provided that the contract documents clearly define where each option is used.

When Option 3 is used, the EOR is required to provide the following information on the contract documents:

- Restrictions on the types of connections permitted.
- Beam shear reactions, axial forces, and connection moments.
- A statement as to whether the reactions, axial forces, and moments are service level or factored-load level.
- A requirement as to whether the load and resistance factor design (LRFD) or allowable strength design (ASD) method is to be used for connection design.
- A list of substantiating information to be submitted by the fabricator's connection design engineer to the EOR—e.g., whether connection design calculations are required to be submitted.

EORs have two choices when delegating connection design per Option 3.

Option 3A permits the EOR to delegate connection design but requires the EOR to design, detail, and document all member reinforcement at connections on the contract documents.

Option 3B requires the EOR to provide project-specific details showing conceptual configurations of member reinforcement at connections where such reinforcement is required, and bidding quantities where each configuration is required. If both are provided, the EOR may delegate design of both the connections and member reinforcement at the connections. If either the project-specific member reinforcement details or the bidding quantities are missing, then bidders are not required to include the cost of the member reinforcement at the connections in the bid price.

Member Reinforcement at Connections

Member reinforcement at connections is a new term in the latest version of the *Code*. Designing member reinforcement at connections is not connection design; it is member design. Such reinforcing is frequently required to address secondary stresses in members at connections, and includes web stiffeners, web doubler plates, and other elements. Such reinforcing may also be required at beam-to-column moment connections, at beam connections with large copes, or at myriad other unique connections where significant eccentricities induce secondary stresses.

Member reinforcement at connections can be labor-intensive and costly. For fabricators to provide their most competitive bid price, they must know where member reinforcement at connections is required, and they must know the details of this reinforcing. Accordingly, the *Code* now explicitly requires designers to provide details showing member reinforcement at the connections for both Options 3A and 3B.

Option 3A requires the EOR to fully design the member reinforcement at the connections, provide details for that reinforcement, and identify all locations where the reinforcement is required. When this option is used, the fabricator's connection design engineer designs the connections, and the fabricator's detailer then details the connections and the member reinforcement at the connections per the details on the contract documents.

Option 3B requires the EOR to provide project-specific details showing the conceptual configuration of member reinforcement at connections, as well as quantities where each detail is required.

Providing this information on the contract documents ensures that all fabricators will be bidding on a level playing field. It is significant that for Option 3B, Section 3.1.2 of the *Code* explicitly states that failure to provide details for member reinforcing at connections and/or failure to provide quantities where each detail is required permits bidders to neglect the costs associated with the member reinforcing. These omissions on contract documents can lead to requests for information (RFIs), arguments, and change orders.

Project-Specific Details

Another new phrase in the 2016 *Code* is *project-specific details that show conceptual configuration of reinforcement*, which I will henceforth refer to as "concept connection details." These details show the EOR's required connection configuration and member reinforcement at the connections (see Figure 1).

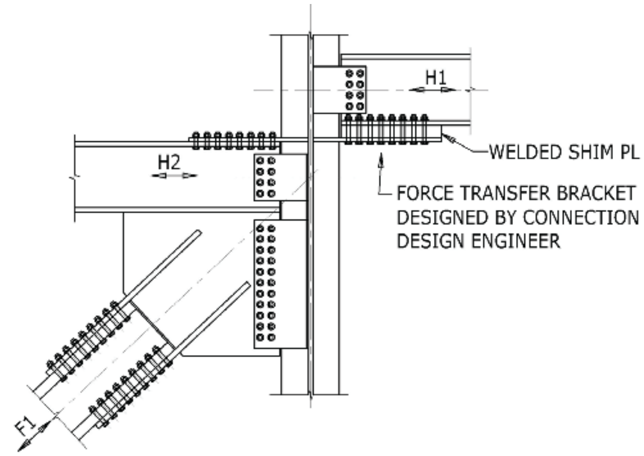


Fig. 1. A concept connection detail on a contract document showing the transfer of axial load "H1" through a column.

Option 3B requires EORs to convey to fabricators the configurations of all unique connection details in sufficient detail such that the cost and design requirements of the details can be readily understood by the fabricator's cost estimator and connection design engineer. Concept connection details need only show general connection configurations with enough detail so that fabricators can consider their cost when bidding the project, and so that connection designers can readily understand the EOR's desired connection configuration. Concept connection details on the contract documents are not required to show all details (bolt sizes/quantities, weld sizes, stiffener plate thicknesses, etc.) but they must show enough information so that the cost of the details can be readily understood by bidders, and also so that connection designers can understand the EOR's design intent. In contrast, Option 3A requires the EOR to convey to the fabricator precise (versus general) details of member reinforcement at the connections. The EOR must consider, during design, how they require connections to be configured, even when delegating connection design.

The absence of concept connection details on the contract documents can lead to the cost estimator pricing special connections using assumptions contrary to what the EOR is expecting, and can also lead connection designers to develop and design connection details different from what the EOR wants. If concept connection details are not provided and shop drawings are submitted showing details contrary to the EOR's expectation, then arguments and change orders will likely follow.

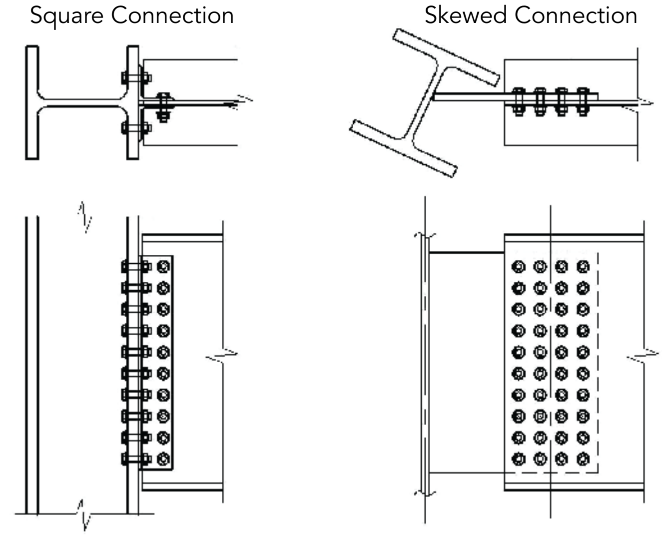


Fig. 2. A beam-to-column connection detail illustrating the difference in complexity between a skewed and a square connection (both with the same shear strength).

Delegation Considerations

Here are a few things to consider when delegating connection design:

Show the reactions. Show all beam reactions, member axial forces, and moments in connections.

Configure framing to simplify connections. The less complex a connection is, the less expensive it will be. Some suggestions:

- Frame members with large reactions square to supporting members (see Figure 2).
- Avoid framing more than one member to any one side of a column.
- Look for connections clashing with other connections.

Connection constructability. Verify that members in the analytical model are configured in a manner that will permit them to be easily connected and assembled in the field.

Connection designability. The EOR must determine, during design, how framing members will be connected to verify that the connections will indeed be designable, and they must develop and provide concept connection details illustrating the configurations of all unique connections (see Figures 3 and 4).

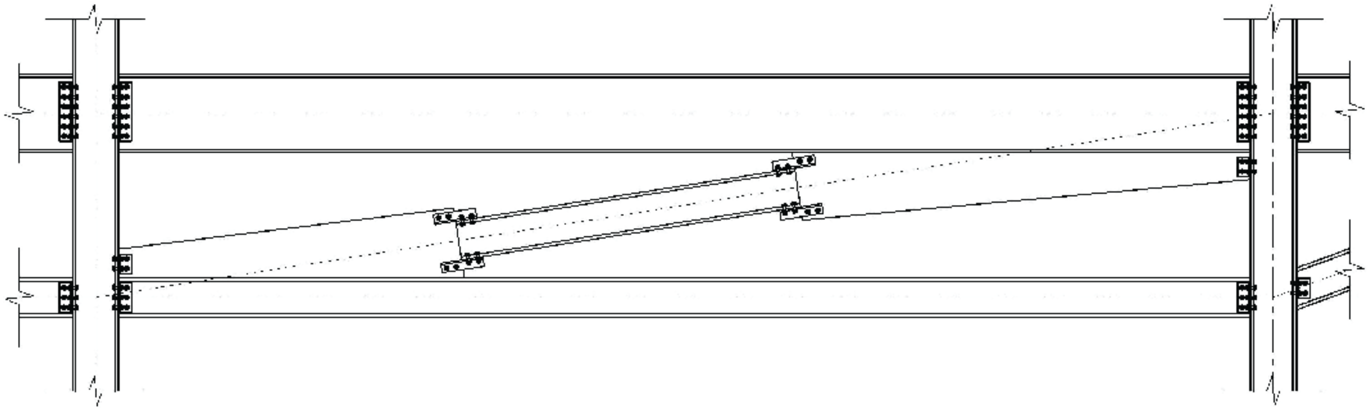


Fig. 3. An impractical ("undesignable") diagonal brace configuration that wasn't discovered until shop drawings were prepared.

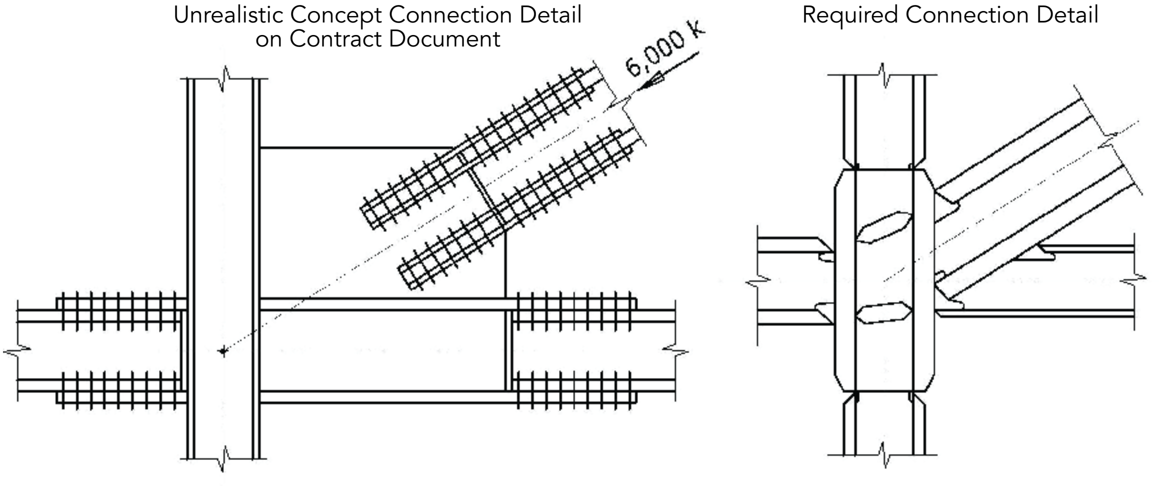


Fig. 4. An ill-conceived diagonal brace concept connection detail on a contract documents (left) and the connection design engineer's solution (right).

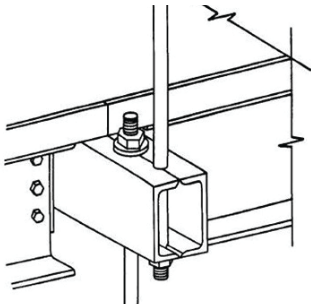


Fig. 5. An offset hanger connection that neglected the kinked (eccentric) load path through the connection.

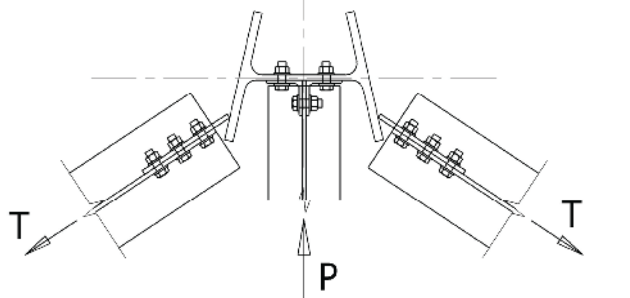


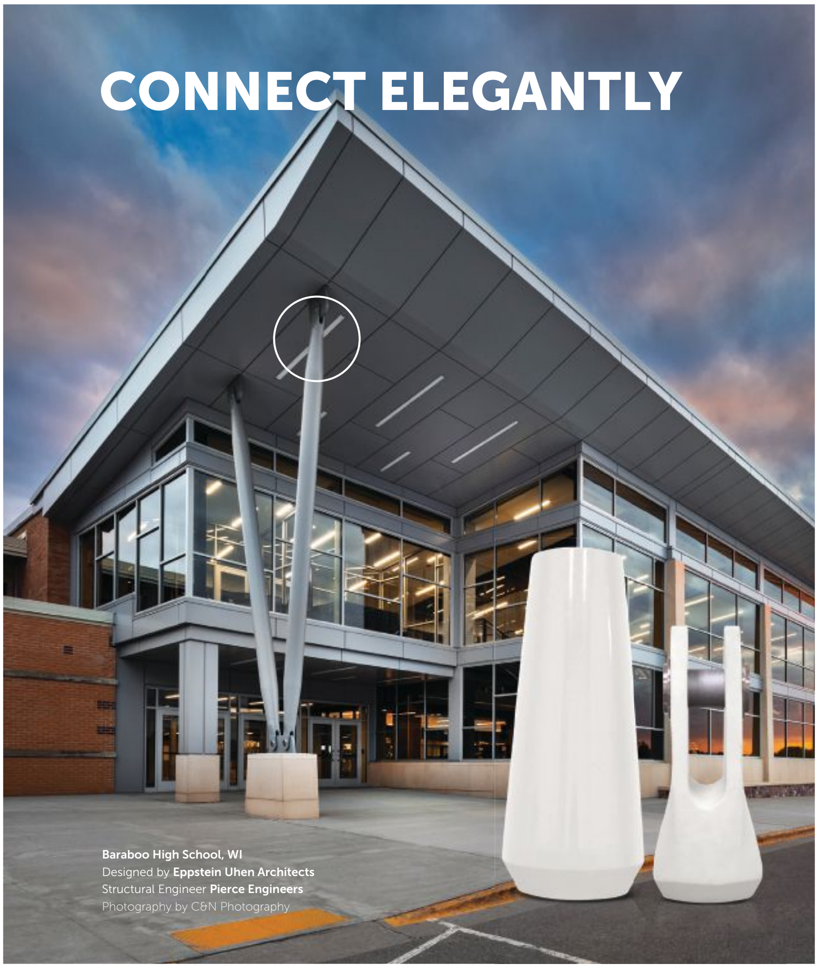
Fig. 6. Column flange deformations due to an ill-conceived tension ring connection detail that ignores secondary stresses.

Look for kinked connections: "Kinked connections" are those where loads traveling through the connections follow irregular jogging (eccentric) three-dimensional load paths. Such connections induce secondary stresses in members. The EOR must locate these connections and either eliminate the kinks by reframing, or deal with the kinks by providing concept connection details showing designable and constructable connections (see Figures 5 and 6).

Limit the tension yield strength ratio: Limit the tension yield strength ratio to 0.75 in tension members to reduce the likelihood that rupture strength will control connection design. Doing so will eliminate costly member reinforcement at the connections.

Section 3.1 of the *Code* provides a concise roadmap to help EORs navigate the most appropriate way to delegate connection design. Reading, understanding, and adhering to the *Code* will enable EORs to produce better contract documents, and will likely make project bids more competitive, improve constructability, reduce costs/RFIs/arguments/change orders, and make everyone's job easier. ■

To learn more about delegating connection design, attend Cliff's session "Delegating Connection Design" at the 2020 NASCC: The Steel Conference, taking place in Atlanta April 22–24. For more information and to register, visit ***aisc.org/nascc****.*



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field notes

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INTERVIEW BY
GEOFF WEISENBERGER

When AISC vice president of market development Tabitha Stine isn't running her staff of nearly 30 or a youth sports league of nearly 900, she's just running.

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

To hear more from Tabitha, including her predictions for the construction market and the National League Central Division this season, visit **www.modernsteel.com**, where you can listen to the interview podcast in its entirety.

Tabitha will present two sessions at the 2020 NASCC: The Steel Conference, taking place in Atlanta April 22–24: "The Crystal Ball: Construction Market Conditions and Forecasting for Buildings and Bridges" and "Innovations in Steel for Architects." For more information and to register, visit **aisc.org/nascc**.

WELCOME TO FIELD NOTES, *Modern Steel Construction*'s podcast series, where we interview people from all corners of the structural steel industry with interesting stories to tell.

Our subject this time is **Tabitha Stine**, PE, AISC's vice president of market development. In addition to managing a team of 30 at work, she also heads up a suburban baseball, softball, and tee-ball league serving nearly 900 kids. To achieve temporary solace from all of these people, she runs. She is also married to another structural engineer, so their house will never fall down.

Everybody has a different "what I want to be when I grow up" story. Was yours "I want to be a structural engineer" or did you figure that out later in life?

I grew up in the family business of construction. My grandfather, post-World War II, started a construction business that my dad and my uncle eventually became partners in. Growing up, every summer I would help my dad work outside doing manual labor, and I loved it. I really love construction, but I also had a fascination with math. So coming out of high school, I was looking at being a math teacher. I had no idea what engineering really was until it was exposed to me by my guidance counselor in high school. I took a shot at civil engineering and I absolutely fell in love with it, and eventually went down the path of structural engineering.

What was it like on your first day as a vice president?

There were big shoes to fill because John Cross, our former vice president of market development, had a legacy in the steel industry. There was conscious mentoring between me and John for a number of years, and eventually there were discussions that he was going to retire. And as I stepped into the role, he was still here almost another year as a vice president of special projects. Because of that, he was a daily asset and supported me while staying at arm's length so I could make decisions. But he never hesitated to help when I asked for assistance and feedback, and to be a listening ear.

Did he give you any particularly valuable advice?

Years ago, he gave his staff the book *Team of Rivals: The Political Genius of Abraham Lincoln* by Doris Kearns Goodwin, which is about how Abraham Lincoln eventually formed his cabinet with people he had beat out for the ticket. The whole concept is that anytime you're trying to build camaraderie or collaborate on an effort, you can't just bring your friends to the table. You really need to bring people to the table that are going to challenge you and make you work harder.

Your husband is also a structural engineer. What's it like having two structural engineers living under one roof?

We have three kids—twins who are in eighth grade and a second grader—and our poor kids have to listen to us talking shop at dinner. He's a bridge engineer but some-

Tabitha with her daughter Madyson, one of the nearly 900 athletes in the suburban youth baseball, softball, and tee-ball league she presides over.

times he's not working on a *steel* bridge, and so there's bantering that happens. We feel it's a little bit of a social experiment on our kids. But we're very excited right now because last week our twins registered for high school and our son is going into what's called Project Lead the Way, which is an engineering track. Our daughter, the other eighth-grader, has zero interest in engineering. I think she's rebelling, but that's good.

I understand you administer a youth sports league.

Yes, we have around 850 kids in the league, and we have tee-ball, baseball, and softball for children ages 4 to 18. As soon as you start volunteering in youth sports, you realize it's almost impossible to get out because they really need good people who are willing to help run practices and the leagues and everything. I've been coaching my oldest daughter since she was four and now she's nearly 14, and for the last three years I've been president of the league. It takes a lot of moving parts to make a league of almost 900 kids run!

You're also a marathon runner. How did you get started in that?

Before I had kids, I met a friend who was joining a running club. I went with her to a couple of club events and she told me she was signing up for her first marathon, and I said, "But you've never even run a 5K." But I watched her run the Chicago Marathon in 2003 and realized that there were people crossing the finish line that I could not believe could complete a marathon, and I said, "I'm going to do this." And the next year, I ran my first marathon, and ever since then, I had a marathon each year that I put on my list as my personal escape from, you know, all the challenges that you have at home and work. All you need is a pair of running shoes, and you can go run. I travel for work all the time, and it's a great way for me to see cities. ■

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business issues

BRING CONFIDENCE TO THE TABLE

BY JIM REEVES

Confidence is the key to effective negotiation. Here are some thoughts on how to build it.

YOU KNOW THOSE TIMES when you feel really good about taking on a task or activity?

You are well prepared. You practiced. You put the time in to get your head in the game. You have a goal in mind and are confident you can achieve it.

It feels good, doesn't it? In almost any activity, having confidence enhances your performance and tells the world you are well prepared and ready to do your best. Confidence gives us mental focus, allows us to speak and move with purpose, and clears our head so we can think creatively.

Not only do we feel good when we are confident, but those around us can sense that confidence too. There's an air of power and credibility that confidence brings. When you are feeling positive about performing your best, the people around you know it.

Unfortunately, confidence doesn't come easily to everyone. But there are plenty of ways to help build it.

It starts with believing you can do something well. After all, confidence has been defined as is the degree to which *you believe* your actions will result in positive outcomes. That's right: Confidence is all in your head.

In negotiations, there are many mental obstacles that work to erode our confidence. The act of negotiating, for many people, is seen as a negative experience. It can feel more like a battle of the wills rather than a process for building value and reaching an agreement. In addition, so much of negotiation is outside of our control. The results of a negotiation are dependent in large part on what the other party does. The uncertainty of what will happen can impact us negatively. And many of us don't have confidence in our skill as a negotiator.

A lack of confidence can leave mental room for uncertainty, hesitation, and second-guessing. A slight hesitation, a flinch, a stammer, a moment of indecision can be perceived as a vulnerability. Lack of confidence can erode your credibility and the ability to build a good rapport with your negotiating counterpart. Those across the table may sense a sign of weakness or lack of preparation.

Having mental focus, knowing your objectives, and feeling positive about achieving them are all essential in negotiation. When you enter into negotiations with confidence, your counterparts on the other side of the table can feel it. You speak with certainty, hold your head higher, and think more creatively. Confidence comes across in your voice and your nonverbal communication. It gives you credibility. You perform without anxiety, distraction, or hesitation.

Studies show that negotiators with confidence are more likely to feel that they can persuade their counterparts more effectively, prevent the other party from exploiting weaknesses, and more effectively establish a rapport with those across the table.

So, how do you become a more confident negotiator? First of all, don't try to fake it. You've probably heard of the "fake it until you make it" approach. But it seldom works in negotiations. It doesn't build your confidence. Why? Because it's not authentic. And

Jim Reeves (jreeves@clearbridge-consulting.com) is a mediator with United States Arbitration and Mediation, a lecturer in law at Washington University in St. Louis, and a principal with ClearBridge Consulting, LLC.

on top of that, experienced negotiators will see right through it. Your credibility will disintegrate. Instead, here are a few more substantive—and authentic—approaches to building your confidence at the table.

There is no substitute for thorough preparation. Those who are confident have prepared. Top performers, whether in sports, the arts, or in the business world have honed their skills by putting the time in to prepare for the task at hand. Likewise, in negotiation, bargaining from the seat of one's pants is a recipe for a less-than-stellar performance. Take the time to know the deal. Who are the people with whom you will be negotiating? Consider not just the company or firms, but the individuals as well. Do some research and get to know the deal, the strengths and weaknesses on both sides of the table, and the people with whom you will be negotiating. Gaining an in-depth knowledge of those with whom you will be negotiating will help you reduce the amount of uncertainty and paint a clear picture of where you're going and how you'll get there.

If you have weaknesses on your side of the table, prepare for them. Give thought to how you will address them and how you might provide other value in order to overcome them. Thinking about weak points in advance of the negotiation helps you to recognize that although weaknesses exist, you have a clear plan to address them, thus eliminating the worry and distraction they present. You will go into the negotiation knowing that you and your company truly have something special to offer.

Rehearse! *Thinking* is one part of preparation. *Doing* is another. Whether it's role-playing or a more informal discussion with your colleagues, practice talking through points you anticipate coming up during the negotiation. There is strength in numbers, and having the opportunity to talk through the negotiation with your business partners, exchange ideas, and get feedback is incredibly valuable in building confidence. Get help refining and presenting key points. Don't avoid weaknesses that you may have on your side of the table. Explore ways of strengthening those weaknesses or discuss a clear strategy for addressing them at the table. Working with others on your side of the table helps you remember that you have a team behind you. With that support comes confidence.

Practice away from the table. We all negotiate every day in and out of our professional lives, often without realizing it. Be mindful of your interactions and think of them as opportunities to use and build your negotiating skills. Practicing negotiation helps build competence and comfort. Practicing every day will help you become a more confident negotiator. ■

Want to learn more about how to up your negotiation game? Attend the session "Negotiating with Confidence" at the 2020 NASCC: The Steel Conference, taking place April 22–24 in Atlanta. For more information and to register, visit ***aisc.org/nascc****.*

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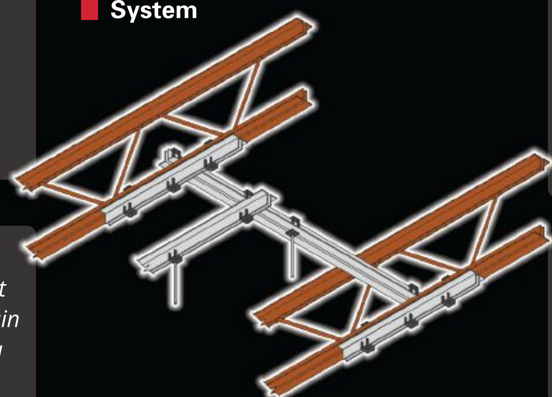

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Heavy-Duty Hardware

BY AMY BARABAS, PE, AND TOM BARABAS, PE

YOU COULD SAY that the University of Maryland has quite a bit of computing power.

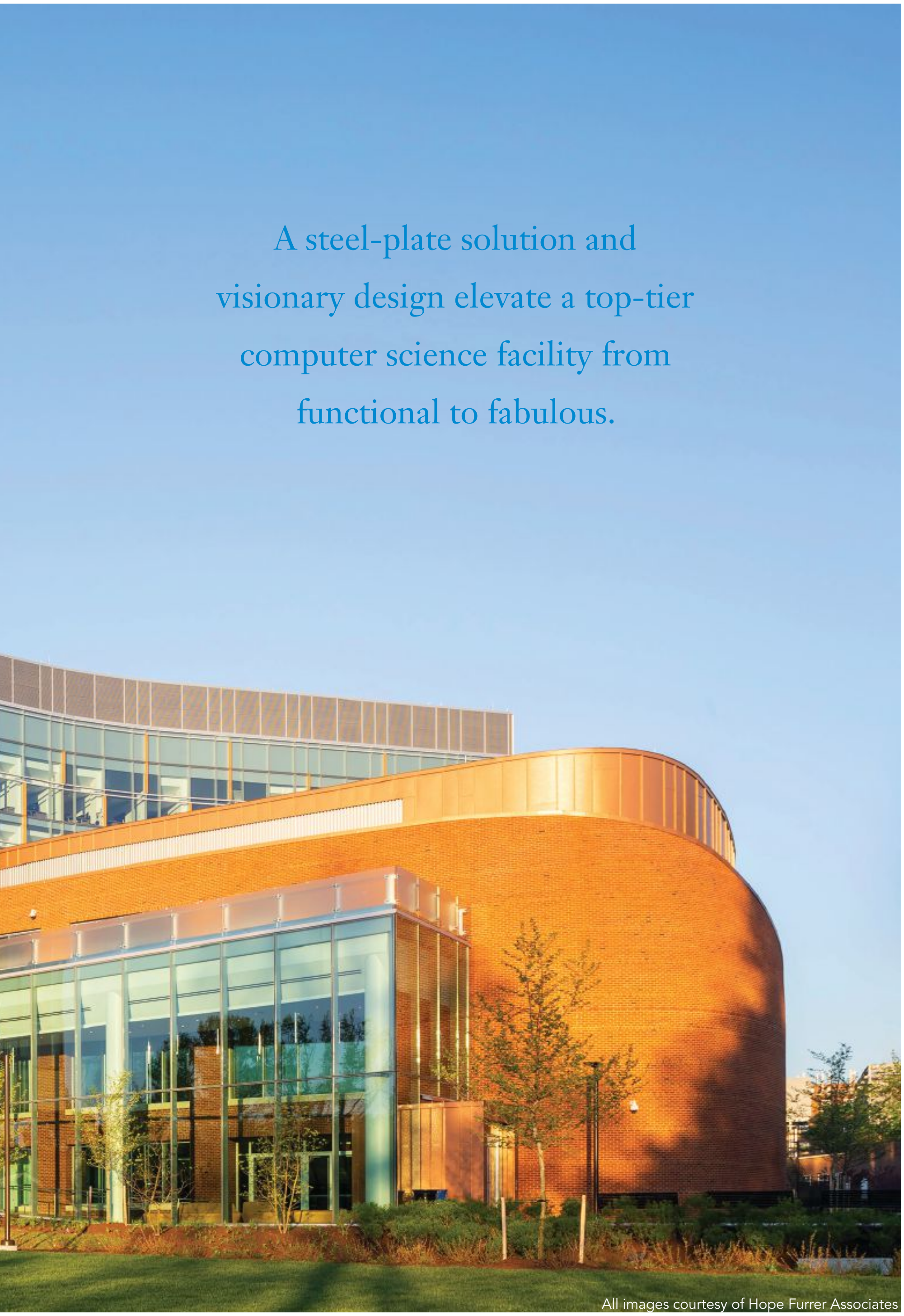
Opened last year on its College Park campus, the new Brendan Iribe Center for Computer Sciences and Engineering houses the school's highly ranked Department of Computer Sciences and the Institute for Advanced Computer Studies. The 215,600-sq.-ft building provides space for research in several tech fields, including cybersecurity, data science, virtual and augmented reality, and artificial intelligence, housing hacker and maker spaces, VR and AR labs, classrooms, and administration space.

Its namesake, a former University of Maryland student and cofounder of Oculus VR, provided a generous donation to reinvigorate the Computer Sciences Department and propel the program to the forefront of technological education and innovation. Additional funding assistance from Oculus cofounder Michael Antonov, the State of Maryland, and the University allowed the $138 million project to move from vision to reality in a span of five years.

Site Logistics

Located at the main campus entrance along Baltimore Avenue, the selected site for the facility lies at the front door of a new "Innovation District." However, the site posed multiple challenges for the design team. The orientation of the building

A steel-plate solution and visionary design elevate a top-tier computer science facility from functional to fabulous.



All images courtesy of Hope Furrer Associates

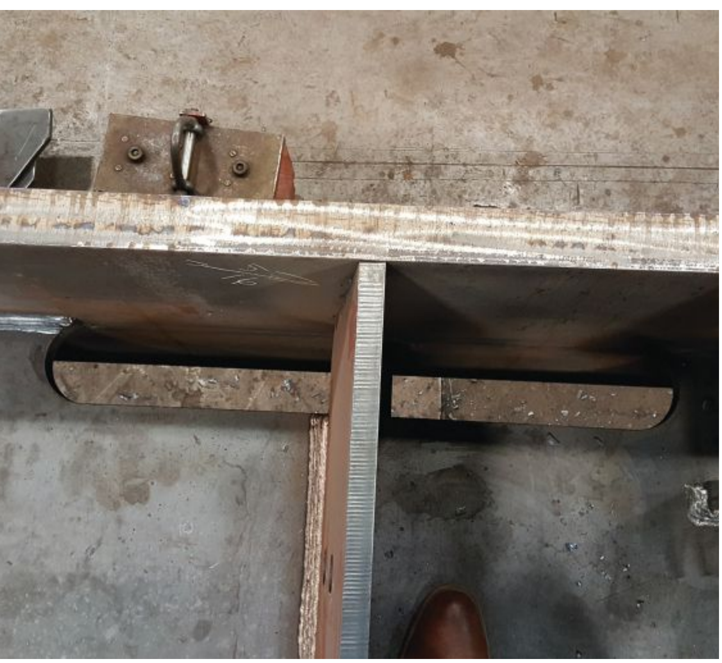
left: The main tower of the Iribe Center is connected to the auditorium structure via a one-story lobby space.

below: Inside the atrium of the 215,600-sq.-ft building. The main stair stringer section incorporates helically curved HSS12×4×.375.

placed the eastern portion of the structure within the 100-year flood plain, and the western end of the building required loading dock access under the tower.

Due to the flood plain, usable space wasn't feasible at the ground level of the easternmost 120 ft of the building. Therefore, the first usable space for this area was the first elevated slab. In lieu of just functionally bringing down the building columns, the architectural team at HDR looked to create a dramatic effect for the supports at the east end. After several design iterations and structural studies, the team landed on a sloped steel column design with cantilevered steel transfer girders in all directions. In concert with the design of the east cantilevers, the decision to also cantilever transfer girders on the west end facilitated column-free access to the loading dock.

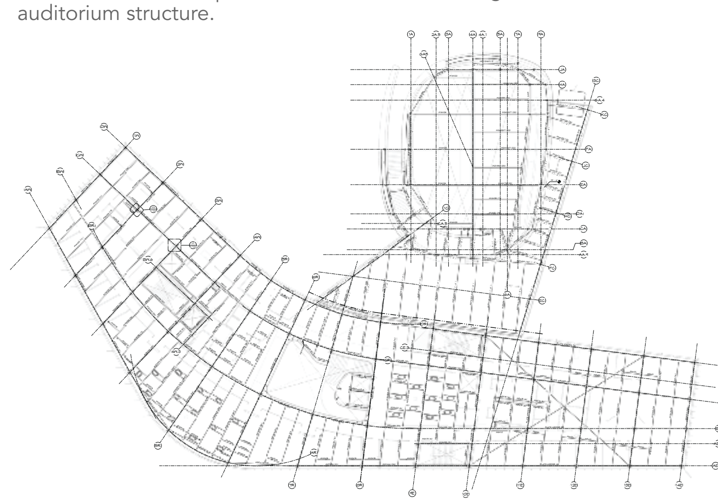
Amy Barabas (abarabas@hfurrer.com) is a project manager and **Tom Barabas** (tbarabas@hfurrer.com) is a principal, both with Hope Furrer Associates.



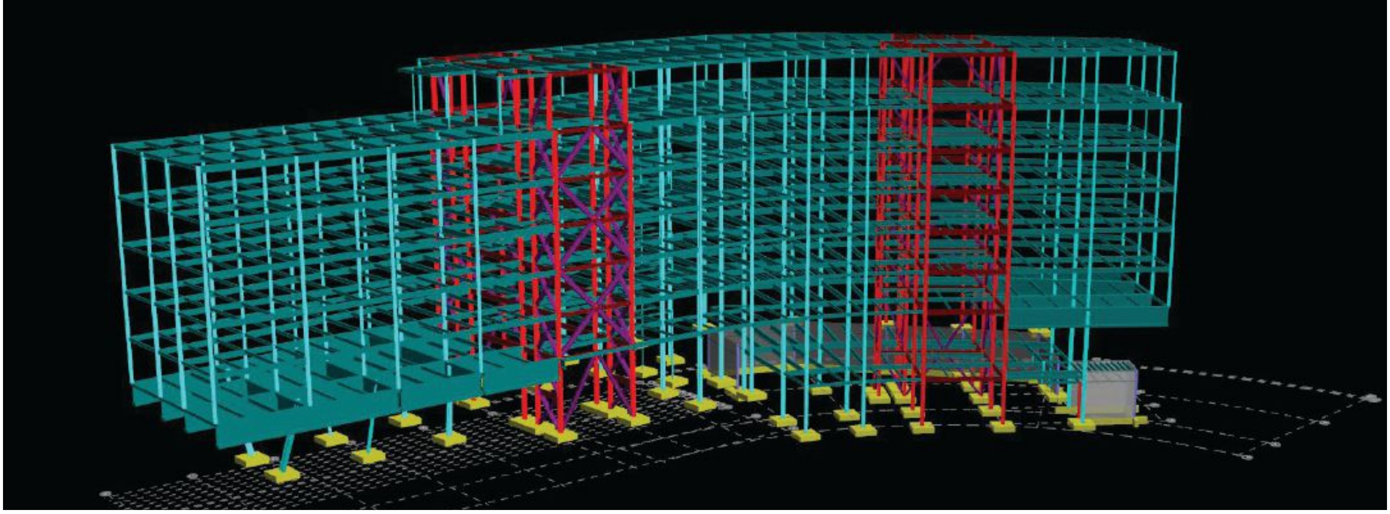
above: A plate girder at Littell Steel's shop, one of 19 the company fabricated for the project.

left: Web penetrations allow for continuous splice plates of perpendicular plate girders on the top and bottom of the flanges.

below: An overhead plan view of the main building and auditorium structure.



The east of end of the structure after substantial completion of steel erection.



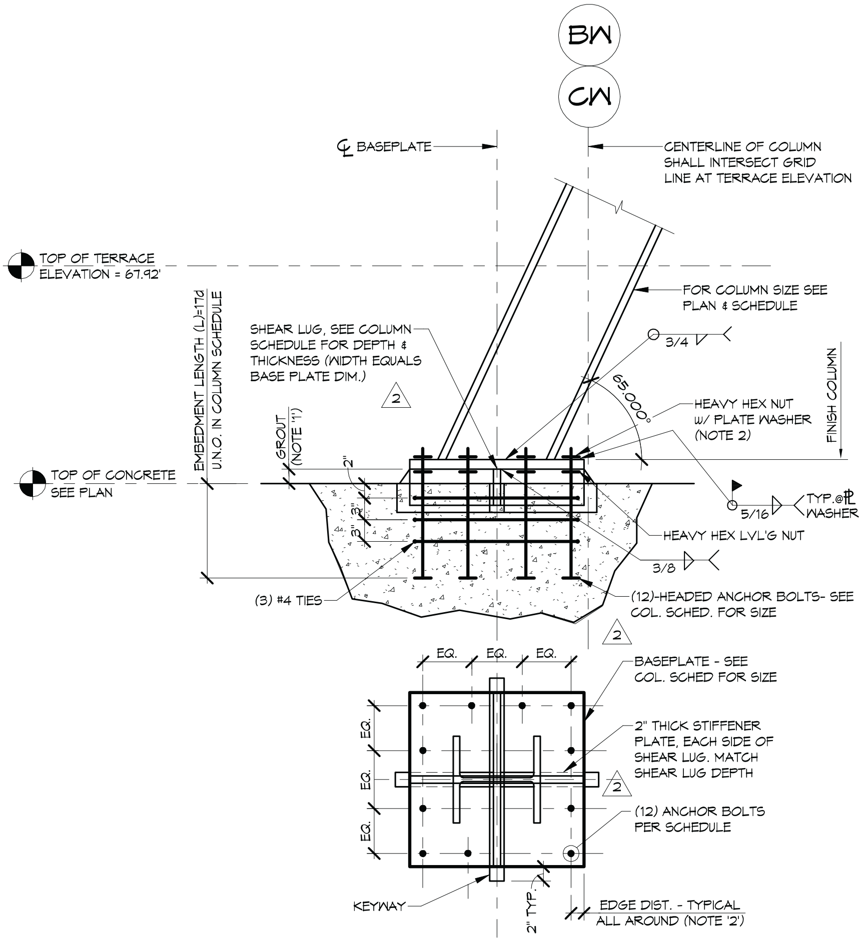
A 3D structural model of the main building (braced frames are shown in red and purple).

Cantilevered Framing

After settling on the design concept for the east end of the building, the structural engineering team at Hope Furrer Associates was tasked with coming up with the most efficient structural framing. With the 25-ft floor-to-floor height from the ground floor to the first floor, ample room existed to provide structural steel transfer girders to support the five steel-framed stories above, capped with a rooftop terrace. The design team reviewed both truss and plate girder concepts and discussed both options with fabricator Cives Steel. Since few utilities would be located in the space designated for structure—the plate girders were located above an outside terrace/entrance area and there were no large ducts as would be the case if they were located at a roof—the simplicity of fabricating and erecting plate girders made the most sense.

The grid of transfer girders is supported by three pairs of sloping columns. The column pairs are spaced 30 ft apart in the east-west direction, and the easternmost pair is set in 30 ft from the exterior of the building above, creating a cantilever. The columns in each set slope equal and opposite to each other and vary from vertical 5° to 25°, with the largest slope located at the easternmost set of columns. Column sizes for the sets of sloping members were W14×257, W14×605, and W14×730, respectively from west to east. The resulting axial, shear, and moment forces on the easternmost set of columns resulted in 48-in. × 48-in. × 5-in. base plates with a 3½-in. × 8-in. shear lug and 12 1¼-in. grade 105 anchor rods.

In addition to supporting the 30-ft cantilever to the east, the transfer girders also support cantilevers beyond the sloping columns in the north and south directions,



above: A detail of the bottom of a sloped column.

below: East-end cantilevered plate girders and sloped columns during steel erection.

ranging from 10 ft to 20 ft depending on the column slope. The total depth of the plate girders was 7 ft, 4 in. and the girders were built from flange plates ranging from 26 in. × 2 in. thick to 28 in. × 3 in. and web plates ranging from 1 in. to 1½ in. thick. Camber was provided at the end of the most heavily loaded cantilevered sections to account for a portion of the dead load deflection and reduce the impacts on the curtain wall.

Since plate girders were required in both directions, spliced connections would need to be designed to transfer the full moment across the perpendicular member. Due to the loads, splice plates would be required on the top and bottom of each flange to allow the bolts to be in double shear, which required web cut-outs of the intersecting plate girders to allow for the plates to pass through.

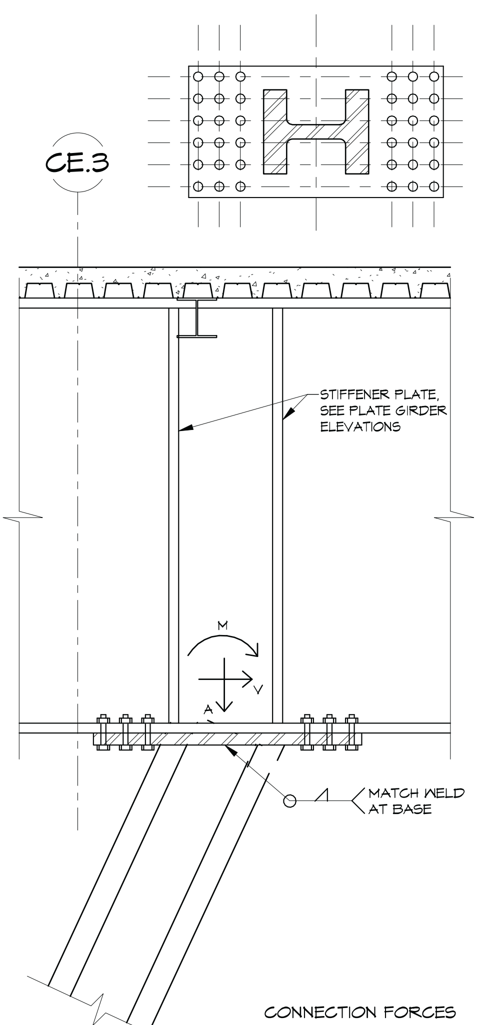
Due to the sloping columns, lateral stability of the transfer level was critical to the design. In accordance with ASCE 7-10: *Minimum Design Loads for Buildings and Other Structures*, Section 4.3.3, partial loading of the structure produced more unfavorable load effects for some members than the same load applied over the full structure. Loading one side of the structure, and therefore only one of the sloping columns, provided the controlling load effect. To resist the resulting instability, moment connections were provided at column to transfer girder joints and horizontal bracing was provided at both the top and the bottom of the plate girders. This bracing went back to braced frame towers at the north and south sides of the building. These towers were instrumental in stabilizing the structure at this end and since they were exposed to view (and coated with intumescent paint) at the exterior, HDR requested

a specific configuration and the use of hollow structural section (HSS) members—HSS20×12×½—for the braces to contribute to the overall expression of the building.

At all floors above the transfer level, additional horizontal bracing was provided to create a horizontal truss at the cantilevered end to resist the imposed lateral loads and provide a load path back to the braced frame towers. The braced frame towers at each side of the building were connected via moment-connected beams to provide additional resistance to the torsion induced on the building frame from lateral loads on the cantilevered diaphragm. Since the west end also required 30-ft cantilevers at the transfer level, the same depth and similarly sized plated girders were provided. However, this end only required plate girders in one direc-

A 48-in. × 48-in. × 5-in. base plate with shear lugs supporting a sloping W14×730 column.

A detail of the top of a sloped column.



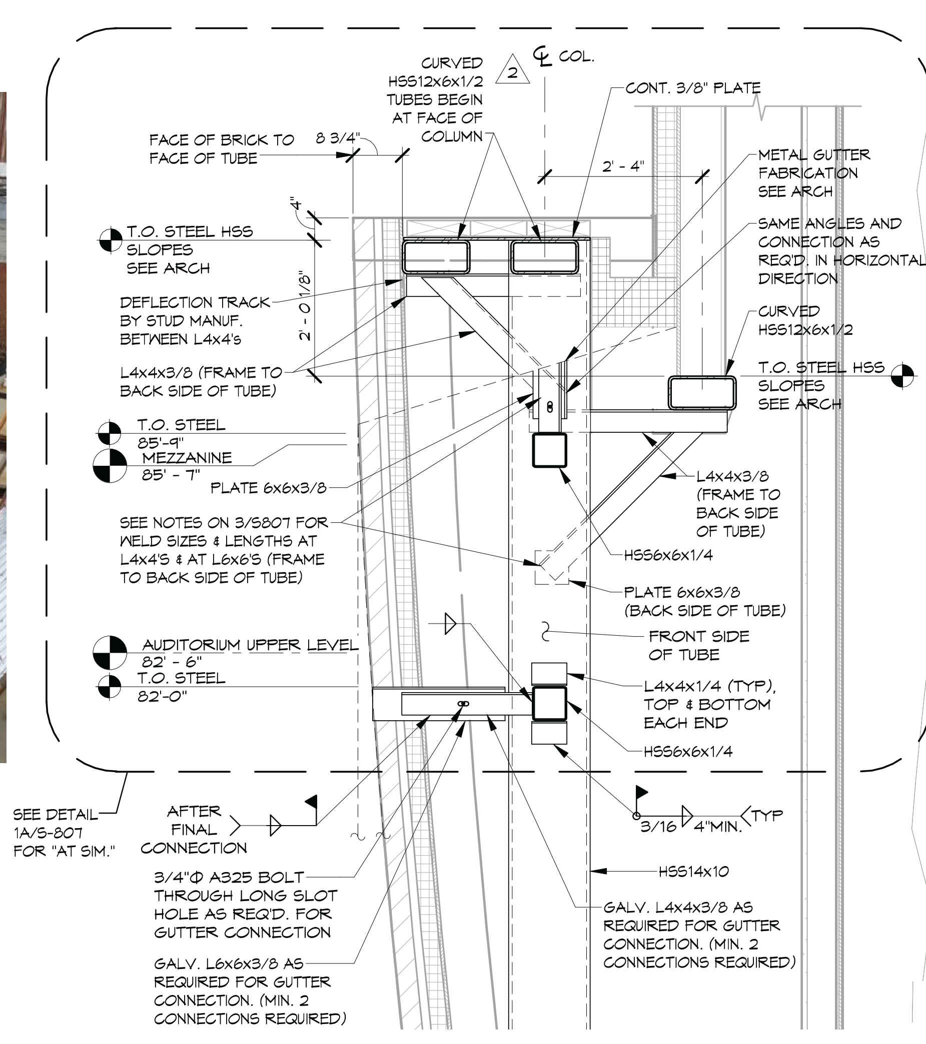
CONNECTION FORCES

	A	M	V
@ 101 + 102	1373	177	103
@ 103 + 104	2859	385	487
@ 105 + 106	2525	1498	938

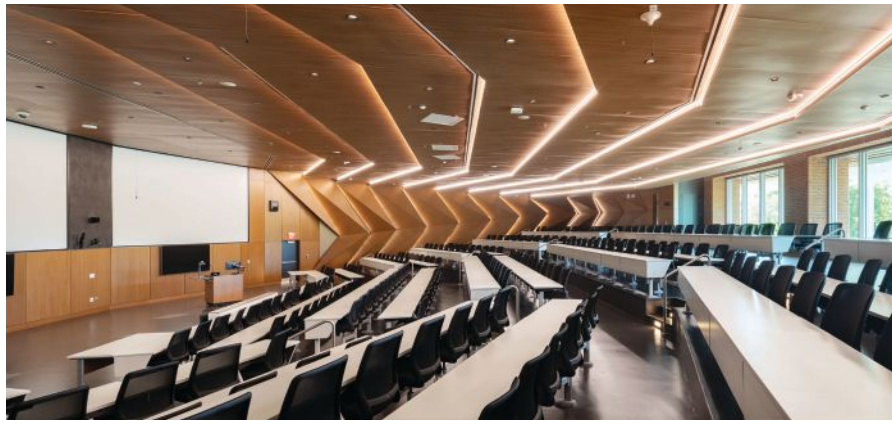
tion. Also, due to the size and weight of the plate girders, Cives subcontracted plate girder fabrication to Littell Steel. (Of the roughly 3,000 tons of steel fabricated for the project, Cives was responsible for 2,550 and Littell provided 450 in the form of 19 plate girders.) In addition, a specialized erection plan had to be developed for the sloped columns and plate girders, with stability for these elements being provided through temporary shoring and the tower's braced frames.

above: A rooftop terrace provides an attractive outdoor oasis on top of the building.

above: Steel framing for the auditorium.



right: The auditorium's brick ledge and gutter required sloping and curved HSS members for support.



The elevated auditorium seating was constructed of wide-flange raker beams.

Auditorium Structure

Beyond the main tower and connected via a one-story lobby space sits a steel-framed auditorium structure housing a 100-seat lecture hall directly below a 300-seat auditorium. The elevated auditorium seating was constructed of wide-flange raker beams with tapered WT shapes welded to the top flange and bent plates to create the seating tiers.

To create a column free space in the auditorium, a 90-ft-long truss was designed to span the length of the building. The bottom chord supports the penthouse floor structure, which houses the MEP equipment needed for the auditorium, and the top chord supports the roof structure. The truss is segmented with the top chord following the shape of the curved roof.

The exterior of the auditorium is curved both horizontally and vertically and cannot be described by a defined shape, incorporating multiple radii in both directions that provided direction for construction. The exterior is clad with brick and required a setback for an internal gutter system. Due to the unique geometry, the brick ledge and gutter are supported by sloping and curved HSS members.

The completion of the Brendan Iribe Center for Computer Science and Engineering establishes the University of Maryland as a focal point for the nation's technology community. Since opening, the facility has worked to foster the student creativity needed to develop the ideas and breakthrough technologies that can change the world, stimulate economic development, and solidify the university as a high-tech resource for the business community. ■

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Whiting-Turner, Herndon, Va.

Architect
HDR, Arlington, Va.

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Hope Furrer Associates, Towson, Md.

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Fabricators
Cives Steel, Winchester, Va. (AISC Certified Fabricator)
Littell Steel, New Brighton, Pa. (AISC Certified Fabricator)

Bender-Roller
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Engineering the Building of Buildings

BY ANDREW TWAREK, SE, PE

Construction engineering is a diverse, challenging, and crucial branch of structural engineering that ranges from shoring supports to designing for temporary loads on existing structures.

Andrew Twarek (**atwarek@rubyandassociates.com**) is a project manager with Ruby + Associates, Inc., Structural Engineers.

WHEN I TELL PEOPLE I'm a structural engineer, they assume I design buildings or bridges—which is fair.

While many structural engineers do that, there are other specializations within the field that aren't geared toward new project design but that still use the background of structural engineering. It's this wide variety of project and client types that I enjoy—especially construction engineering.

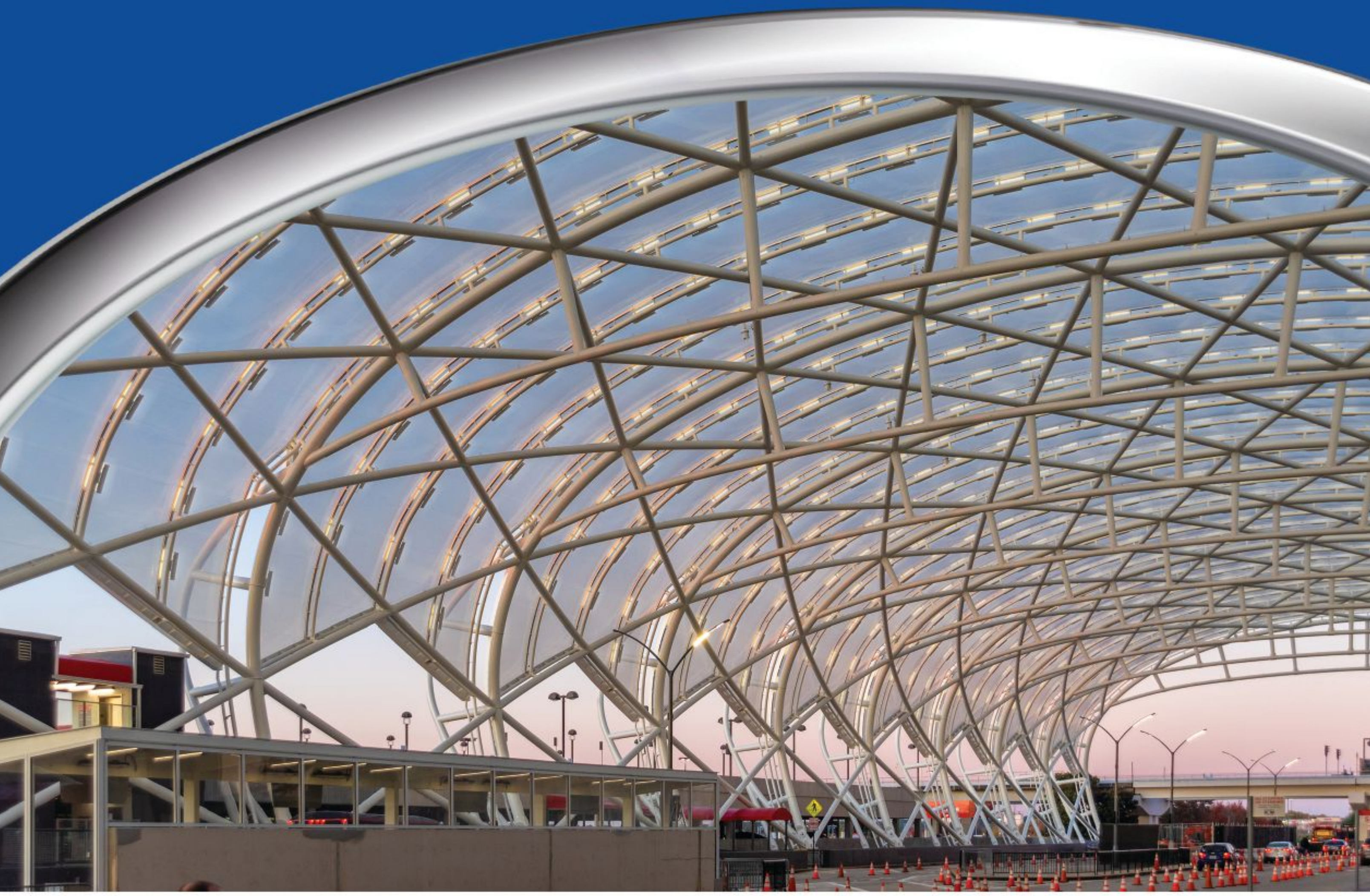
Construction engineering, as a branch of structural engineering, is distinct from the engineering needed to design the structure itself and often includes assistance with the contractor's "means and methods" and the details that are needed to get a project from a plan to the real world. For purposes of this article, it can be defined as specialty work performed by a structural engineer (usually with a PE or SE license) to provide solutions to problems encountered during the construction or modification of a structure.

However you define it, construction engineering is rarely if ever mentioned in college curriculums, and I've never seen a textbook for it. Instead, it relies on basic structural engineering principles (statics, and sometimes even dynamics!), material-based codes and specifications—such as AISC's *Specification for Structural Steel Buildings* (ANSI/AISC 360, **aisc.org/specifications**)—and a variety of specialty or proprietary resources (like shoring tower manufacturer brochures, concrete anchor calculations, rigging components, construction equipment documentation, and more).

What does a construction engineering project look like? Project types are diverse, but typical examples include:

- Temporary shoring or supports
- Demolition design and stability analysis
- Reviewing construction equipment loading on elevated structures—e.g., a worker lift on a second-floor slab
- Designing for temporary loads on existing structures—e.g., crane pressures on a basement wall

Rolling up for Departure



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4	Flat Bar The Easy Way	INSIDE DIA.	36" x 12" Flat
5	Square Bar	INSIDE DIA.	18" Square
6	Beam The Easy Way (Y-Y Axis)	MEAN DIA.	44" x 335#, 36" x 925#
7	Beam The Hard Way (X-X Axis)	INSIDE DIA.	44" x 285#
8	Channel Flanges In	OUTSIDE DIA.	All Sizes
9	Channel Flanges Out	INSIDE DIA.	All Sizes
10	Channel The Hard Way (X-X Axis)	INSIDE DIA.	All Sizes
11	Tee Stem In	OUTSIDE DIA.	22" x 142½# Tee
12	Tee Stem Out	INSIDE DIA.	22" x 142½# Tee
13	Tee Stem Up	MEAN DIA.	22" x 142½# Tee
14	Angle Heel In	INSIDE DIA.	8" x 8" x 1" Angle
15	Angle Heel Out	OUTSIDE DIA.	8" x 8" x 1" Angle
16	Angle Heel Up	MEAN DIA.	8" x 8"x1" Angle
17	Square Tube	INSIDE DIA.	24" x ½" Tube
18	Rectangular Tube The Easy Way (Y-Y Axis)	INSIDE DIA.	20" x 12" x ⅝" Tube
19	Rectangular Tube The Hard Way (X-X Axis)	INSIDE DIA.	20" x 12" x ⅝" Tube
20	Square Tube Diagonally	MEAN DIA.	12" x ⅝" Square Tube
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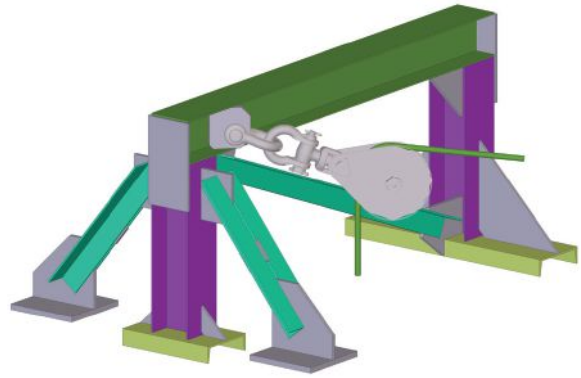


A 3D model of a steel support frame used to install an electrical transformer on a tight site where a crane wasn't feasible.

- Loads for construction safety equipment or systems (personal fall-arrest tie-off points, temporary platforms, etc.)
- Field modifications or repairs to construction defects

A Tight Fit

Let's get into the details of some real-life construction engineering projects that Ruby + Associates has been involved with.

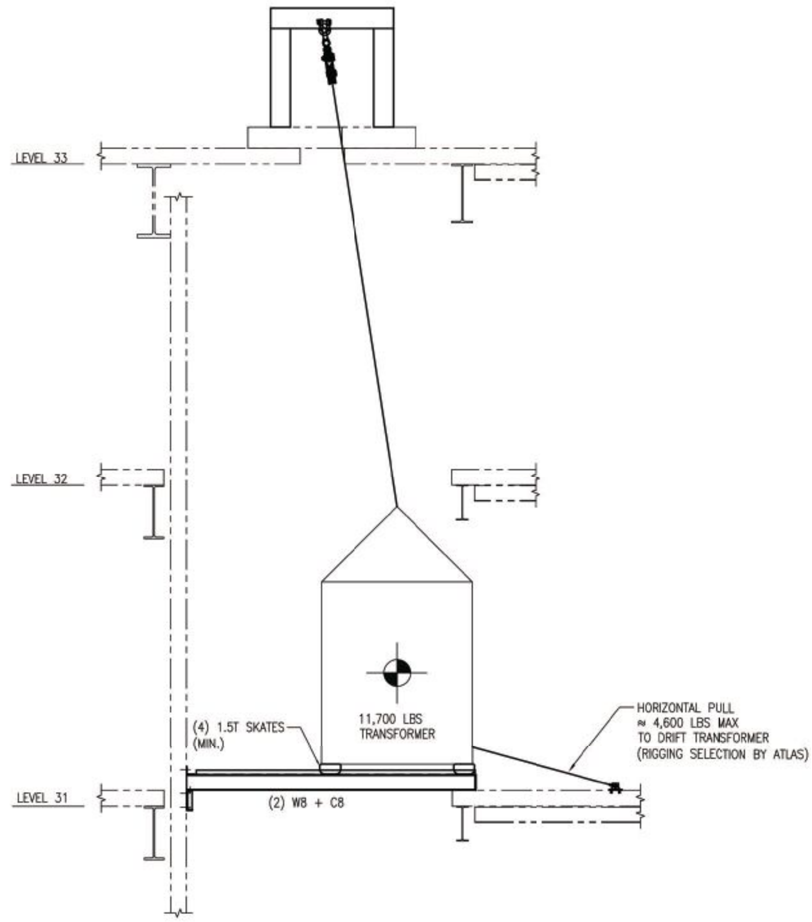
In the first one, a longtime client called us to assist with the installation of an electrical transformer for a building. My initial thought was that it sounded like something I'd done several times before. I pictured a crane placed next to a concrete pad, a semi trailer pulling up alongside, and the crane picking up a box and setting it down. Easy peasy.

Unfortunately, the transformer was to be installed in a downtown area with limited room for cranes and material lay-down. Additionally, the building was over 500 ft tall—beyond the reach of the largest hydraulic crane in the region.

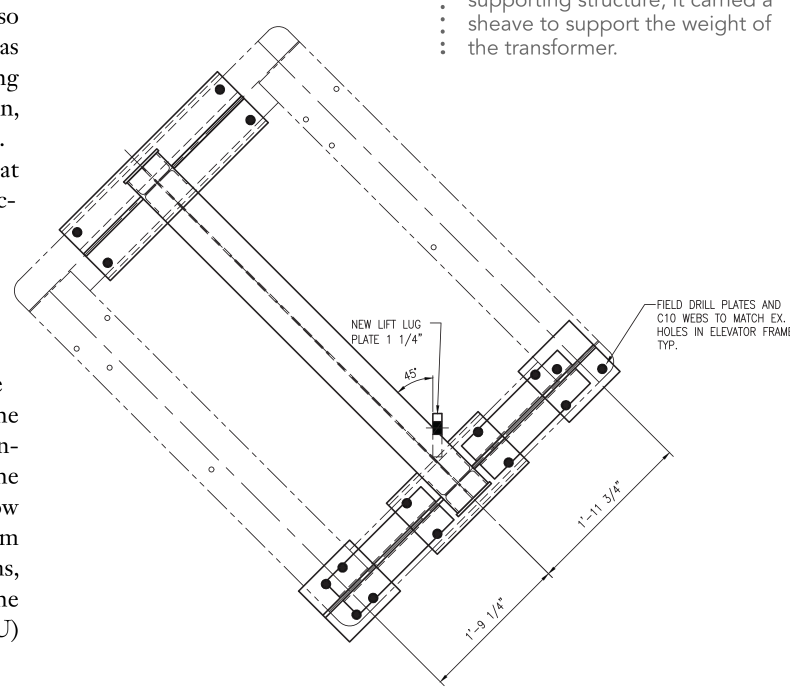
However, the transformer was just small enough to fit in the freight elevator shaft and could be raised that way, so that's what the contractor decided to do. The only catch was getting it into the shaft and raising it 30-plus stories. Using the elevator motor and cables wasn't going to be an option, so the contractor needed a structural engineer to help out.

We started by designing a small steel hoist structure that could be installed on the elevator support beams. Structural steel was the only solution that provided enough strength and could also be brought up in small enough pieces to be put into place. Once connected together and bolted to the supporting structure, it would carry a sheave to support the weight of the transformer.

An air tugger (or winch) was placed on the other side of the elevator equipment room wall, and we analyzed the existing steel floor framing and designed some small connector beams to anchor the tugger to the floor. Once the transformer was raised to the proper level one floor below the temporary hoist structure, it had to be removed from the elevator shaft. The Ruby team designed track beams, which were supported on the concrete slab outside the shaft and anchored into the concrete masonry unit (CMU) shaft wall at the other end, to "skate" the transformer.



A small steel hoist structure used to lift the transformer was installed on the support beams of an elevator shaft. Once connected together and bolted to the supporting structure, it carried a sheave to support the weight of the transformer.



With tight tolerances, many limitations, and a short schedule, this project presented plenty of challenges that required outside-the-shaft—er, box—thinking.

Shored Up (Down)

Our second example is tied to a common source of construction engineering projects: modification of existing structures. Building renovations requiring changes to a structure—like adding elevators, for example—can trigger the need to meet updated code requirements.

Hydraulic elevators are efficient for low-rise structures, and their equipment requires a pit below the lowest floor serviced. It's rarely convenient to place an elevator in the middle of a bay, so the elevator pit often interferes with an existing column footing. Additionally, if the original building drawings have been lost, identifying the size of the existing footing typically can't be done before design is complete and construction begins.

In this case, our client received drawings with a note indicating "existing footing, field determine if depth and extent prior to placement of elevator foundation, underpin and cut existing footing as needed to install elevator." This is a fairly vague statement for a contractor. How much underpinning? How to provide stability during construction? Once again, the contractor needed help from a structural engineer.

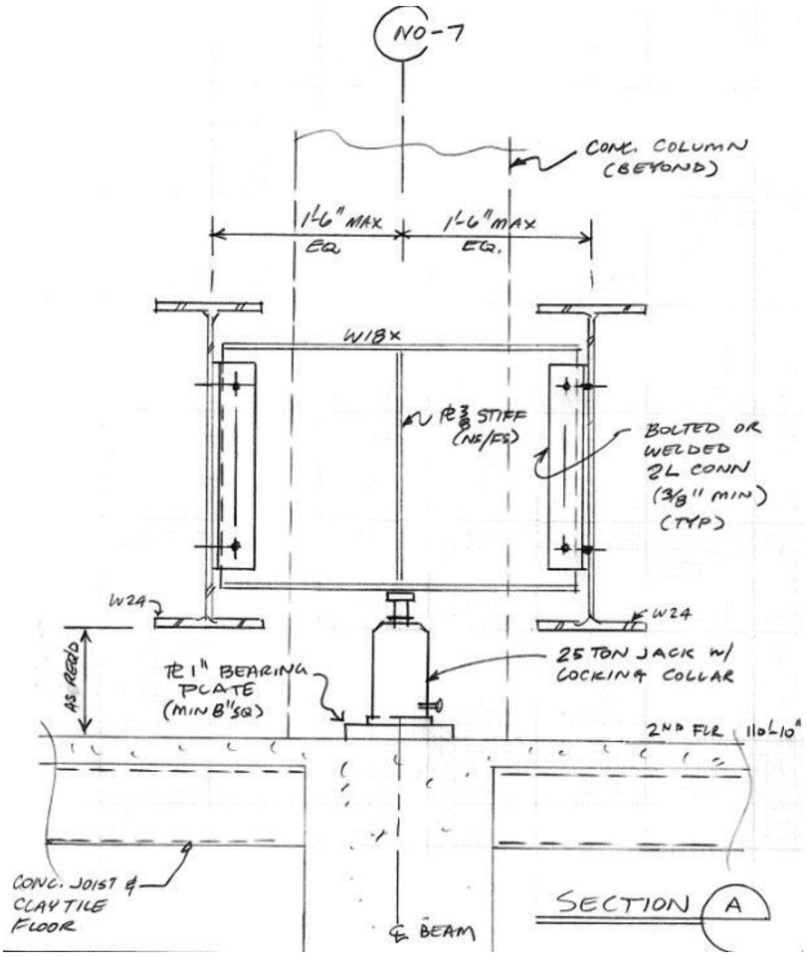
We came in and looked at the problem with the contractor, who revealed that there were additional space limitations in the basement that

The framing for the transformer hoist system, in place.

prevented increasing the footing size. As such, providing support in the basement during undercutting would be even more difficult.

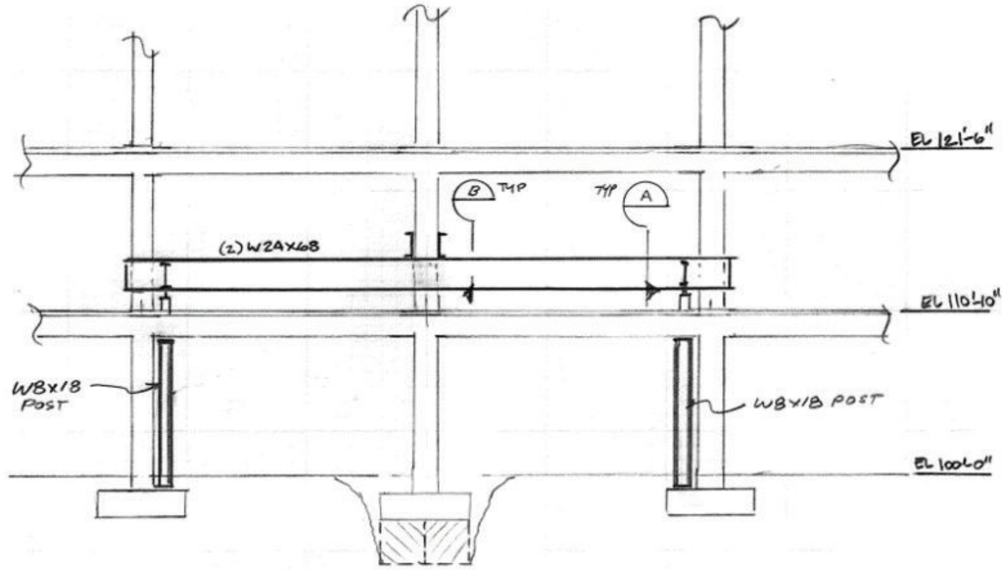
The solution we came up with was to provide shoring—but from above. Looking at the load on the concrete column during construction and the capacity of the adjacent footings, we determined it would be possible to spread the column load using structural steel beams at the first floor.

Two W24×86 beams were brought in through windows at the first floor level and installed to sandwich the existing column. Heavy threaded rods were grouted through the column and connected to bearing channels to load the beams. In order to remove load from the footing, hydrau-



above: A sketch for a temporary shoring system used to modify an existing elevator footing.

right: The system involved spreading a concrete column load using structural steel beams.



For the elevator footing project, W24×86 beams were installed to sandwich the existing column.

lic jacks preloaded the ends of the shoring beams. This allowed the construction crew plenty of clearance—and enhanced safety—to dig out and remove the corner of the existing footing "as needed."

Flying Platform

Construction engineering isn't just for traditional buildings, but also for structures such as oil refineries. These facilities process

Structural, Construction, or Erection?

A branch of structural engineering similar to construction engineering is erection engineering, which deals with the sequencing and stability of a structure during the construction or erection process to ensure the partially assembled structure remains safe until its completion.

The term construction engineering is also used by the Construction Institute of the American Society of Civil Engineers (ASCE CI) to refer to "the designing, planning, management, and delivery of vertical and horizontal infrastructure construction projects. The work performed on the projects may include new work, additions, alterations, or maintenance and repairs."

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hundreds of thousands of barrels of crude oil a day, so every day that they aren't operating is problematic. They often have to work months or even a year in advance of an anticipated turnaround to plan, schedule, and make sure everything happens smoothly and without delay.

For a recent Ruby construction engineering project, a refinery client was preparing for a large turnaround, replacing a major reactor vessel and many connecting components. Preplanning as much work as possible and staging equipment to save time once the oil stopped flowing was crucial to minimizing downtime.

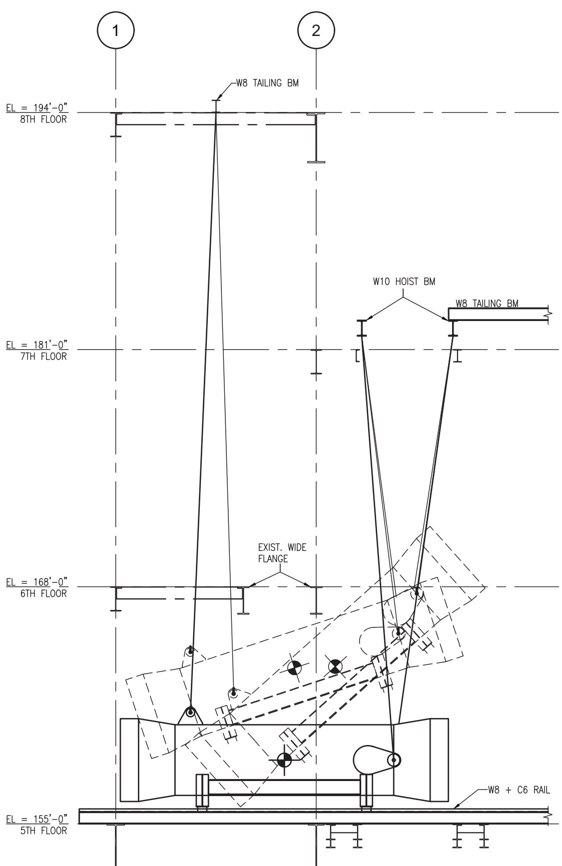
The reactor was fed by two 8-ft- to 10-ft-diameter risers that were to be replaced. Instead of putting the new ones in the same location as the old ones (which could only happen during the turnaround) the new risers were to be installed adjacent to the existing ones and connected as fully as possible in advance—with just a short tie-in piece to be installed when the new reactor was ready. The steel tower around the risers and reactor required extensive modification designed by the structural engineer of record to support the new riser, but the matter of installing sections was up to the contractor.

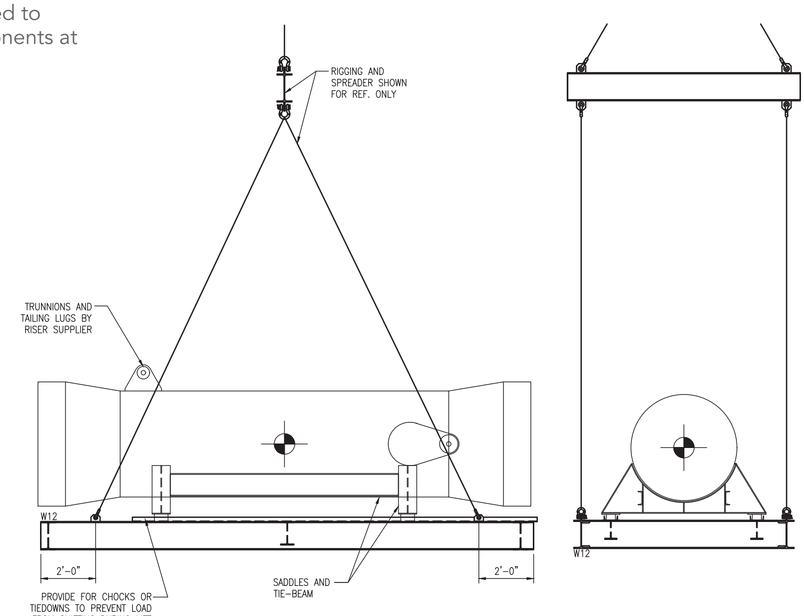
The fifth floor provided the best clearance into the steel tower, but the sections had to come in horizontally. We designed a series of saddles that could be bolted together into a rolling cart for each section. The cart would then ride on a platform with a track of upturned C6×8.2s. Each section was loaded onto the platform at the ground level and tied off, and then the whole platform was lifted to the fifth floor. Once the flying platform was lashed to the structure, the cart was rolled off the platform and onto additional skate beams (with C6s). The matter of "uprighting" the riser sections was accomplished carefully with chain falls from hoist beams designed to span the existing steel at the seventh floor.

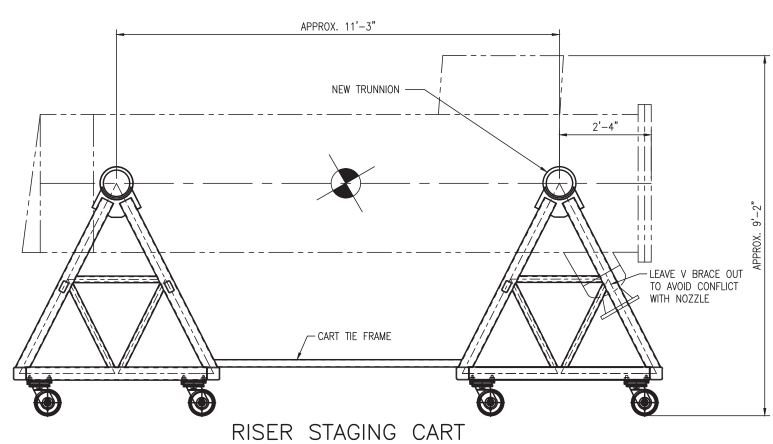
To save additional time during the turnaround, the client wanted to stage a cart underneath the lowest piece of the existing riser for removal. We designed trunnions to be welded to the sides of the pipe and triangular hollow structural section (HSS) frames to support the trunnions, with enough clearance for the riser section to be lowered into place—all using industrial casters for easy removal. The new riser section was then ready and waiting on a separate 8-ft-tall custom cart, ready to be rolled in for the installation.

These three projects are just a small example of the variety of work that keeps life interesting and makes construction engineering so much fun. From old buildings to new buildings, industrial facilities, refineries, and power plants, construction engineering provides a myriad of challenges to a structural engineer—as well as a solid, safe plan for bringing projects together. ■

Various views of the steel "flying" platform and rolling cart used to replace a major reactor vessel and multiple connecting components at an oil refinery.







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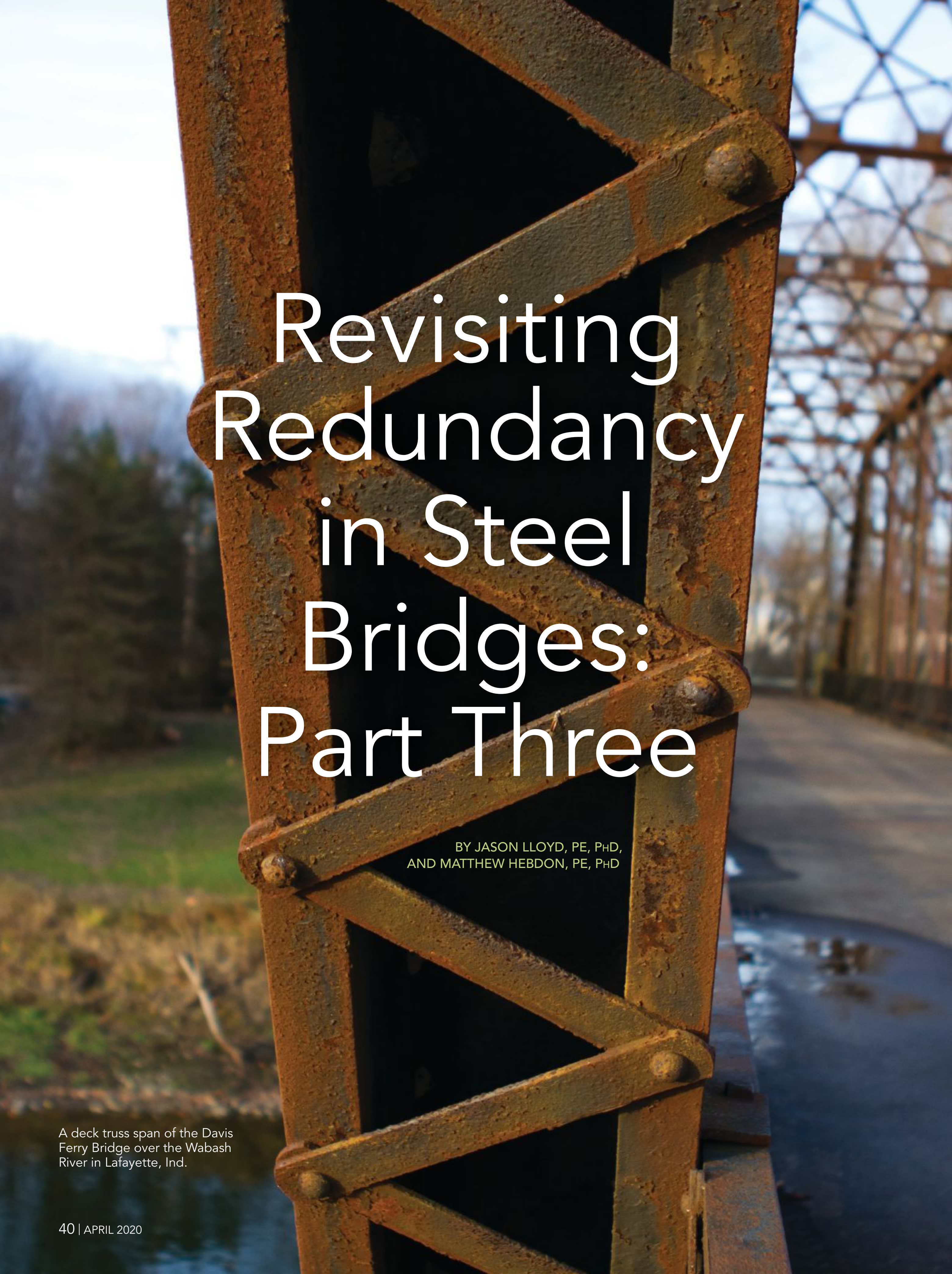

Revisiting Redundancy in Steel Bridges: Part Three

BY JASON LLOYD, PE, PhD, AND MATTHEW HEBDON, PE, PhD

A deck truss span of the Davis Ferry Bridge over the Wabash River in Lafayette, Ind.

Want to exploit member-level redundancy? A new AASHTO resource can help.

BUILT-UP STEEL BRIDGES have a long history.

Built-up member bridge construction practices using wrought iron can be traced back as far as the late 18th century. From the 1840s onward, construction of long-span wrought-iron bridges in the U.K. continued the advancement of riveted connections and use of built-up member construction. The dawn of rolled steel mills in the late 19th century and early 20th century further advanced the use of built-up construction, making it the most widely used form of building and bridge construction at that time. Hot-driven rivets were predominantly used to fasten together multiple components, such as plates and angles, until the late 1950s and early 1960s, when high-strength bolts and welding processes became preferred methods of construction.

Today, thousands of bridges possessing built-up members continue to serve the highway and railway industries, and many are more than a century old! They remain a vital part of U.S. and international infrastructure, and in many cases have become historic and iconic structures. While built-up construction may not be the most economical design option in current markets, some applications, such as built-up through-girders or built-up steel bents, may be tactically advisable to take advantage of internal redundancy to prevent catastrophic failure.

The new AASHTO *Guide Specification for Internal Redundancy of Mechanically Fastened Built-Up Steel Members* (referred to hereafter as the *IRM Guide Spec*; visit **www.transportation.org**) is a tool to help engineers better understand and leverage internal redundancy when it comes to built-up member structures, and exploit their strength advantages and resistance to failure. The document brings a fresh perspective on how internal redundancy might be exploited in new designs and also provides the industry with a quantitative analysis method for the purpose of showing redundancy and establishing rational inspection intervals for built-up members. The guidelines are realistic about what can be reliably found during inspections and for what duration undiscovered damage may be safely tolerated.

This, however, must be kept in context when discussing new steel bridges that are designed and built to the standards of the facture-control plan (FCP) which has resulted in *zero* fractures in the past 40 years. In addition, for the past 60 years, no built-up members classified as fracture-critical members (FCMs) are known to have failed due to the fracture of a single member component. Three known cases of component failure in built-up FCMs are the Hastings Tied Arch Bridge (two separate fractures), Milton-Madison Bridge (experimentally fractured for research), and the North Fork Molalla River Bridge. In all three cases, the FCMs did not fail, and the bridges continued to carry service loads until repairs were made. Keep in mind that risk is the product of both likelihood and consequence. The *IRM Guide Spec* helps evaluate the consequence of a member component fracture, conservatively ignoring likelihood and linking damage tolerance to rational inspection requirements.

Designating an FCM is left to the designer or inspector/owner and is currently decided through engineering judgement based on the number of girder lines. This implies that the decision to define a member as an FCM has largely been performed without regard to internal redundancy. The mechanical separation of components within an IRM (internally redundant member) produces an inherent fracture resistance at the component boundaries known as cross-boundary fracture resistance (CBFR). Full-scale experimental research indicates that mechanically fastened built-up members possess CBFR independently of the toughness of the steel. This is a beneficial outcome for owners because a majority of built-up members were fabricated long before the FCP of 1978 began requiring a minimum toughness level. The *IRM Guide Spec* equally applies to new designs and existing members, including all built-up flexural and axially loaded members, as well as members subjected to a combination of flexural and axial loading (e.g., tension ties). Simplified solutions allowing for hand calculations have been developed for a majority of the member types to date, and more will be added in 2020.

Jason B. Lloyd (**lloyd@aisc.org**) is NSBA's West Region bridge steel specialist, and **Matthew Hebdon** (**mhebdon@vt.edu**) is an assistant professor in the Department of Civil and Environmental Engineering at Virginia Tech. He was also one of AISC's 2019 Early Career Faculty Award winners.

above: An approach deck truss span of the former Milton-Madison Bridge over the Ohio River in Madison, Ind.

below: A riveted built-up connection on the Mathews Bridge over the St. Johns River in Jacksonville, Fla., showing built-up tension members.

below: A riveted built-up approach span of the Liberty Bridge in Pittsburgh.

The basic steps for analyzing a built-up member for internal redundancy using the *IRM Guide Spec* are:

- Screening criteria such as condition and remaining fatigue life
- Strength limit checks in the assumed faulted condition
- Fatigue life check in the assumed faulted condition
- Selection of a special inspection interval based on fatigue crack growth rates

The provisions of the *IRM Guide Spec* first require the member intended for evaluation to be screened for certain conditions, such as the presence of damage and remaining fatigue life, to ensure a high likelihood of reliable, long-term performance. New and existing members must also meet specified proportioning limits to qualify for this evaluation. Existing members that do not pass the screening criteria should be automatically excluded from further evaluation. The *IRM Guide Spec* is not intended to justify leaving a severed member component in service once discovered, or any other damage that is believed to prohibit reliable service.

Next, the factored load is calculated using the new reliability-based load combination called "Redundancy II" (described in Part Two of this series in the February 2020 issue) and detailed in NCHRP Report 883. Researchers used the same reliability-based procedures to develop Redundancy II that were used to establish the various load combinations of the AASHTO *LRFD Bridge Design Specifications*. Factored loads are used to compute after-fracture stresses for strength and fatigue, assuming that a single component within a member has suddenly failed. For flexural members, the outer cover plate is generally assumed to fail. For axial members, this process is iterated considering failure of a different component each time to find the controlling case, taking advantage of member cross-sectional symmetry. Gross and net section properties are checked for remaining strength in the assumed faulted condition. Laboratory testing and finite element parametric studies have demonstrated that when a member component is severed, localized stress amplifications occur in the adjacent component(s) as a result of load redistribution into and out of the adjacent component. Stress amplification factors are provided in the *IRM Guide Spec* to account for the local stress effects of shear lag and localized bending. For the strength limit state checks, the local amplification has little impact on the global strength. However, because local yielding, slip, and load redistribution allow the section to fully develop the cross section, amplification factors are set to unity. Factored demands are then compared to factored resistance, identical to a typical strength check made during design. If it is found that the member possesses sufficient strength in the faulted condition, the analysis may continue. If not, the member is removed from further analysis (for existing members), or for new designs the member cross section is simply adjusted and reevaluated.

Following strength limit checks, the third step in the analysis is evaluation of fatigue life in the faulted condition. Unlike with strength checks, localized stress amplification of the live load stress ranges must be taken into account when considering the fatigue limit states for the faulted condition. The *IRM Guide Spec* provides simple equations and tables with illustrative cross-section types to help the user determine amplification factors to apply for each case. Fatigue detail categories for members in the faulted condition are provided as well. These were established through full-scale experimental testing of members following failure of a single component. If the member possesses positive fatigue life in the faulted condition, then it has satisfied the provisions of the *IRM Guide Spec*.

The final step is calculation of the special inspection interval. The special inspection process is similar in rigor but replaces the arms-length FCM inspection without changing requirements for routine inspection. The *IRM Guide Spec* includes a methodology to establish the interval for special inspections intended to focus on identifying any tension component that has possibly failed. This inspection of IRMs is referred to as a "Special Inspection," as defined in the *Code of Federal Regulations*, and must be of sufficient depth to reliably detect a severed component. Conceptually, this is a significant departure from the arbitrary, calendar-based, two-year interval intended to find fatigue cracks. The reality is, however, that internal redundancy has been serving us well in our built-up members for well over 100 years.

The *IRM Guide Spec* provides a helpful new tool for built-up steel bridge design and analysis. In addition, NSBA has recently developed a spreadsheet tool that performs the IRM analysis for multi-component axial members. A similar tool is under development for built-up flexural members. These IRM evaluation tools, and many other free and practical design resources, can be found at **aisc.org/nsba/design-resources**. ■

Part One of this series appeared in the November 2019 issue and Part Two appeared in the February 2020 issue. Both are available at ***www.modernsteel.com***.

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How will AI transform your design and forensic processes?

conference preview

A NEW LEVEL OF INTELLIGENCE

BY ROBERT OTANI, PE, AND BADRI HIRIYUR, PhD

RAPID ADVANCES IN ARTIFICIAL INTELLIGENCE (AI) technologies are touching all aspects of our lives, both personal and professional.

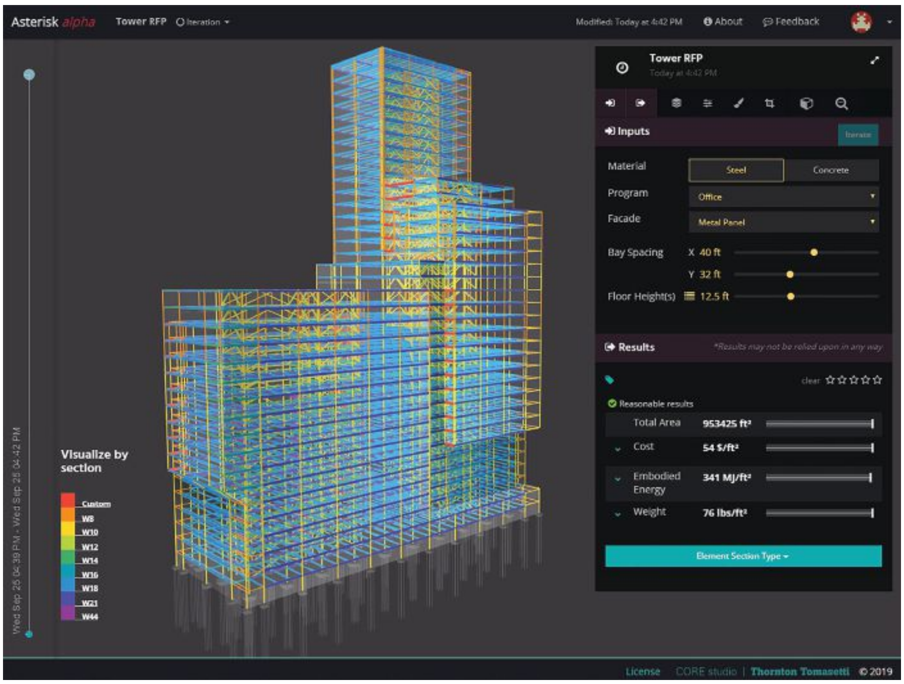
Computer vision-based AI systems have shown better results than human experts at medical diagnoses. Voice assistants and chat-bots are becoming more sophisticated in their conversational ability and performance of everyday tasks, and robots are becoming increasingly capable of complex maneuvers.

Even within the AEC industry, these technologies are starting to make an impact. We are still years, or perhaps decades, away from an AI agent with sufficient intelligence to execute an entire construction project without supervision from start to finish. However, even the narrow AI technologies that are currently maturing can help automate or streamline much of today's processes.

Thornton Tomasetti's CORE Studio has been researching machine-learning AI since 2015 and has developed many working applications that leverage these technologies. One application, called Asterisk, is an "optioneering" web-based software package that can provide a concept-level design of a building structure (gravity, lateral, and foundation systems) in under a minute using data analytics rather than engineering analyses. Imagine an expert engineer faced with sizing a column near the base of a high-rise building. Taking into account the building typology, height, bay spacing, and various other features, the expert would intuitively "guess" the necessary column size without doing all the necessary load analyses, takedowns, and code-checks. And given their years of experience, the guess is usually close. Following the same paradigm as this expert engineer, Asterisk has been trained on thousands of structural member designs representing many decades of project work and custom workflows to map various building and element features to the required sizes. This allows the program to infer appropriate member sizes of any element virtually instantaneously, and it does this at scale for the whole building, resulting in a rough design within seconds. Asterisk allows the design team to evaluate multiple design options quickly at the early stage of a project—where it would normally take an engineering team weeks to complete just one design option.

Another application developed by CORE is the Thornton Tomasetti Damage Detector (T2D2). It uses deep learning models for computer vision, such as convolutional neural networks, to automatically detect and classify various defects and damage in building façades and other structures, such as spalls, fractures, and corrosion. The models have been trained on thousands of photographs of different damage conditions on steel, concrete, masonry, and timber structures. To enhance the detections, T2D2 uses various classifiers that have been trained to detect the material type (e.g., steel, brick, stone masonry, concrete, glass etc.), distance from camera to structure (nearby, moderately close, or far away), and others. The computer vision models have been deployed as both a web and mobile app and support images and

Robert Otani (rotani@thorntontomasetti.com) is chief technology officer and head of CORE Studio, and **Badri Hiriyur** (bhiriyur@thorntontomasetti.com) is director of artificial intelligence and machine learning, both with Thornton Tomasetti.



Asterisk is an "optioneering" web-based software package that can provide a concept-level design of a building structure (gravity, lateral, and foundation systems) in under a minute.

video feeds taken from drones, handheld cameras, and mobile phones. This method allows an engineer to detect conditions and mark up hundreds or thousands of images in a matter of seconds as opposed to hours or days.

In addition, many of the narrow AI technologies can significantly disrupt or transform various functions within our industry. Computer vision and deep learning will be used for drawing reviews, QA/QC, and generative design; natural language processing will be used for understanding communication between teams and responding to queries; and data analytics will be used for predicting, forecasting, and optimizing various roles, ranging from design and engineering to project management and accounting.

In general, AI can be used to advance through any decision point while automating tasks that are high volume, low value, and repetitive. And in cases where full automation may not be feasible, AI can be used to augment human inputs, allowing us to be more productive and helping us more quickly process options than we could on our own. AI can already do quite a lot and in the coming years, it will be able to do even more. Whether you're an early adopter or in the late majority when it comes to technology like AI, it's good to have an idea of where it is now and where it could—and will—lead in the future. ■

Want to learn more about artificial intelligence in the construction industry? Attend the session "Artificial Intelligence: The New Frontier in Structural Design" at the 2020 NASCC: The Steel Conference, taking place in Atlanta April 22–24. For more information and to register, visit ***aisc.org/nascc****.*

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LOOKING TOWARD TOMORROW

BY JENNIFER TRAUT-TODARO

An NASCC: The Steel Conference panel discussion looks to transform equity in the construction industry, seen as innovative today, into the norm tomorrow.

Jennifer Traut-Todaro (**trauttodaro@aisc.org**) is a senior staff engineer with AISC's Steel Solutions Center.

INNOVATION COMES IN ALL FORMS. As a structural engineer at AISC, I have been tasked with following a variety of innovations in the structural steel industry from their infancy to their successful execution. Each innovation has a champion and the story is always an interesting one. After I wrap my head around the technical aspects of the innovation, I take off my structural engineer (hard) hat and dive into the developers' stories of challenges, obstacles, experimentation, risk, and eventual success.

Equity as Innovation

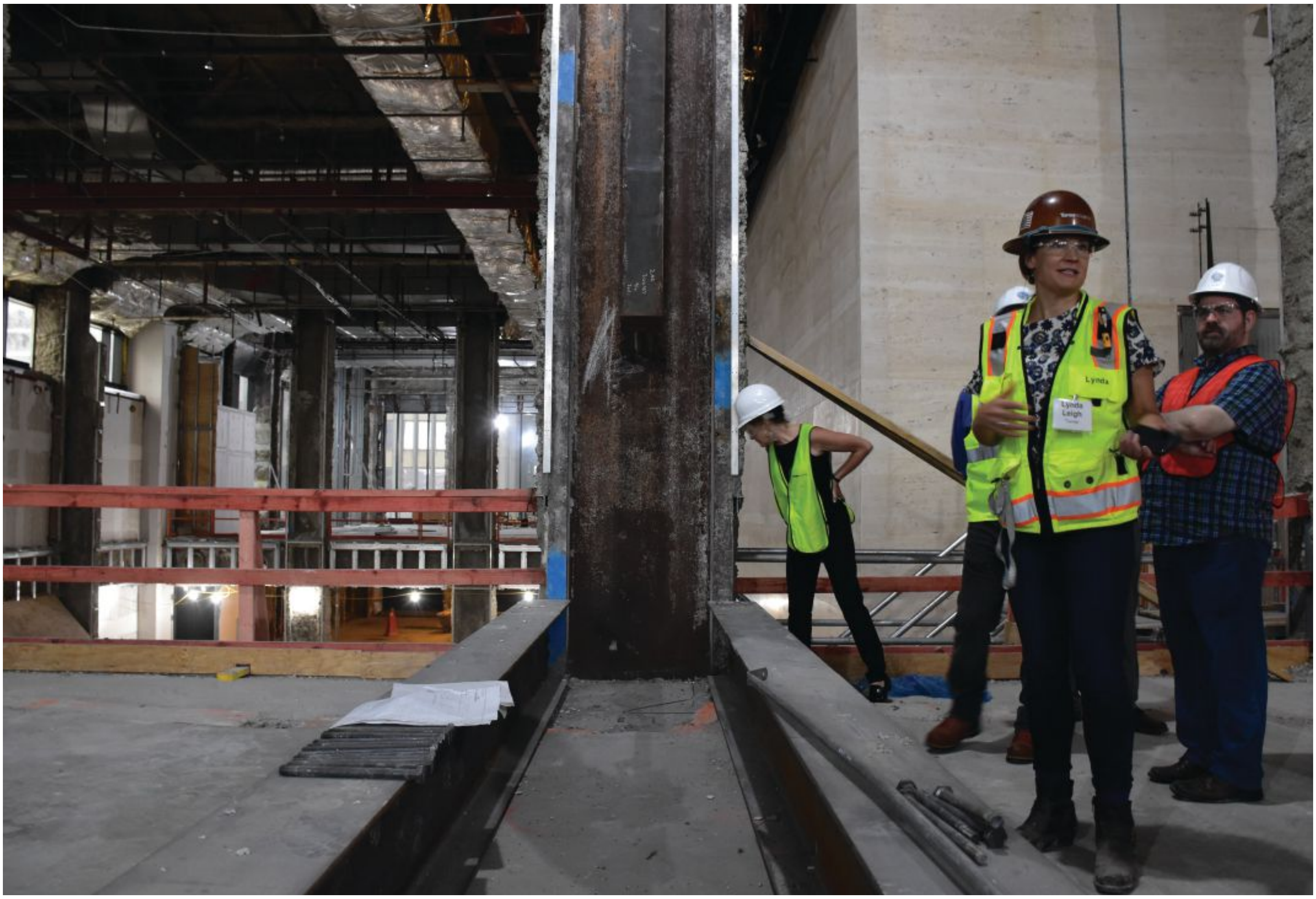
Though intentional equity in the construction world might not typically be thought of as an innovation, sadly, it is still seen as forward-thinking and progressive rather than the norm. And the rather visible lack of equity in our industry has been holding us back. Excluding or quieting a voice without regard for its unique perspective stifles progress. That's why the NASCC: The Steel Conference panel discussion "A Job Site Built for Tomorrow" will bring together three powerful, construction industry voices who are innovating for the engagement and safety of all construction workers: Vicki O'Leary with Ironworkers International, Lynda Leigh, SE, with Turner Construction, and Nyckey Heath, PE, with AISC member Bosworth Erectors.

This panel discussion session will discuss how the job site is actively changing to bring in more diverse talent and support the increasing need for safety and equity. The three panelists will share perspectives from their varied on-site experiences and also provide details on the successful new training program #BeThatOneGuy, which gives the power of keeping harassment off the job site back to the workers at every level and in every trade. In addition, attendees will learn how to attract more diverse talent to their site, their shop, and their office through the implementation of intentional safety and equity policies.

Vicki O'Leary

Lynda Leigh

Nyckey Heath



Leigh, leading a tour of the (steel-framed) newly renovated portion of Chicago's Willis Tower.

Leveraging the Workforce

O'Leary, a career ironworker, has moved into an experience-based policy-making role with Ironworkers International, where her initiatives have gained a lot of traction and support. A few years back, another NASCC speaker suggested I reach out to O'Leary to gain a better perspective on the challenges women face on-site. The call came on the heels of an incredible win for female ironworkers, and she was thrilled to share the story. Ironworkers International had just codified paid maternity leave. Let that sink in. Ironworkers are the first trade to provide paid maternity leave. As a woman who was born in the early 1980s and arrived on the professional scene with certain benefits provided without question, that blew my mind. Without any formal compensation available during a planned short-term leave, there is a tacit decision that is forced upon women considering the trades: a career or a family.

Not stopping there, O'Leary has since continued to push the industry to do the right thing and protect those on the front line. #BeThatOneGuy is the next movement that is gaining attention and accolades. The innovation? Equip everyone with the ability to stand up against harassment in the name of safety. Training led by O'Leary is now held around the country for rank and file members, union leadership, and safety advocates. Ironworkers are taking this effort to heart as O'Leary appeals to their desire to keep their brothers and sisters safe on-site and on their way home to their families every night.

Parallel Steps

This kind of innovation isn't singular, nor does it exist in a vacuum. Efforts are being reported and celebrated, from skilled trade recruitment to site and corporate leadership. How can we innovate for the future on our own site or in our own shop? The panelists will provide insight based on their own experiences, with Leigh discussing her career evolution from consulting engineer to project executive with a major general contractor, and Heath drawing upon her job-site experience as a project manager with a steel erection company.

Come join the discussion and help continue to push for equity to move from being "innovative" to the norm. ■

This article is a preview of the "A Job Site Built for Tomorrow" panel discussion at the 2020 NASCC: The Steel Conference, taking place in Atlanta April 22–24. For more information and to register, visit ***aisc.org/nascc****.*

conference preview

A REAL LOOK AT YOUR JOB SITE

BY THAD WESTER

Reality capture can tell you everything you've wanted to know about your steel project, providing a heads-up on otherwise unknown conditions and also saving multiple trips to the site.

Thad Wester (**tbwester@gmail.com**) is the founder of Clarity Scanning.

AROUND 15 YEARS AGO, laser scanning started making its way onto construction sites.

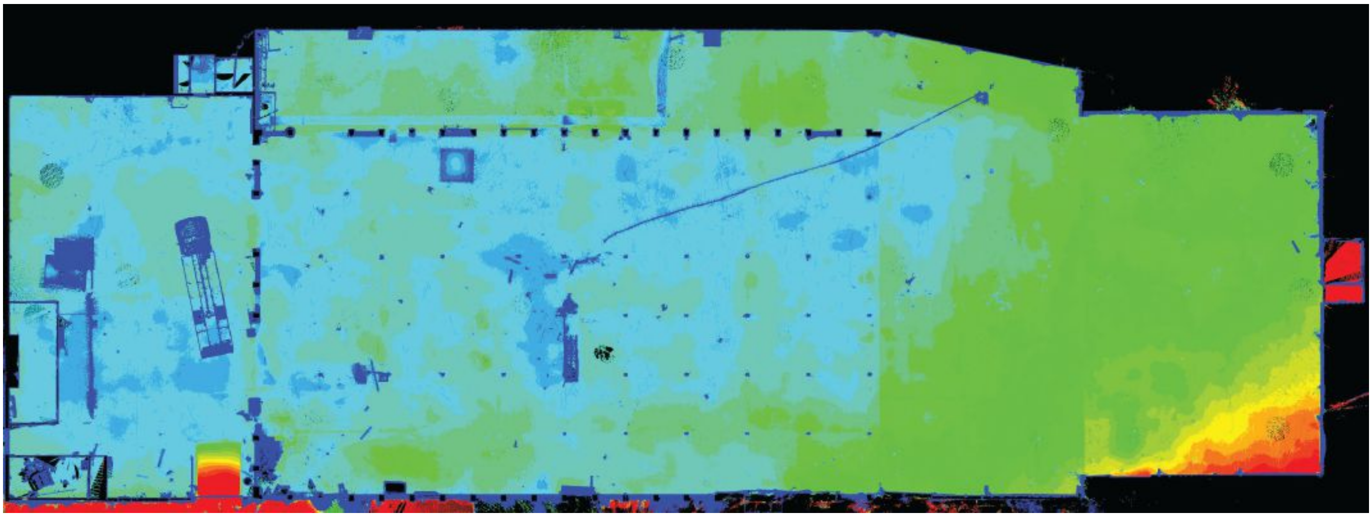
Early adopters found some success in niche applications, but generally most were left feeling scanning technology just didn't work.

Fast-forward to today and you will find "reality capture" is undergoing wide adoption across the AEC industry. And companies that leverage reality capture have a distinct advantage in understanding the projects they bid, design, and construct.

So what is reality capture? It's all about capturing the best, most accurate data about real-world conditions—for our purposes, on a steel-framed building or bridge project site, especially one involving structural rehabilitation. Reality capture is led by three technologies that excel at providing high-quality, complete data from a site: laser scanning, 360° photography, and drone photogrammetry. Capture is the key word here, as all three allow sites to be *captured*, not drawn or interpreted. Compare this with typical owner drawings or site surveys that often do not tell the whole story of twisted steel, out-of-plumb walls, and un-level floors that may lurk unknown and undocumented on job sites.

After a decade of niche applications, the last several years have begun to see a wider adoption of reality capture across all types of projects, regardless of their complexity. And for many, it's not just a bonus item but rather an expectation. Large developers, general contractors, and owners are even investing in their own teams of reality capture engineers to help them understand the nuances of every project they look to undertake.

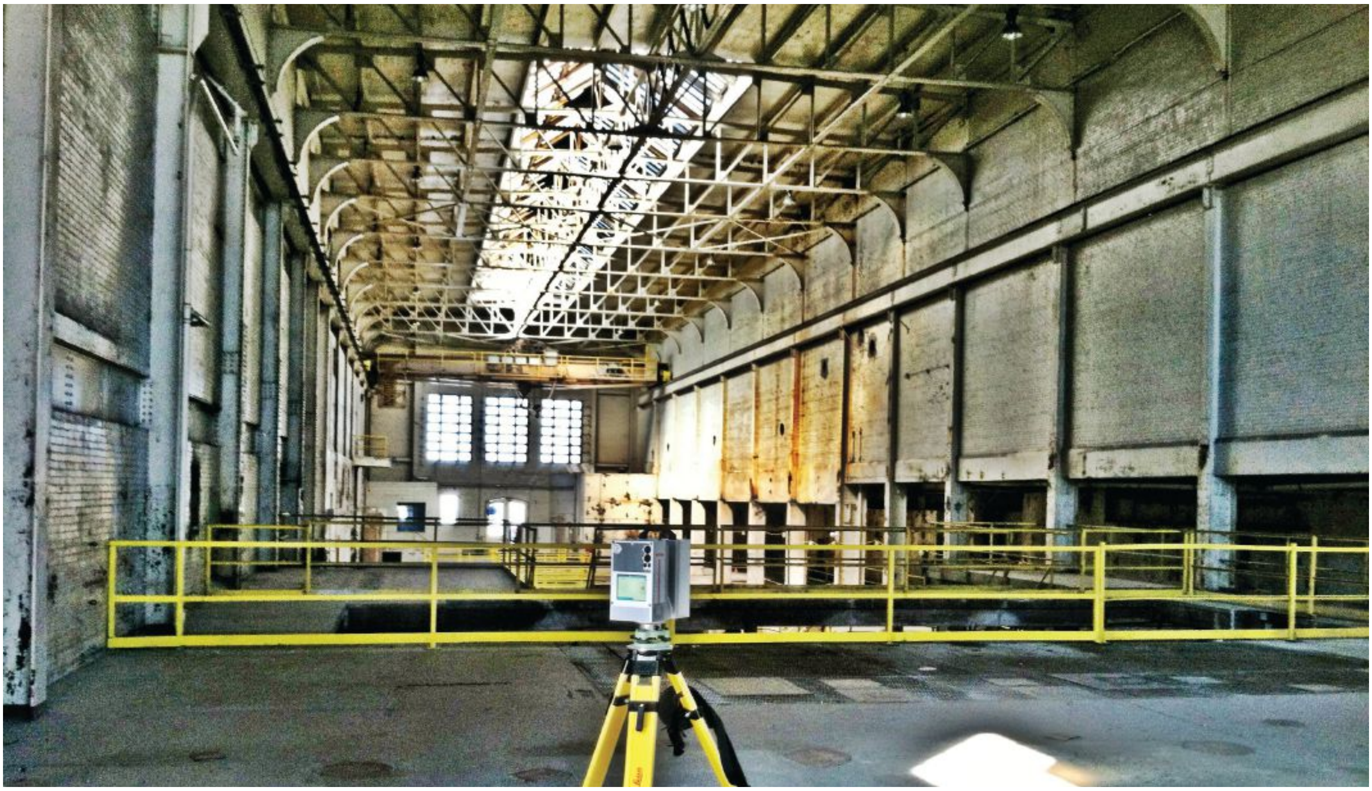
A laser scan image of an older building for a typical retrofit project.



In one retrofit project, laser scanning revealed a significant drop-off in the southeast (lower-right) corner of the scanned level.

Looking Beyond the Surface

Laser scanning first found a foothold in projects that were difficult to measure, such as a high façade portion on a skyscraper in a congested city or a century-old, decommissioned power plant with existing steel framing, portions of which would remain if they were determined to be in the proper condition to meet upgraded demands. The level of detail a laser scan can provide is incredible. The photo on the previous page shows a laser scan image of a typical retrofit project of an older building. For this particular project, after scanning the floor, the design team was able to quickly determine the exact floor slope, including a 4-in. drop-off in the southeast corner of the building where an addition was being made.



Laser scanning is a reality capture technology that has seen increased use in recent years, especially for projects involving structural renovations.

Large outdoor areas—rooftops in particular—are a sweet spot for drones.

Virtual Site Walk

Over the last four years or so, 360° imagery has become more prevalent on job sites thanks to better portability, increased ease of use, and lower costs. The beauty of 360° imagery equipment is that it does not need to be "aimed" but rather captures reality in all directions so you don't miss any details. It also cuts down the need for added site visits and can provide a historical reference once walls are closed up or areas that were once easily accessible are no longer so.

View from Above

Drones are also legitimate, reliable tools for reality capture. And they're cool! Large, outdoor areas are their sweet spot—rooftops in particular because they are usually difficult to view from the ground, dangerous to walk on, and much easier to view from a bird's-eye perspective. While output from drone collections usually lean toward simple yet high-res "pictures," they are also capable of producing some very impressive 3D data and can provide topography studies or fill in data gaps where precision laser scan can't quite reach. ■

Want to learn more about capturing reality? Attend Thad's session "New Technology, Existing Spaces" at the 2020 NASCC: The Steel Conference, taking place in Atlanta April 22–24. For more information and to register, visit ***aisc.org/nascc****.*

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SOLVING THE PUZZLE

BY CAROL DRUCKER, SE, PE, PEng, AND SAYLE LEWIS, PE

When delegating connection design, be sure to provide a clear, full picture of your intent.

Carol Drucker (carol@dzse.com) is a principal with Drucker Zajdel Structural Engineers, Inc., and **Sayle Lewis** (sayle.lewis@fluor.com) is a director-level structural engineer with Fluor.

For more on delegating connection design, see the SteelWise article "Delegating Connection Design" on page 16.

WHAT'S THE LAST THING to be done when designing a structural steel building? Typically, the connections.

After structural steel design is settled and the final analysis is completed, the information is finally available for connection design. When the structural engineer has delegated the connection design to a fabricator's engineer, the connection design information is provided as prescriptive connection requirements with enveloped axial and transfer forces. This approach presents the connection engineer with a puzzle to solve: What are the true forces on the connections, and what was the desired load path through the structure from the roof to the foundations?

When solving a jigsaw puzzle, most people turn all the pieces face up on the table, arrange the edge pieces, and then review the box-top picture to begin assembling the puzzle. (Note that it is taken for granted that all the pieces are there.) After the pieces are arranged, the puzzle is put together and a complete picture is formed.

Delegated connection design should be the same. It should be an efficient work-sharing partnership between the design engineer and the connection engineer. The design engineer should provide enough information so that the connection engineer can understand the forces at each connection in the structure and have a full picture of the structure's load path.

But when an incomplete picture of the true forces on the connections is presented, delegated connection design may not be an easy—or even solvable—puzzle. The connection engineer often receives prescriptive connection requirements (one-half uniform design load, minimum shear, etc.), enveloped axial forces, and statically unbalanced connection forces that are overly conservative or confusing. Often, the connection engineer does not understand how to correctly put the pieces together to solve the connection design puzzle—or worse, might even leave some pieces out (see Figure 1).

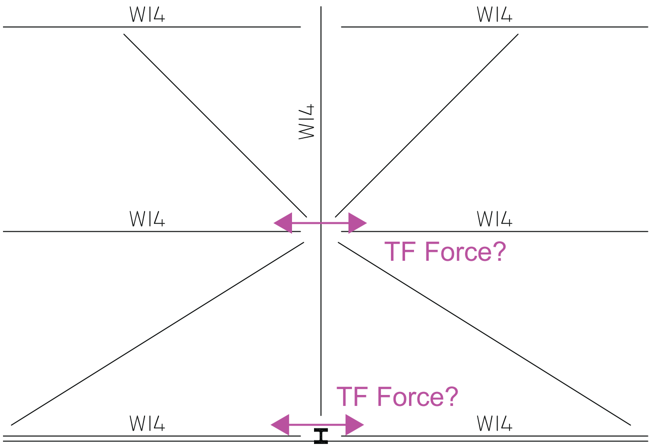


Fig. 1. Where are the transfer forces?

How does the connection engineer react to these missing pieces? Usually through numerous requests for information (RFIs), conference calls, and assumptions about the design engineer's intended load path (and we all know what they say about assumptions). These RFIs, calls, and assumptions take time for the connection engineer to prepare and even more time for the design engineer to answer. This cycle can become frustrating to all parties, as they are spending unexpected time asking and responding to questions.

So how to best provide *all* of the puzzle pieces and the *full* picture to the connection engineer? One way is via a simple Excel force output file (see Figure 2). This file transfers the actual forces and the model geometry digitally to the connection engineer, allowing them to efficiently design the connections and easily track changes. The idea of the force output file is that each member in the model is identified with start and end nodes. The member connection design forces, including transfer forces, are then clearly given at the start and end points.

Another advantage of the force output file is that the possibility of data input error during connection design is reduced since the forces can be automatically extracted from the force output file. The file becomes the central hub, and then the connection design spreadsheets link to this hub. For example, as shown in Figure 3, there is main link for gravity connections and a main link for the vertical bracing design. These links gather the required information needed for design then disperse it to the other design worksheets.

The idea is to automate connection design as much as possible. For vertical bracing design, the brace ID is inputted into the brace-to-gusset design spreadsheet. This spreadsheet is then programmed to extract other design information such as the section shape, node IDs, and forces from the force output file. More automation can be achieved using VBA (visual basic for applications) programming in Excel to cycle through the force out file and automatically extract the design information. ■

Want to learn more and get the full picture on delegated connection design? Attend Carol and Sayle's session "Solving the Puzzle of Delegated Connection Design" at the 2020 NASCC: The Steel Conference, taking place in Atlanta April 22–24. For more information and to register, visit ***aisc.org/nascc****.*

	A	B	C	D	E	F	G	H	I	J
1	memid	section	risa_member_type	section_id	start_max_axial_transfer	start_min_axial_transfer	start_max_shear_transfer	start_min_shear_transfer	Start_Max_axial	Start_min_axial
2	Column1	Column2	Column3	Column4	Column5	Column6	Column7	Column8	Column9	Column10
84	ROS_172	LL5x5x8x3	VBrace	LL5x5x8x3					191.201841	-0.44519998
85	ROS_173	LL5x5x8x3	VBrace	LL5x5x8x3					229.61399	-0.29399999
86	ROS_174	LL5x5x8x3	VBrace	LL5x5x8x3					239.931289	-0.31814999
98	ROS_190	LL5x5x8x3	VBrace	LL5x5x8x3					257.088288	-0.49874998
99	ROS_191	LL5x5x8x3	VBrace	LL5x5x8x3					232.496239	0
100	ROS_192	LL5x5x8x3	VBrace	LL5x5x8x3					266.979288	0
101	ROS_193	LL5x5x8x3	VBrace	LL5x5x8x3					241.310989	-0.40844998
102	ROS_194	LL5x5x8x3	VBrace	LL5x5x8x3					254.741538	-0.43784998
103	ROS_195	LL5x5x8x3	VBrace	LL5x5x8x3					240.674689	-0.38219998
104	ROS_196	LL5x5x8x3	VBrace	LL5x5x8x3					253.032139	-0.50504998
105	ROS_197	LL5x5x8x3	VBrace	LL5x5x8x3					265.292988	0
106	ROS_198	LL5x5x8x3	VBrace	LL5x5x8x3					229.29584	-0.46829998
107	ROS_199	LL5x5x8x3	VBrace	LL5x5x8x3					242.536339	-14.9005493
110	ROS_200	LL5x5x8x3	VBrace	LL5x5x8x3					255.835638	-14.8028993
114	ROS_205	LL5x5x8x3	VBrace	LL5x5x8x3					343.513784	-21.442049
115	ROS_206	LL5x5x8x3	VBrace	LL5x5x8x3					332.024685	-24.9647989
116	ROS_207	LL5x5x8x3	VBrace	LL5x5x8x3					341.390684	-0.23204999
117	ROS_208	LL5x5x8x3	VBrace	LL5x5x8x3					328.254135	0
118	ROS_209	LL5x5x8x3	VBrace	LL5x5x8x3					348.604184	-0.30764999
120	ROS_210	LL5x5x8x3	VBrace	LL5x5x8x3					331.561635	-0.30764999
121	ROS_211	LL5x5x8x3	VBrace	LL5x5x8x3					354.462134	-0.32234999
122	ROS_212	LL5x5x8x3	VBrace	LL5x5x8x3					337.168635	-0.21209999

Fig 2. A sample force output file.

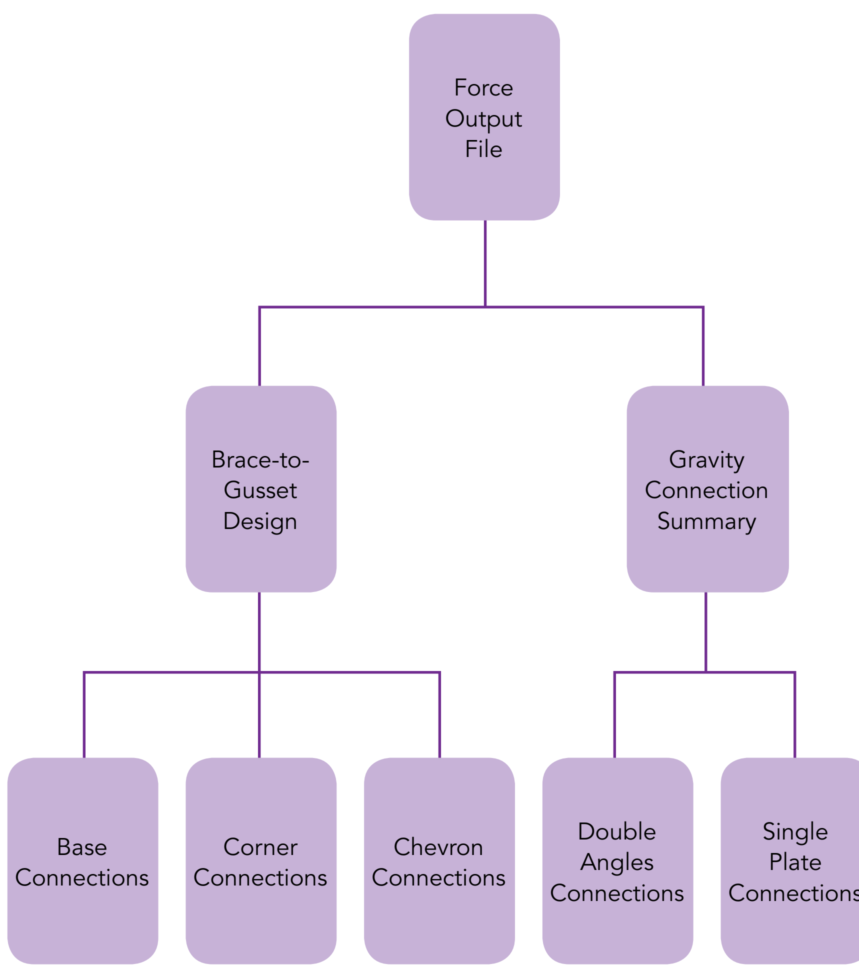


Fig. 3. A sample connection design workflow.

conference preview

A TEMPORARY (BUT CRUCIAL) PLAN

BY TROY DYE, SE, BARRY ARNOLD, SE, PE, AND RYAN GODFREY

A properly planned temporary erection plan can help ensure a safe and successful steel project.

Troy Dye (troyd@arwengineers.com) is an associate principal and **Barry Arnold** (barrya@arwengineers.com) is a vice president, both with ARW Engineers. **Ryan Godfrey** (rgodfrey@suresteel.com) is vice president of operations with Sure Steel.

BUILDINGS UNDER CONSTRUCTION are at the greatest risk of collapse—sometimes with devastating consequences.

The Occupational Safety and Health Administration (OSHA) investigated 96 fatalities and injuries, from 1990 to 2008, caused by structural collapses during construction. These incidents injured 235 construction workers and killed 117.

Of the 96 incidents, 60 took place on steel structures. The primary cause of steel building collapses during construction, though, is not environmental loads like snow and wind, but rather issues related to temporary construction bracing during steel erection.

ASCE 37-14: *Design Loads on Structures during Construction* states: "During erection of a structure, the permanent lateral load-resisting system is generally not complete. Also, other elements of the structural system that are essential to the overall performance of the structure may not be in place or may only be partially secured. As such, the structure may be vulnerable to severe and widespread damage should a single, local failure or mishap occur."

Although the structural engineer of record (EOR) is responsible for the structural adequacy of the design in its completed state, this document implies that additional, temporary bracing may be needed. This bracing should be designed by a qualified specialty structural engineer (SSE) well versed in construction sequencing, site-specific design parameters, and applicable code provisions for the bracing.

Because of the potential for loss of life, severe injury, damage to the structure, and delays in the construction schedule, it is important that the erector and SSE understand the risk and responsibility of structural stability during the erection process. The AISC *Code of Standard Practice for Steel Buildings and Bridges* (AISC 303, **aisc.org/specifications**)—aka the *Code*—requires the erector to include temporary bracing that properly addresses the stability and safe erection of a structural steel frame. The purpose of the bracing is to provide interim stability and stiffness until all structural elements of the building are assembled. In order to do this, the erector may need to solicit design help from an SSE to develop a thorough temporary bracing plan.

A Road Map

A temporary bracing plan is more than just a document showing where temporary braces are to be installed and what materials should be used. It becomes a road map showing how and when the structure should be stabilized. When developing the plan, the erector and SSE should answer the following questions:

- What are the environmental loads (wind, seismic, stability) that may be present on the project site?
- How long will it take to erect the building?

- What is the proposed erection sequence? (See Figure 1.)
- How many framing bays will be erected per day?
- When will the final conditions such as flange bracing, girts, purlins, joist bridging, wall and roof panels, and floor and roof decking be installed?
- Will concrete floor be poured prior to the removal of the temporary bracing?
- Is the roof or floor decking used as part of the lateral loading?
- What type of bracing materials and connections are typically used? (See Figure 2.)
- How will deviations from the bracing plan be addressed during construction?
- When will grouting be installed at the columns?
- When can the temporary bracing be removed?
- Can the permanent bracing be used as part of the temporary bracing?

With the answers to these questions in hand, the SSE can determine the loads on each portion of the day-to-day erected sequence and propose temporary bracing layouts. This process requires extensive coordination with the contractor, erector, and other trades to ensure bracing locations and connections will not interfere with other construction work on-site. Locations of permanent lateral force-resisting systems and connection diaphragm elements for lateral strength and stability in the completed structure should be clearly identified in the contract documents provided by the building EOR per Section 7.10.1 of the *Code*.

Note that the *permanent* lateral force-resisting system is designed for the *completed* structure. However, many structures may experience higher wind loading on the unsheathed or partially sheathed structure than on the completed, enclosed structure. In many cases, stronger members and connections than originally designed for the permanent structure will have to be provided to support construction loads. Temporary bracing may be used separately from or in combination with permanent bracing. The latter option clearly requires coordination between the

Fig. 1. A sample erection sequencing plan.

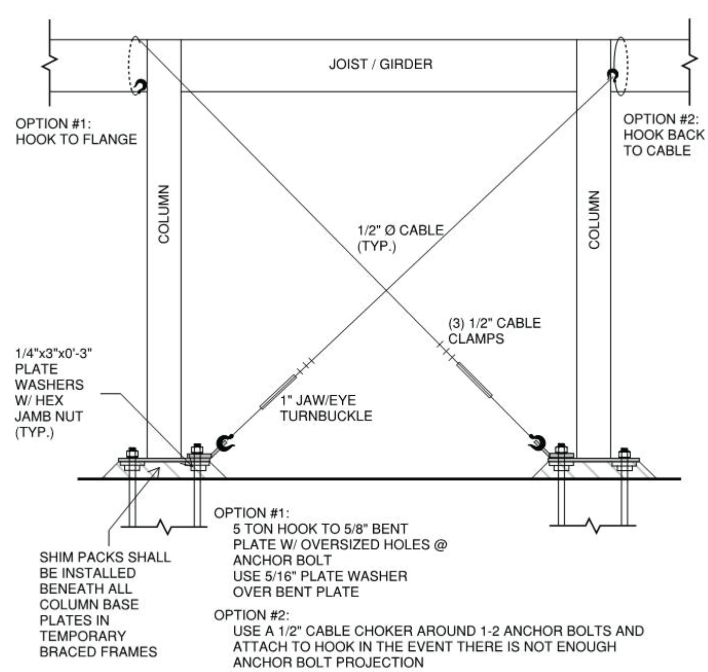
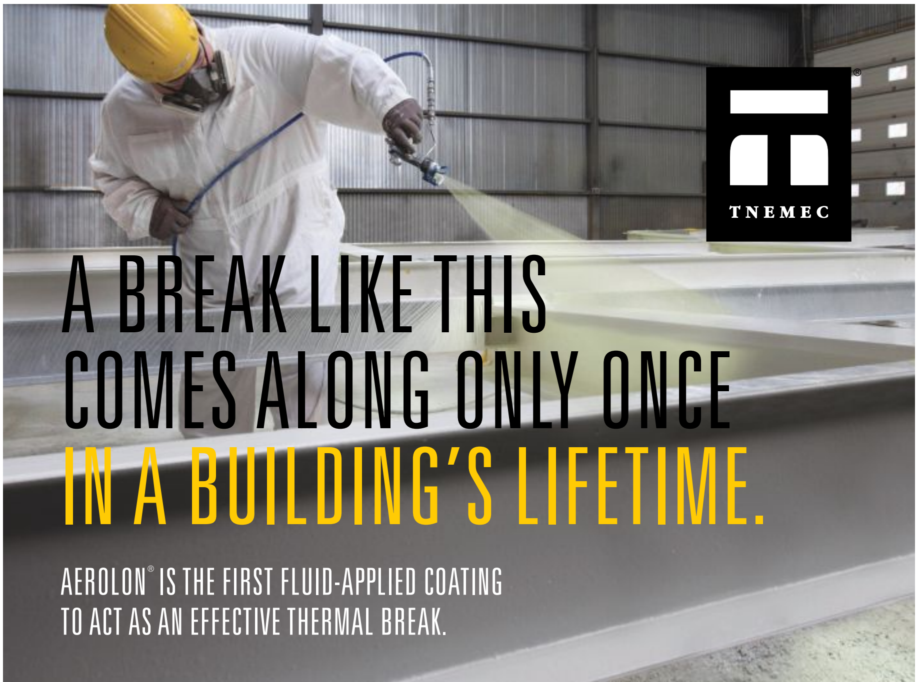


Fig. 2. A temporary erection plan should address typical bracing materials and connections, as this sample cable bracing configuration drawing does.



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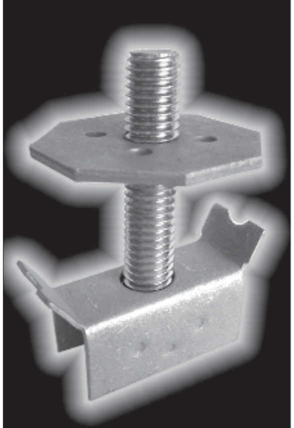

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Sticking to the Plan

A significant amount of time and effort are put into creating temporary bracing plans by the erector management team and the SSE. The next critical step is communicating the importance of *following* this plan to the field supervisors and erectors. Construction is a dynamic process and unexpected changes to the bracing plan may be required due to changes in schedules, site accessibility, material delivery, crane access, etc. Any proposed deviations from the established temporary bracing plan need to be communicated back to the erector management team and SSE before implementing them. The temporary bracing plan is a living document that may need to be updated and communicated to the field erectors on an ongoing basis until the erection process is complete.

The temporary bracing plan serves as a critical tool and process to reduce the risk of building collapse and injury or death during construction. Such a plan, along with trust, teamwork, and regular communication, can help ensure a safe, efficient, and successful steel erection process for any project. ■

*Want to learn more about developing an effective temporary bracing plan for your next steel project? Attend the session "The Importance of Temporary Bracing" at the 2020 NASCC: The Steel Conference, taking place in Atlanta April 22–24. For more information and to register, visit **aisc.org/nascc**.*

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NASCC

NASCC: The Steel Conference to Feature Multiple Conferences within a Conference

There's still time to register for the 2020 NASCC: The Steel Conference, taking place April 22–24 in Atlanta. This year's show includes several "sub-conferences," all included in the main registration price.

The **World Steel Bridge Symposium** (WSBS) brings together bridge design engineers, construction professionals, academics, transportation officials, fabricators, erectors, and constructors to discuss and learn state-of-the-art practices for enhancing steel bridge design, fabrication, and construction techniques.

This year's show also marks the debut of the first-ever **QualityCon**. In more than 20 sessions, industry experts will share the latest on both the principles of quality management and specifics on how improving your quality processes will boost your bottom line. Whether you are AISC certified, a fabricator, an erector, or just want to learn more about quality system, these sessions are for you!

The Structural Stability Research Council's **Annual Stability Conference** has been held in conjunction with the Steel Conference since 2001. In addition to 13 sessions with more than 60 papers, the SSRC Conference includes the 2020 Beedle Award and 2019 MAJR Medal presentations.

The National Institute of Steel Detailing has developed a 13-session program specifically for detailers. The program parallels the NISD Certification program and provides practical information to help make you a better detailer!

Finally, the **Architecture in Steel** conference, which offers AIA LUs, features exciting sessions on topics such as sustainability, performance-based fire design, facades, and designing with new materials. It's also a prime opportunity for architects to meet other designers with similar interests as well as engineers and fabricators.

For more information, visit **aisc.org/nascc**. And for a list of session preview articles in this issue, see the table of contents on page 4.

People and Companies

- **The National Academy of Engineering (NAE)** recently recognized **Ron Klemencic, SE, PE, Hon. AIA**, chairman and CEO of **Magnusson Klemencic Associates**, as a member of the NAE Class of 2020, for "innovation in the design of high-rise buildings worldwide and for research and design guidelines to advance structural engineering practices." Most recently, Klemencic championed the development of the SpeedCore system (**aisc.org/speedcore**), a revolutionary concrete-filled composite steel plate shear wall core system that has been implemented on the soon-to-be-open Rainier Square Tower in Seattle. In addition, Klemencic is giving multiple presentations at the 2020 NASCC: The Steel Conference, including one on SpeedCore.

- The **National Steel Bridge Alliance (NSBA)**, the **American Iron and Steel Institute (AISI)**, and the **American Association of State and Highway Transportation Officials (AASHTO)** recently presented **Robert J. Connor** with the 2020 **Richard S. Fountain Award**. Named for the founder of the **Steel Bridge Task Force**, the award recognizes leadership in steel bridge research and outstanding efforts to advance AASHTO specifications. Connor is the Jack and Kay Hockema Professor in Civil Engineering at **Purdue University's Lyles School of Engineering**. In 2018, **AISC** honored Connor with the T.R. Higgins Lectureship Award. You can view his keynote address from the 2018 Steel Conference at **aisc.org/2018nascconline**.

MEMBER NEWS

AISC Member Fabricator Lexicon to Install Nearly 11,000 Solar Panels

Lexicon, Inc., is going solar. The AISC certified member fabricator and erector is installing 10,868 solar panels at two of its facilities this year, pending approval from the Arkansas Public Service Commission. The company anticipates approximately $320,000 in annual savings, offsetting 50% of its total electrical costs for its fabrication division, steel mill maintenance operations, and headquarters. Seal Solar will install the solar modules at Lexicon's facilities in Carlisle and Blytheville, Ark. "Lexicon defines excellence in everything we do—from cutting-edge fabrication equipment to comprehensive project management software," said Patrick Schueck, president and CEO of Lexicon. "And the choice to go solar is no different. This project is not only good for the environment, it's a wise business decision."

SPRING CLEANING

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Welcome to Safety Matters, which highlights various safety-related items. This month's topics include OSHA's annual Safety Stand-Down and the dangers of distracted driving.

National Safety Stand-Down

For the sixth straight year, OSHA is encouraging companies to host Safety Stand-Down events to raise fall hazard awareness. The National Safety Stand-Down for 2020 takes place May 4-8. While the event is focused on construction, falls clearly happen in industry as a whole.

Last month, we mentioned that falling incidents comprise a very high proportion of citations issued by OSHA—and they happen from a higher level to a lower one as well as on the same level. For fiscal year 2018, 338 out of 1,008 recorded construction fatalities were caused by falls—and all of these deaths were preventable. Dedicating a specific time to review and enhance safety practices as they relate to fall protection and mitigation is an appropriate response to what is clearly a common and serious problem. It is the right thing to do, both for the safety of our employees and the future of our companies.

And that's what the Safety Stand-Down is all about. Note that it is a completely voluntary program. Also, if falls are not the main hazard needing emphasis at your company, you can select and discuss a different hazard—or even just safety in general.

So how does it work? Companies can conduct a Safety Stand-Down by taking a break and holding a "toolbox talk" or other safety activity related to falls or the selected hazard. OSHA has suggestions for preparing and running a successful stand-down. In addition, if you do conduct a Stand-Down, OSHA would like to hear about it and has provided a place to send them highlights of your activity and download a Certificate of Participation. Visit **osha.gov/stopfallsstanddown** for all of this information and more about the Safety Stand-Down Program.

AISC Safety Committee Notes

Motor vehicle crashes are the leading cause of work-related deaths in the U.S., according to the Bureau of Labor and Statistics. Distracted driving crashes are not only harmful to the persons involved, but also to businesses in the form of liability costs.

Due to the increase of electronics integration in both our daily lives and the vehicles we drive, the National Safety Council (NSC) has dedicated the entire month of April to getting the word out on paying closer attention to the road and less attention to handheld and in-dash electronics. NSC recognizes that as many as nine Americans die and upward of 100 unfortunate others are injured due to distracted driving each day. The organization cites specific instances where cell phone-related crashes have cost businesses millions of dollars for singular events. These accidents and tragedies are avoidable if drivers intentionally ignore their devices while in the car and put all of their focus on the road. You can find more information on this subject at **nsc.org/liability**.

Here are some simple ideas to avoid being distracted while driving:

- Do not use your phone while driving unless for emergency purposes
- Secure items prior to departure that may move around and cause you to reach for them
- Make adjustments to your vehicle and enter GPS information prior to driving off
- Do not drive while tired or fatigued (physically or mentally)
- Avoid eating while driving

Dates to Note

- National Work Zone Awareness Week
  April 20–24, **www.nwzaw.org**
- Worker's Memorial Day
  April 28, **www.aflcio.org**
- World Day for Safety and Health at Work
  April 28, **un.org/en/events/safeworkday**

We are always on the lookout for ideas for safety-related articles and webinars that are of interest to *Modern Steel* readers and AISC member companies. If you have any safety-related questions or suggestions, we would love to hear them. Contact Tom Schlafly at **schlafly@aisc.org**. And visit AISC's Safety page at **aisc.org/safety** for various safety resources.

Also, check out "A Temporary (but Crucial) Plan" on page 56 to read about safety and temporary bracing.

news & events

ENGINEERING JOURNAL

Second Quarter 2020 *EJ* Now Available

The second quarter 2020 issue of AISC's *Engineering Journal* is now available. You can access the current issue as well as past issues at **aisc.org/ej**. Below is a summary of this issue, which includes articles on analyzing concentrically braced frames, the indirect analysis method, and column base connections.

Investigation on the Performance of a Mathematical Model to Analyze Concentrically Braced Frame Beams with V-Type Bracing Configurations
Alireza Asgari Hadad and Patrick J. Fortney

The chevron effect and the corresponding mathematical model used to predict the beam shear force and bending moment demands on beams in concentrically braced frames with V- or inverted V-type (also known as chevrons) configurations is studied in this paper. The common analysis approach considers beam span, work point location, and a concentrated force representing the unbalanced vertical forces of the braces while ignoring any local effects resulting from the brace connection geometry. The assumptions and load distribution mechanisms in the connection region that have been discussed in earlier literature are presented, and the performance of the mathematical model based on chevron effect (CE method) is examined by comparing its results with the results of a net vertical force method (NVF) in addition to those obtained by finite element analysis. The analysis procedure recently proposed for beams in chevron concentrically braced frames is used to design the beams in a group of 20 beam-gusset assemblies. The results revealed the presence of the chevron effect in chevron beams. It also showed the CE method is able to estimate the beam maximum shear force and bending moment. Additionally, the stress distribution along the gusset-to-beam interface is studied.

The Indirect Analysis Method of Design for Stability: An Amplifier to Address Member Inelasticity, Member Imperfections, and Uncertainty in Member Stiffness
Rafael Sabelli

Design for stability requires multiple considerations, including geometric second-order effects (P-Δ and P-δ effects) and the effects on structure response of member inelasticity, member imperfections, and uncertainty in member stiffness. The "indirect analysis method" provides a simple amplifier approach to addressing these effects such that effective length factors may be taken as 1.0. The indirect analysis method meets the stability design requirements of the AISC *Specification* and can reduce analysis and design effort for many typical building structures.

Self-Centering Column Base Connections with Friction Dampers
Judy Liu

Recent work on a self-centering column base connection with friction dampers is highlighted. This research is a collaborative effort by Senior Researcher Massimo Latour and Professor Gianvittorio Rizzano from the University of Salerno, Italy, and Professors Aldina Santiago and Luis Simões da Silva of the University of Coimbra, Portugal. The Salerno-Coimbra team has developed an alternative self-centering column base solution to minimize initial costs and economic losses. Specific objectives are to limit damage and residual drifts, with connection components that are easy to repair or replace if needed. The self-centering column base has been validated through quasi-static cyclic testing and pseudo-dynamic testing. The self-centering connection has also been investigated through numerical time-history analyses of moment-resisting frames comparing conventional, fixed column bases to self-centering column bases. Some highlights of the research are presented.

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Ricardo Pulido

DEFYING GRAVITY

ARCHITECTURE AND DESIGN FIRM LITTLE'S Monumental Stair is the focal point of its new home—and its support system appears to hover above the lowest floor of the office space.

The company resides on the 14th, 15th, and 16th floors of a newly built high-rise in downtown Charlotte, N.C., all connected by the three-story suspended, sculptural stair. Instead of being traditionally anchored and reinforced at the lower level, which would have disturbed existing tenants on the 13th floor below, the 15-ton stair—designed by Little and fabricated by AISC member C. M. Steel—hangs from a structural mast on the underside of the building's 17th floor. This mast, composed of four hollow structural sections (HSS), distributes the load of the stair to the underside of the 17th floor beams with bolted steel channels and transfers some of the load to the 16th and 15th floors, allowing the existing structure to adequately carry the appropriate load required by code.

The stair is a 2020 AISC IDEAS^2 winner. Want to learn more about it—and the rest of this year's winners? Check out next month's (May) issue at **www.modernsteel.com**. ■

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