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MODERN **STEEL** CONSTRUCTION

February 2009

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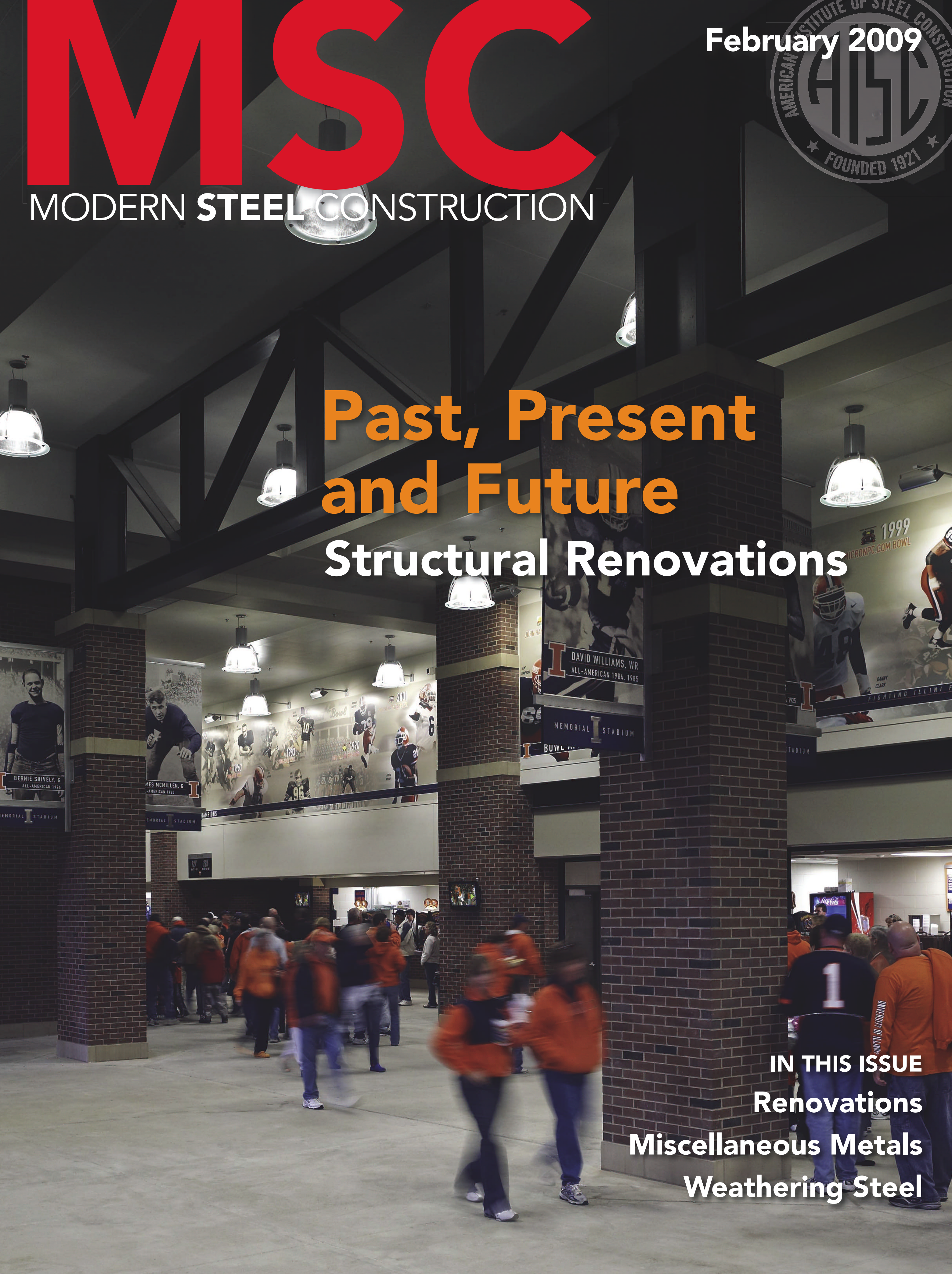

Past, Present and Future
Structural Renovations

IN THIS ISSUE
Renovations
Miscellaneous Metals
Weathering Steel

Deck Design Data Sheet No. 101

Designers' Checklist for STEEL DECK

Composite Floor Deck

☐ Check fire rating requirements... Designs Dxxx in U.L. (pp. 63 - 65 of our manual). Note on project drawings when the fire rating requires spray fireproofing.
☐ Check relative costs of lightweight and normal weight concrete. Note: Lightweight concrete can usually fulfill fire rating needs with thinner slabs.
☐ Check pour stop requirements (p. 61 of our manual).
☐ Check hanger requirements - for ceilings, ducts, pipes, etc.
☐ Check maximum unshored spans to select deck gage and pattern. Note: It usually costs less to have unshored construction (pp. 35 - 55 of our manual).
☐ Check the SDI Construction Loading (p. 30 of our manual). Maximum unshored spans are based on these loading conditions. If additional loading conditions exist and/or buggies or screed machines will be used additional analysis is required.
☐ Check diaphragm shear and stiffness requirements (pp. 122 - 129 of our manual).

Roof Deck

☐ Check fire rating requirements... Designs Pxxx in U.L. (p. 23 of our manual). Note on project drawings when the fire rating requires spray fireproofing (typically P7xx and P8xx series).
☐ Check loads for: 1. snow drifting 2. additional dead load from ballasted roof systems 3. maintenance loads... use SDI criteria (pp. 5 - 16 of our manual).
☐ Check any other insurance requirements such as Factory Mutual. Note that maximum spans may be reduced to meet FM requirements. Specify the critical perimeter zones.
☐ Check diaphragm shear and stiffness requirements and select the fastener type and pattern. Use the Diaphragm Interaction Program on our website or diaphragm tables (pp. 95 - 121 of our manual).

Form Deck (Centering)

☐ Check fire rating requirements... Designs Gxxx in U.L. (p. 86 of our manual).
☐ Check requirements for finish. If deck is galvanized it will last the life of the structure and will always carry the slab weight; if the deck is uncoated or if the deck is shored, the slab should be reinforced to carry the slab weight as well as live loads.
☐ Check venting requirements if the deck is supporting an insulating fill... always use galvanized deck for this purpose.
☐ Check any diaphragm requirements (pp. 130 - 153 of our manual).

All Deck

☐ Check material specifications. The proper specification for galvanized steel is ASTM A653. The ASTM specification is A1008 for steel that is to be left uncoated or painted (but not galvanized). The minimum yield point of steel for most of our products is 40 ksi. The proper specification that covers the galvanized coating is ASTM A924.
☐ Check CMC Joist & Deck for any deck information - prices, delivery, design data. Use our website to download our *2008 Design Manual and Catalog of Steel Deck Products* and to find our office nearest to you.

New 2009

Our new 166 page DECK DESIGN MANUAL has been completely updated to provide you with the latest and most comprehensive information for the design and construction of steel deck. To get your free copy please call 1.866.808.1189.

For technical assistance please contact our engineering office at 1.866.808.1189 or visit us on the web at www.cmcjd.com - United Steel Deck.

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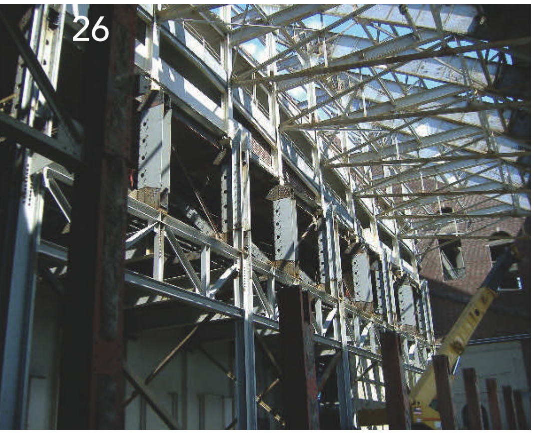

ON THE COVER: University of Illinois' Memorial Stadium in Champaign (Photo by Brad Feinknopf, courtesy of HNTB.)

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editor's note

THE OTHER NIGHT WE BROUGHT IN some take-out Chinese food and I was about to tear open the little packet of soy sauce that always comes with take-out, when for some reason I took a look at the ingredients. Now normally, soy sauce includes soy beans, wheat, water, and salt. But this packet simply listed water, salt, and monosodium glutamate. In other words, it was just salt water with some MSG for flavor.

Of course, it wasn't the first time I was surprised by ingredients. I remember back when I was in college and working at the food service, we were always careful when posting the menu board. Some nights we had hamburgers, but other nights it was beef patties. The difference? Beef patties had a lot more fillers (and I think none us want the details on that!).

Similarly, I think we all need to be careful with what we think is in the proposed "American Recovery and Reinvestment Plan." To me, it seems obvious that the plan's purpose is to stimulate our economy by consuming American goods and services and creating American jobs. But unless it's clearly stated in the plan that the funds are to be used only on the purchase of American goods and services, it's likely that it will not have the intended effect. It's conservatively estimated that even a 5% level of non-domestic construction and related industry spending will result in the failure to create or retain between 100,000 and 150,000 jobs (with a resultant loss of between $3.5 billion and $5.3 billion in personal earnings).

Put another way, the Associated General Contractors of America (AGC) estimates that for each $1 billion in construction spending, 9,700 jobs are created. And with the stimulus package proposing $115 billion in construction activity by the end of the second year of the package, it should mean the addition of more than 1.1 million jobs (plus another half-million jobs in related manufacturing industries).

Unfortunately, the use of the "American Recovery and Reinvestment Plan" to stimulate the American economy is not a given. And thanks to loopholes large enough to drive a forklift through, not even the inclusion of the so-called "Buy America" or "Buy American" provisions guarantee that American goods and services will be used on the planned infrastructure and other construction projects. (For more on this, see Angela Stephens' article "Made in America?" on page 23 of this issue.)

I'm reminded of a story I once heard about the International Monetary Fund's efforts to stimulate a third-world country's economy through, in part, the construction of a large bridge. Unfortunately, a foreign contractor underbid all competitors (through substantial government subsidies). The material wasn't just shipped in, but so were all the laborers. And to add insult to injury, the laborers slept and ate on the working ship—so while the country got a new bridge, there was no other positive impact to the local economy.

I urge everyone to contact their congressional representative and senators and insist that the "American Recovery and Reinvestment Plan" be used to stimulate our economy and to create American jobs. This taxpayer-funded plan should be used to maximize the domestic content of all construction related projects—both of labor and of materials. (If you need assistance with the wording of a letter to your congressman or a letter to your local paper, please let me know. Also, visit **www.aisc.org/buildamerica** for more information, including white papers with more details.)

And I hope to see all of you at NASCC—The Steel Conference (April 1-4 in Phoenix). Stop by the AISC booth and let us know what you and your company are doing—and let us know how AISC can help you.

Scott Melnick

SCOTT MELNICK
EDITOR

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SDS/2 DESIGN DATA

2008 SDS/2 SOLID STEEL COMPETITION: COMMERCIAL
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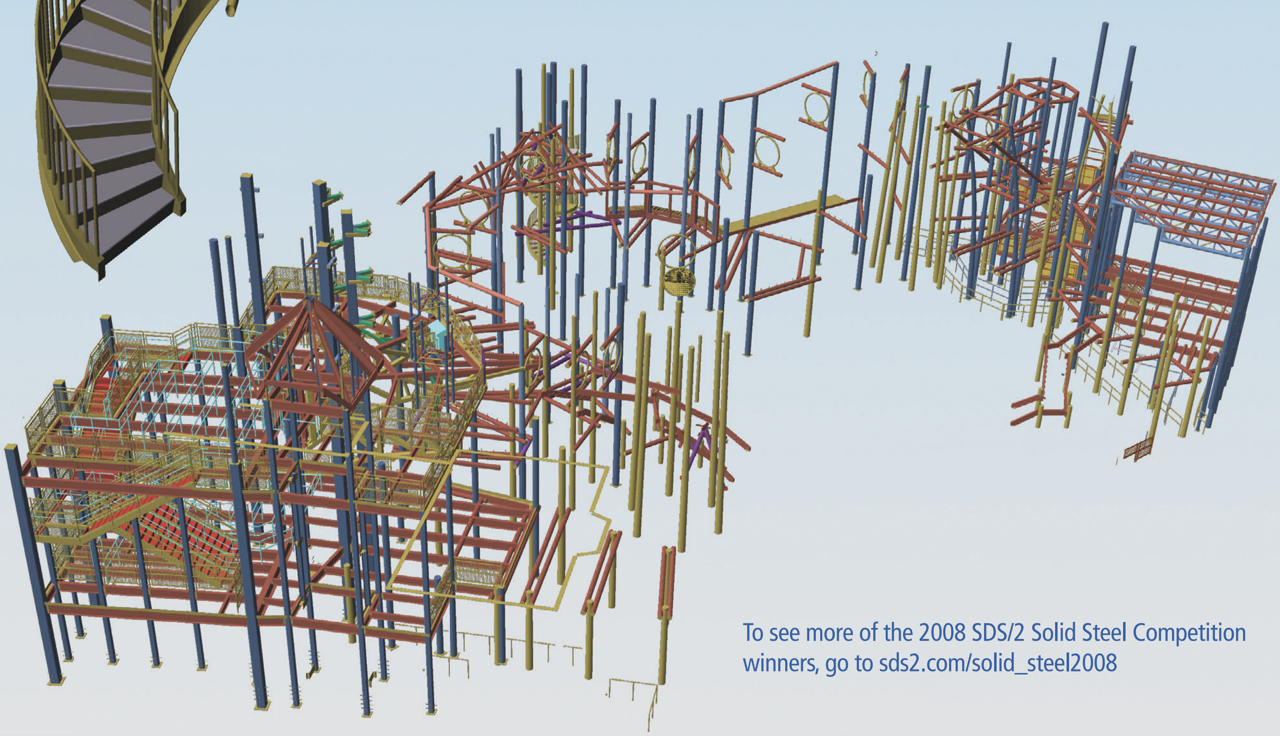
Second Place: Seminole Machine and Welding, Inc., Jungala at Busch Gardens, Tampa, Florida

Jungala is the latest attraction at Busch Gardens in Tampa, Florida. This all-inclusive family play area includes three levels of walkways, net sky crawls, net climbs and mazes, zip line rides, and a shot and drop ride. It also features interactive animal attractions, gardens and fountains. This complex, 720-ton, 8,500-member project includes truss-like platform supports, a spiral staircase and sloping pipe columns, as well as a tree house facade over the steel.

Seminole Machine and Welding was able to get unfolded layout views and plot them out full size to get an exact fit in the field — an SDS/2 feature that shortened fabrication time in the shop and increased the speed of construction.

Using SDS/2's RFI Creator, Seminole was able to embed rotatable 3D images of the SDS/2 model in PDF files, which streamlined communication with architects and engineers on the project.

To view the spiral staircase and other project features in 3D, go to sds2.com.



To see more of the 2008 SDS/2 Solid Steel Competition winners, go to sds2.com/solid_steel2008

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IF YOU'VE EVER ASKED YOURSELF "WHY?" about something related to structural steel design or construction, *Modern Steel Construction*'s monthly Steel Interchange column is for you! Send your questions or comments to solutions@aisc.org.

Extended Single-Plate Shear Connections

The last paragraph on 10-103 of the 13th edition AISC *Manual* states that this design procedure permits the column to be designed for an axial force without eccentricity. Does this also apply to girders used as the supporting member? In other words, if this design procedure is followed for a beam-to-girder connection, does the girder need to be designed for an eccentric load from the extended single-plate beam connection?

The design procedure for the extended single-plate connection included in the *Manual* was developed so that the supporting member is not required to resist any additional moment from the shear connection. This applies to beams/girders as well as columns.

The point of this discussion was to highlight the possibility of designing connections in which the column is required to resist additional moment so that the demand on the plate and/or bolt group might be reduced. Supporting beams/girders are not mentioned in this discussion because they would have to resist any additional moment through torsion, which generally makes this option impractical.

Larry S. Muir, P.E.

Compactness Criteria for Angles

Could you help me understand the connotation of the "Compactness Criteria for Angles Table" shown on page 1-47 of the 13th edition *Manual*?

The Table on page 1-47 of the 13th edition *Manual* is merely an aide in determining the width/thickness ratios for legs of angles to meet the compactness criteria of the *Specification*. The first column relates to the requirement for compression members and the other two columns relate to the requirements for flexural members. These are based on angle material with F_y = 36 ksi.

As an example, if you are looking at the angle subject to compression, the table shows that an 8-in. angle leg is non-slender when the thickness is ⅝ in. or greater.

Kurt Gustafson, S.E., P.E.

IMF and OMF Connections

Is an IMF connection required to be stronger than an OMF connection?

The requirements for IMF connections are generally more stringent than those for OMF connections because greater deformation capability is required for the IMF system. IMF connections are also subjected to requirements for conformance demonstration, whereas OMF connections are more prescriptive. You can find the requirements for IMF beam-to-column connections in Section 10 of the AISC 341 (the AISC S*eismic Provisions*); OMF beam-to-column connections are covered in Section 11.

Kurt Gustafson, S.E., P.E.

k_c Factor?

Table B5.1 in the 9th edition *Manual* incorporates a k_c factor for defining the Compact/Non-Compact behavior of flanges for I-shape welded beams in flexure. Why is this factor used and is there any update to this provision?

k_c is a coefficient for slender unstiffened elements, which accounts for the interaction of flange and local web buckling.

The 2005 AISC *Specification* (a free download at **www.aisc.org/2005spec**) is the current version of the *Specification*. Table B4.1 in the 2005 *Specification* also employees the k_c factor, which is discussed on page 224 of the *Commentary*.

Kurt Gustafson, S.E., P.E.

Bending Bolts?

Is it okay to heat and bend a structural bolt that was placed in concrete in the wrong place? The contractor placed the bolts anywhere from 1½ in. to 3½ in. out of alignment, then heated the bolts and bent them like a snake and told me that they would be okay. I do not feel comfortable with this assurance. I did find one article that says to look in the 9th edition of the AISC *Manual* on page 4-4, but I do not understand what this means. Could you explain this in more detail?

I do not know of any authority that condones the practice of bending of structural bolts, whether heated or not. Do you mean that there is now a longitudinal offset, which might affect the strength and performance of the as-built elements? If so, I think there is more to it that must be considered.

Page 4-4 in the 9th edition *Manual* contained a statement recommending against the heating and welding of anchor rod material that is quenched and tempered. Many types of anchor rods are mild carbon steel that are suitable for heating and welding. However, this statement does not address the subject of bending of bolts or anchor rods.

Since you are describing the fastener as being embedded in concrete, I am assuming that you are talking about anchor rods rather than structural bolts. Mistakenly bent anchor rods of mild carbon steel are often straightened back to vertical alignment, sometimes with and sometimes without heat application. However, the engineer of record will often place limitations on the amount of bend that can be straightened and usually if the rod is bent in the threaded area, straightening is not allowed.

From your description, it sounds like the rods are purposely being bent to remedy a misplaced location. This is an entirely different matter than straightening of bent rods. This involves the structural performance of the base anchorage. Assuming that the rods serve a required function in the final structure, it would appear that any tension in the rod would have a tendency to straighten that rod as the load is applied. This is a condition that could detrimentally affect the performance of the base connection and should be evaluated by the responsible design professional.

Kurt Gustafson, S.E., P.E.

steel interchange

Restrained or Unrestrained Rating?

My understanding is that we are able to consider all beams in a building as restrained for fire protection requirements, regardless of whether they are part of an interior bay or an end bay. Can you provide me with insight into the accuracy of this statement?

Much effort has been spent disseminating the research sponsored by the American Iron and Steel Institute (AISI) that confirmed the performance of steel framing and the use of restrained ratings in the selection of fire protection. The conclusion of that research remains valid: steel-framed structures can be considered thermally restrained.

The test data supporting this conclusion are documented in "Restrained Fire Resistance Ratings in Structural Steel Buildings," which was published by Gewain and Troup in the 2nd Quarter 2001 AISC *Engineering Journal*. Furthermore, AISC Design Guide No. 19, *Fire Resistance of Structural Steel Framing*, correctly reports that with few exceptions, steel structures should be considered thermally restrained.

The issue of restrained vs. unrestrained construction is unique to the United States. It has been a source of confusion since the concept's introduction in 1970. To assist the design professional in determining this parameter, AISC has collected information demonstrating that steel-framed construction qualifies for a restrained classification and makes it available so that the provisions of section 703.2.3 of the International Building Code can be satisfied.

John Ruddy, P.E.

Editor's note: John Ruddy was the lead author of AISC Design Guide No. 19 and was widely considered an expert in the fire resistance of structures. Sadly, John passed away only several days before this inquiry was received. As John had answered a similar question before, we were able to share his thoughts with the inquirer, which are reprinted here as a tribute to the service John has provided for the design community and steel industry both as an engineer and as an expert in fire-resistant design.

Camber Measurement

Section 6.4.4 of the AISC Code of Standard Practice includes the following sentence:

"For the purpose of inspection, camber shall be measured in the Fabricator's shop in the unstressed condition."

What does the term "unstressed" imply? Does the "unstressed condition" include or exclude the dead weight of the beam?

The term "unstressed condition" is generally taken to mean that for measuring the vertical camber in a beam, it is laid down on the side in the shop such that the self weight of the member does not affect the camber measurement.

Kurt Gustafson, S.E., P.E.

I_{yc} of Compression Flange

Section H1.1 of the AISC *Specification* states, "...I_{yc} is the moment of inertia about the y-axis referred to the compression flange." Could you please expand on the definition of I_{yc}?

I_{yc} is the moment of inertia of the compression flange around its major axis. Of course, the major axis of the flange corresponds to the y-axis of the entire shape. For a rectangular compression flange, I_{yc} is equal to $t_f b_f^3/12$.

Amanuel Gebremeskel, P.E.

What is r_{ts} ?

What does the r_{ts} listed in Table 1-1 of the AISC *Steel Construction Manual* represent? How is this function calculated?

The r_{ts} listed in Part 1 of the *Manual* is an effective radius of gyration. This parameter is defined in the Symbols section of the AISC *Specification* as the "effective radius of gyration used in the determination of L_r, for the lateral-torsional buckling limit state for major axis bending of doubly symmetric compact I-shaped members and channels."

The method of calculating r_{ts}^2 is defined in Equation (F2-7) of the *Specification*, which is the basis of the values listed in the *Manual* tables. The user note in that section of the *Specification* also provides a method to determine a conservative approximation of r_{ts}.

Kurt Gustafson, S.E., P.E.

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

Kurt Gustafson is the director of technical assistance and Amanuel Gebremeskel is a senior engineer in AISC's Steel Solutions Center. Larry Muir is a part-time consultant to AISC. John Ruddy is AISC's former director of building design. Charlie Carter is an AISC vice president and the chief structural engineer.

Steel Interchange is a forum to exchange useful and practical professional ideas and information on all phases of steel building and bridge construction. Opinions and suggestions are welcome on any subject covered in this magazine.

The opinions expressed in Steel Interchange do not necessarily represent an official position of the American Institute of Steel Construction, Inc. and have not been reviewed. It is recognized that the design of structures is within the scope and expertise of a competent licensed structural engineer, architect or other licensed professional for the application of principles to a particular structure.

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

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steel quiz

LOOKING FOR A CHALLENGE? *Modern Steel Construction*'s monthly Steel Quiz tests your knowledge of steel design and construction. Most answers can be found in the 2005 *Specification for Structural Steel Buildings*, available as a free download from AISC's web site, **www.aisc.org/2005spec**. Where appropriate, other industry standards are also referenced.

This month's Steel Quiz is on walking vibrations and the AISC/CISC Design Guide 11, *Floor Vibrations Due to Human Activity*. It was submitted by Brad Davis, University of Kentucky, and Tom Murray, Virginia Tech.

1. Is the criterion for walking vibration in Design Guide 11 based on a heel-drop impact or resonance due to walking?
2. What peak acceleration is an acceptable level of vibration due to walking in a quiet environment?
3. What is the recommended damping for an office floor layout with demountable partitions on top and typical ductwork and ceiling below?
4. What are the recommended live loads for use in vibration calculations for (a) residences, (b) paper-oriented offices, and (c) electronic-oriented offices?
5. What is the recommended vibration dead load in addition to the weight of the structural system?
6. Why is a typical concrete on deck and rolled steel beam structural system considered fully composite for vibration analysis even if it is designed and constructed as a non-composite system?
7. True/False: Joist seats are fully effective shear connectors for vibration.
8. What are "beam panels" and "girder panels" according to AISC Design Guide 11?
9. What is the upper limit of the effective width of "beam panels" and "girder panels?"
10. When can the effective weight of "beam panels" be increased by 50%?

TURN TO PAGE 14 FOR ANSWERS

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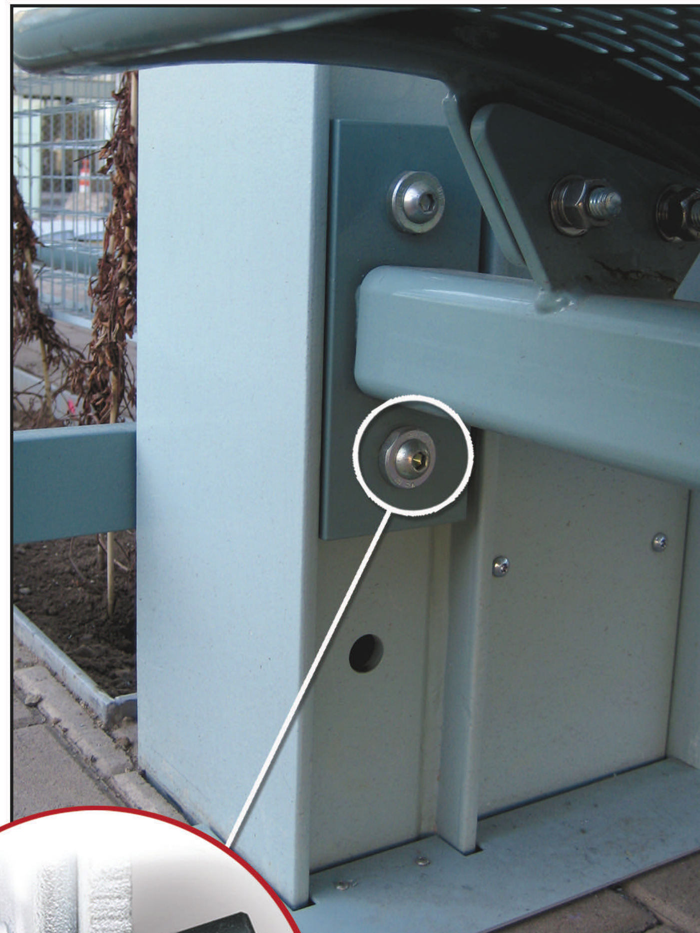

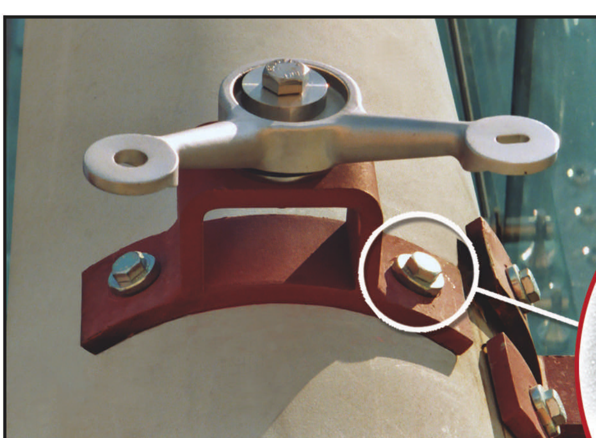

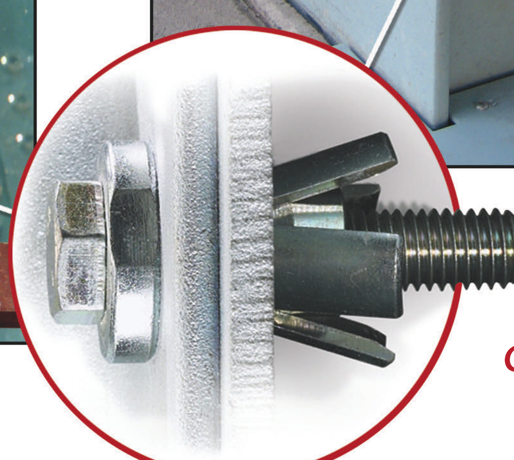

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steel quiz

ANSWERS

1 The criterion for walking vibration in Design Guide 11 is based on resonance caused by walking. Previous criteria were based on a heel-drop impact, but those are no longer recommended. Low levels of damping found in modern buildings, mainly because of open office layouts, may result in resonant response of floors, which necessitated this change.

2 A peak acceleration of 0.5% of gravity (0.005 times the acceleration of gravity) is an acceptable level of vibration due to walking in a quiet environment (See Table 4.1 of Design Guide 11).

3 The recommended damping for an office floor with demountable partitions on top and typical ductwork and ceiling below is 3% of critical damping (See Table 4.1 of Design Guide 11).

4 (a) The recommended vibration live load for residences is 6 psf. (b) For paper-oriented offices it is 11 psf. (c) For electronic-oriented offices it is 6 to 8 psf. These values represent actual day-to-day loads as recommended in Chapter 4 of Design Guide 11 and ASCE-7-05 Table C4-2.

5 The vibration dead load recommended in Design Guide 11 (Chapter 4), in addition to the weight of the structural system, is 4 psf for typical ductwork and typical suspended ceilings. A larger value should be used for heavier ceilings and if raised floors are part of the fit-out.

6 Vibration loads produce very little horizontal shear at the deck/beam flange interface. Even deck-to-flange puddle welds are sufficient to cause full composite action for these small shear loads. Therefore, typical non-composite concrete on deck and rolled steel beam systems are considered fully composite for the vibration analysis.

7 **False.** Full-scale testing has shown that joist seats are not fully effective shear connectors for vibration because of their transverse flexibility. See Design Guide 11, Section 3.6 for details.

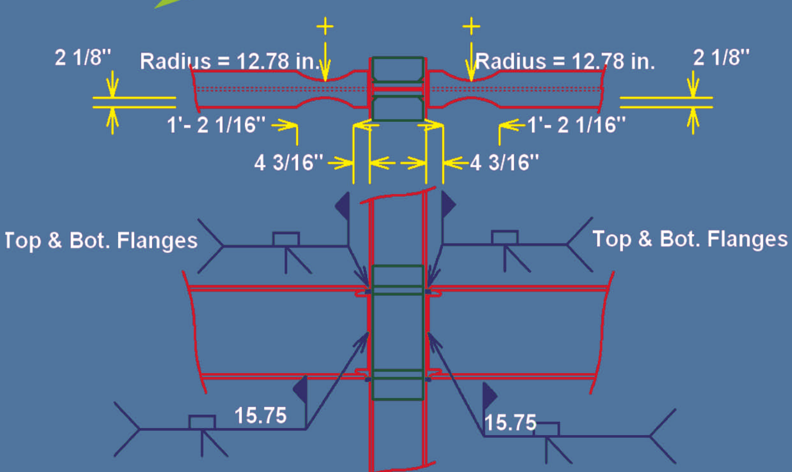
8 The term "beam panel" defines the area of the floor associated with the beam vibration mode (along with no girder bending) from which the beam panel mode effective weight is calculated. Similarly, the term "girder panel" defines the area and effective weight associated with the girder panel vibration mode.

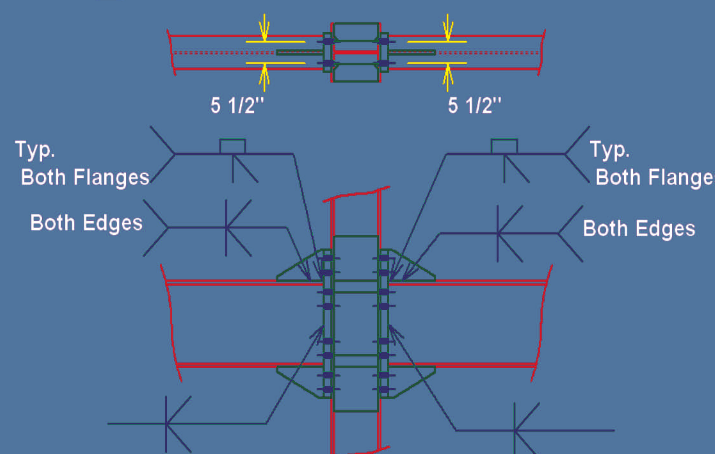
9 The upper limit of the effective width of "beam panels" is two-thirds of the entire floor width (width of floor perpendicular to the beam span) and the upper limit for "girder panels" is two-thirds of the entire floor length (length of floor perpendicular to the girder span). These limits apply to Design Guide 11 Equations 4.3a and 4.3b as illustrated in the examples of Chapter 4.

10 The effective weight of "beam panels" can be increased by 50% when the beams are shear connected to the girders and the adjacent span is greater than 70% of the beam span associated with the beam panels (Design Guide 11 Section 4.2). Increasing the beam panel weight reduces the predicted acceleration.

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

Steel SolutionsCenter


2 1/8''
Radius = 12.78 in.
Radius = 12.78 in.
2 1/8''
1'- 2 1/16''
1'- 2 1/16''
4 3/16''
4 3/16''
Top & Bot. Flanges
Top & Bot. Flanges
15.75
15.75


5 1/2''
5 1/2''
Typ.
Both Flanges
Typ.
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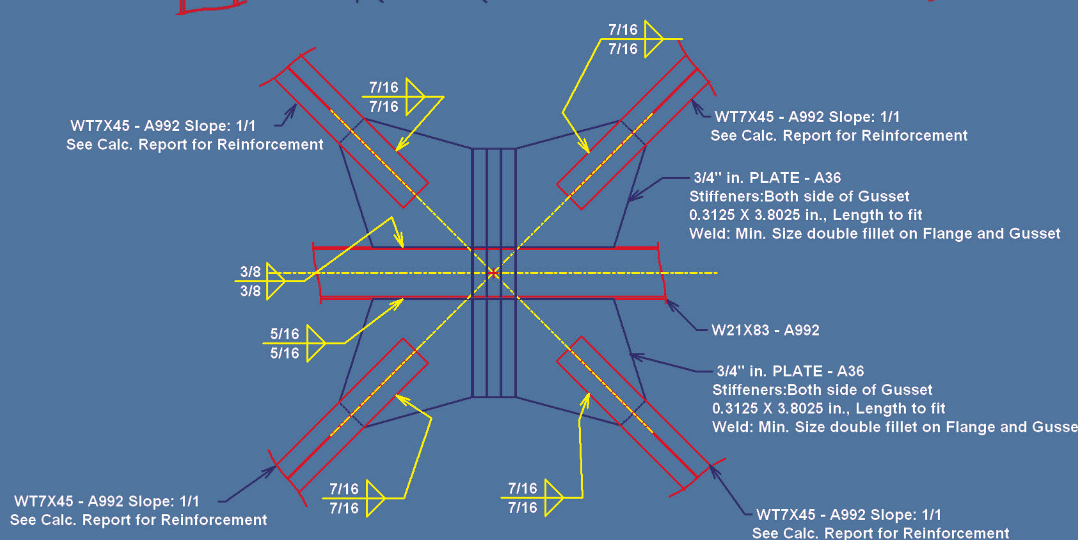

7/16
7/16
WT7X45 - A992 Slope: 1/1
See Calc. Report for Reinforcement
WT7X45 - A992 Slope: 1/1
See Calc. Report for Reinforcement
3/4'' in. PLATE - A36
Stiffeners:Both side of Gusset
0.3125 X 3.8025 in., Length to fit
Weld: Min. Size double fillet on Flange and Gusset
3/8
3/8
5/16
5/16
W21X83 - A992
3/4'' in. PLATE - A36
Stiffeners:Both side of Gusset
0.3125 X 3.8025 in., Length to fit
Weld: Min. Size double fillet on Flange and Gusset
WT7X45 - A992 Slope: 1/1
See Calc. Report for Reinforcement
WT7X45 - A992 Slope: 1/1
See Calc. Report for Reinforcement

CERTIFICATION

AISC Announces New Certification Program for Bridge and Highway Metal Component Manufacturers

AISC is pleased to announce the new Certification Program for Bridge and Highway Metal Component Manufacturers. The "Component Standard" provides a means for component manufacturers to confirm to owners, the design community, and the construction industry that a certified manufacturing firm has the personnel, organization, experience, procedures, knowledge, equipment, and commitment to produce components of the quality required for normal bridge and highway construction.

What should you know about this new standard? The Component Standard describes certification requirements for facilities that manufacture and supply specific components composed primarily of metal to bridge and highway construction projects. These facilities have quality management systems with defined functions and responsibilities. The scope of this new certification does not include installation or erection of the components.

The quality management system of these manufacturing facilities (not products) is certified. The certification should not be interpreted as a product inspection of components. Certification includes all functions of manufacturing and providing components from receipt of contract through final delivery. To maintain certification status, the manufacturer shall follow its quality management system, regardless of whether the requirement for this certification is in the contract documents, and shall supply and be responsible for the entire component.

The certification program is open to all manufacturers of components covered by this standard, regardless of size and regardless of AISC membership status.

Who may become Certified to this standard? Certification to the Component Standard is appropriate for manufacturers of components that include bracing not designed for primary loads (diaphragms, cross frames, and lateral bracing); camera, light, sign, and signal support structures; bridge rail; stairs; walkways; grid decks; drains; scuppers; expansion joints; bearings; ballast plates; and mechanical movable bridge equipment. Manufacturers of camera, light, sign, and signal support structures; high-mast light towers; bridge rail; complex expansion joints; high load multi-rotational (HLMR) bearings; and mechanical movable bridge equipment shall also meet specific supplemental requirements to this standard.

Why you should be interested in the new Certification program? The Certification Standard for Bridge and Highway Metal Component Manufacturers offers assistance to manufacturing and transportation professionals and to owners in assessing manufacturers' capabilities to satisfy component quality needs. It is anticipated that the Bridge Component Manufacturer Certification program will provide a valuable means for qualifying firms and serve as an effective way for steel bridge fabricators and manufacturers participating in the program to communicate their commitment and capability with respect to quality.

When will the Component Program be implemented? The bridge component standard has been finalized and is now available to the industry.

If you have any questions regarding the Component Standard or AISC Certification in general, please call 312.670.7520 or e-mail certinfo@aisc.org.

ENGINEERING JOURNAL

New EJ Publication Opportunity—and Editor—and a Continuing Call for Papers

You are invited to submit a design example problem and solution for review and possible publication in the AISC *Engineering Journal*. Accepted submissions will be published in a new feature called "Design Examples." These submissions will undergo the same peer review process currently used for submitted EJ papers.

AISC *Design Examples* are provided on the companion CD accompanying the 13th Edition AISC *Steel Construction Manual*. In general, all current design examples illustrate the use of provisions and other information in the AISC *Specification for Structural Steel Buildings* or *Steel Construction Manual*. Submissions should exemplify topics related to these AISC documents or illustrate the use of the 2005 AISC *Seismic Provisions for Structural Steel Buildings* or the AISC *Seismic Design Manual*. These submissions will be used to help expand upon the currently available set of AISC *Design Examples*.

The successful design example problem and solution will be concise, accurate, and illustrate the use of a provision or concept not already addressed in the AISC *Design Examples* currently included on the CD Companion. Only design examples conforming to the 2005 AISC *Specification for Structural Steel Buildings* and/or 2005 AISC *Seismic Provisions for Structural Steel Buildings* will be considered. Submissions must provide ASD and LRFD solutions in parallel (see the style used on the CD Companion). In addition, the design example must adhere to the EJ author guidelines available via the below link.

If your design example is selected for publication, it will be considered for inclusion in a future edition of the AISC *Steel Construction Manual* CD Companion, and you will receive complimentary admission to an AISC seminar!

Please go to **www.aisc.org/ej** to submit your design example problem according to the format indicated in the author guidelines, which can be accessed at the above page via the submittal-related links.

Engineering Journal

American Institute of Steel Construction

Second Quarter 2008 Volume 45, No. 2

www.aisc.org

New EJ Editor

Starting with the second quarter issue, Keith Grubb, AISC's new senior research engineer, will take over the editorial duties at EJ. Keith was formerly an AISC regional engineer and was also MSC's managing editor for several years. Cindi Duncan, AISC's director of engineering and EJ's longtime editor, will continue to focus on AISC's specifications and other publications.

Call For Papers

AISC is always looking for EJ articles on interesting topics pertinent to steel design, research, and fabrication methods, or new products of significance to the uses of steel in construction. We are especially seeking technical articles with practical applications in the steel industry. If you have a new idea or an improvement on an old idea, please submit a paper to AISC for publication in EJ. Send your paper in duplicate to:

Keith Grubb
Editor, *Engineering Journal*
AISC
One East Wacker Drive, Suite 700
Chicago, Ill. 60601
grubb@aisc.org

Detailed information on our review process and requirements for submittals can be found on the inside back cover of each issue of EJ.

IN MEMORY

AISC Director of Building Design John Ruddy Passes Away

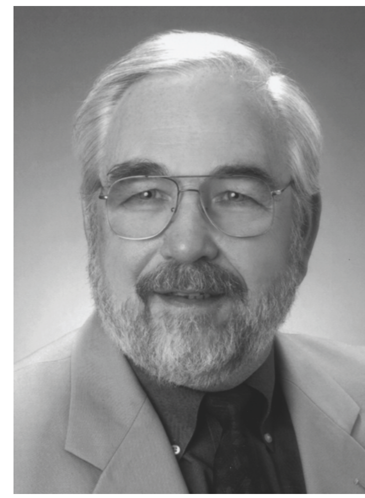
John Ruddy, AISC's former director of building design, died on December 11, 2008 in Rockville, Md., after a long battle with brain cancer.

"John was a great engineer and a shrewd innovator, who counted all of his colleagues among his friends because he also was a warm and genuine person," said Charles J. Carter, S.E., P.E., AISC vice president and chief structural engineer. "As important as his career as a structural engineer was to him, you could see how much more important his family was to him the moment he began telling you about his four boys and the devotion with which he and his wife Jeanette raised them. I will miss my friend John, but it is comforting to know that he no longer is suffering."

Over the course of his career, John built a strong reputation for innovation and the ability to develop cost-effective structural solutions for buildings. Among his many notable accomplishments, he pioneered work in fire resistance and safety in steel building structures. He also received numerous awards, including the Clemens Hershel Award in 1988 for his lecture "Evaluation of Structural Concepts for Buildings" and the Special Achievement Award in 2008 from AISC for his work in fire resistance and design of steel structures.

John began has career in Cleveland in 1965 with Dalton, Dalton, Little and Newport, a large architectural engineering practice. In addition to project engineer responsibilities, he developed computer applications for structural engineering in the early days of computer use for structural analysis and design. During that same time, he also taught evening courses on structural analysis and design at Cleveland State University. In 1973, he joined John Bowes and Associates, a small structural engineering consulting practice, as an associate.

In 1977, John moved to Bridgeport, Conn. to accept the position of chief structural engineer with Fletcher Thompson, Inc., a 150-person A/E practice. In 1981, he was named vice president of engineering, with responsibility for the



direction and coordination of all in-house engineering disciplines. In 1993, John was elected to the Board of Directors for the company.

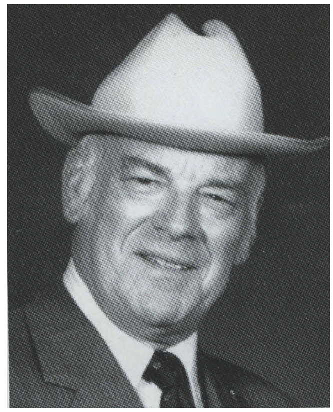
In 1998, John relocated to Nashville, Tenn. to become the chief operating officer of Structural Affiliates International, Inc. After almost a decade with SAII, John joined the AISC staff as director of building design. Located in Washington, D.C., he was responsible for AISC seminar development, speaker training, and educational activities.

John received his undergraduate civil engineering degree from the University of Dayton in 1965 and his master's degree in civil engineering from Cleveland State University in 1971.

A devoted husband and steadfast family man, John raised four boys with his wife Jeannette. All four boys attended Catholic University of America in Washington, D.C., and started their families in the area. When Jeannette died of lung cancer in 2005, John moved from Nashville to Washington to be closer to his sons. John is survived by his sons and daughters-in-law, Shawn and Young Mee of New York City, David and Laurie of Washington, D.C., Daniel and Laura and granddaughter Kristen of Silver Spring, Md., and Kevin and Elizabeth of Baltimore.

AISC would like to express our deepest sympathies to the Ruddy family. John will be greatly missed.

Former AISC Board Chairman Dies



Ralph H. Clarbour, a member of the AISC Board of Directors from 1981 to 1996 and Board Chairman from 1989 to 1991, died December 19, 2008 of heart failure.

Born October 18, 1924, Clarbour was a veteran of World War II in which he served as a turret gunner and photographer in the U.S. Navy for nearly three years between 1942 and 1945. Upon returning from the war, he entered the steel industry, a tenure that took him from working for his uncle at erecting contractor Dahl Olson, Inc. to becoming the president and CEO of Arlington Structural Steel Co., Inc. (AISC Member Fabricator). He was a member of AISC for more than five decades, joining in 1956.

He was also a member of the Central Fabricators Association, which he joined in 1949—and served as director and treasurer from 1960 to 2003—and the Iron League of Chicago, where he served as president in 1960.

Besides professional organizations, Clarbour was also involved in local politics. A resident of Arlington Heights, Ill. since 1949, he served as a village trustee from 1971 to 1981 and was appointed village president in 1974.

According to the *Daily Herald*, current village president Arlene Mulder said, "He had his opinion and he didn't care if a million (people) agreed with him or 10. He epitomizes what is wonderful about America and democracy."

Ralph is survived by his wife of 63 years, Mary, and his children Richard, Lee Anne, David, and Dan, and four grandchildren.

Michelmann Steel Chairman, Bill Gerdes, Dies

William Frederick "Bill" Gerdes III, chairman and former president of Michelmann Steel Constuction Company (AISC Member Fabricator) in Quincy, Illinois, died on January 6 at age 74.

Born in Quincy, Bill spent most of his life there, leaving to attend Knox College in Galesburg, Ill. and eventually graduating from the University of Illinois at Urbana-Champaign with a B.S. in civil engineering. He received his P.E. license in Illinois, Missouri, and Iowa.

Bill worked for Michelmann Steel for more than 50 years, joining the company in 1957. He served as president from 1975 until 2006, when he became chairman of the board. The company was founded by Bill's great-grandfather, J.H. Michelmann, in 1865.

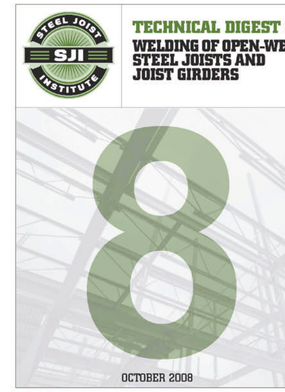
Bill was active in several professional and educational organizations, including the Michelmann Foundation, University of Illinois Alumni Association, American Society of Civil Engineers, Central Fabricators Association, and Illinois Society of Professional Engineers, where he served on the board of directors.

Bill is survived by his wife, Barbara, his children, Laura Gates Gerdes Ehrhart, William Frederick "Wil" Gerdes IV, and Parker Lee "Chip" Gerdes, and four grandchildren.

See "What's Cool in Steel" (MSC 8/08, available at www.modernsteel.com) for a story on the commemoration of Bill's 50 years of service with the Michelmann Companies.

JOISTS

SJI Releases Second Edition of Technical Digest No. 8



A second edition of Technical Digest No. 8 has been developed by an ad-hoc group of the Steel Joist Institute's (SJI) Engineering Practice Committee and is an extensive update of the digest originally released in August 1983. *Welding of Open-Web Steel Joists and Joist Girders* details the requirements that SJI member companies must follow in the manufacturing of steel joists and joist girders and provides information on the various types of welding processes and weld types, as well as weld designs currently and previously used by SJI member companies.

Frequent reference has been made throughout the 91-page digest to the American Welding Society Welding Specifications. Compliance with AWS criteria will satisfy the SJI welding requirements, and in many cases the SJI requirement is in compliance with a particular AWS provision. However, there are some differences, and the reasons for SJI to maintain its own specification language for welding is discussed throughout this document.

Technical Digest No. 8 sells for $25, plus $5 per order for regular handling and shipping within the continental United States. To order a hard copy, download an order form, or download the document, visit **www.steeljoist.org**.

People and Firms

- Two Rice University engineering alumni, John and Ann Doerr, have given their alma mater $15 million via the Benificus Foundation, a private charitable organization they've set up, to fund the new **Rice Center for Engineering Leadership**.
- Carol Post, P.E., S.E., LEED AP, and Thomas Poulos, P.E., S.E., have been promoted from vice president/principal to senior vice president/principal; and Garret Browne, S.E. and David Wiehing, P.E., S.E., LEED AP, were promoted to vice president from senior associate in **Thornton Tomasetti, Inc.**'s Chicago office.
- **The Association of Union Constructors** has named Wayne Creasap as its new director of safety and health. He comes to the association after 13 years with the Construction Employers' Association, where he most recently served as their director of safety and education.
- Jeffrey Knauf, president of Medalist Laserfab, Inc., of Oshkosh, Wis., and Dan McLeod, district manager of A. J. Forsyth in Delta, British Columbia, Canada, were elected to the board of directors of the **Fabricators and Manufacturers Association, International (FMA)** at the group's recent annual meeting.
- Brian Turmail has joined the **Associated General Contractors of America** as senior director of public affairs, having just served as director of communications at the U.S. Department of Transportation

NASCC: THE STEEL CONFERENCE

New Sessions Added to Upcoming NASCC: The Steel Conference

Two new short courses, a look at the relationship between art and structural design, and an expanded fabricator workshop have been added to the roster of more than 80 technical sessions at the upcoming 2009 NASCC: The Steel Conference (April 1-4 in Phoenix).

The conference is the premier educational event aimed at providing structural engineers, steel fabricators, erectors, and detailers with practical information and the latest design and construction techniques. In addition, the Steel Conference offers an extensive trade show featuring products and services, ranging from engineering software to the latest fabrication equipment, from more than 200 exhibitors. It's a once-a-year opportunity to learn the latest in design methodology, see the most innovative products, and network with your peers. The conference continues to grow each year, and last year's attendance exceeded 3,700.

Last year's conference, in Nashville, drew more than 3,700 attendees, an NASCC record.

Recently added to the roster of short courses is an eight-hour program on Bracing for Stability and a four-hour session on Building Information Modeling. Other short courses include sessions on Practical Connection Design for Economical Steel Structures; Unlocking the Simplicity of Analysis and Design with ANSI/AISC 360; Wind Load Provisions of ASCE 7; Understanding the Costs and Risks of Insurance Wrap-Ups; Design and Fabrication for Galvanizing; Exploring Building Design with Steel Joists, Joist Girders, and Steel Deck; ASCE 7.05 Seismic Provisions; and Inspection of Hot-Dipped Galvanized Steel.

The conference kicks off with a potentially controversial session provocatively titled "Connection Design Responsibility: Is the Debate Over?" In the hour-long program, Charlie Carter, AISC's vice president and chief structural engieer, presents the findings of a joint task group formed by the Council of American Structural Engineers (CASE) and AISC. Kirk Harman from The Harman Group in Philadelphia and Glenn Bishop from LBYD in Birmingham join the debate on the merits of delagating or not delegating the work of connection design.

Another session sure to draw a lot interest is being presented by AISC vice president John Cross on "Current Sales Forecasts and Outlook." This session will provide key market information for the remainder of 2009 with an in-depth look at specific market segments, such as health-care construction and educational facilities.

Other sessions that are sure to draw large crowds include: "The Wal-Mart Effect and Your Business" (a discussion of how to compete against the low-price leaders and to create more profitable jobs); R. Shankar Nair's presentation on "Skyscrapers—Past, Present and Future;" "Connections: The Last Bastion of Rational Design" by Bill Thornton; "CSD University" (a special series of presentations based on the training program that one of the country's most successful and innovative engineering firms uses for their new hires); "Who's Responsible When a Job Goes Bad" (a look at what can happen during a fast track, design-build project); "Specifying Camber—Rules of Thumb for Designers;" and "Introduction to Earthquake Engineering and Seismic Design." For a complete list of sessions, or to register, please visit **www.aisc.org/nascc**.

The conference also provides attendees with the opportunity to tour Schuff International's fabrication shop on Wednesday, April 1. Schuff has one of the largest and most advanced facilities in the country and will give designers a good look at the technology being used to fabricate their projects today. Among Schuff's recent projects are The Palazzo, a 70,000-ton, 7-million-sq.-ft addition to the Venetian Resort Hotel Casino in Las Vegas, and the Phoenix Convention Center. While there is no charge for this tour (including transportation and refreshments), space is limited and attendees must register in advance (**www.aisc.org/nascc**).

Schuff Steel Company

Schuff's fabrication facility, near downtown Phoenix.

Made in America?

BY ANGELA R. STEPHENS

The Buy America and Buy American Acts appear to promote domestically produced steel, but loopholes in both allow for other shopping destinations.

AS THIS ARTICLE GOES TO PRESS, more details of the Obama administration's 2009 Economic Stimulus Package are being released. Common wisdom is that, when complete, the Stimulus Package will include a public works component to fund construction and renovation of bridges, highways, and public buildings from the federal level down to local school districts. Included in the stated goals for building construction are increased energy efficiency and sustainability.

The rationale accompanying the Economic Stimulus Package emphasizes the "three P's": (1) Put money into the economy; (2) Put Americans back to work; and (3) Provide needed infrastructure upgrades (transportation, heavy civil/utility, and building construction). Sadly, under the current federal law there is no guarantee that American funds applied to rebuild the infrastructure will be paid to American workers or American companies. Under the interpretation of the current law there is every possibility that foreign mill steel and foreign fabricated steel could find its way into public works projects funded by the 2009 Stimulus Package. It is clear that most Americans are not aware of the loopholes in the current law. At this writing it is still unclear whether our legislators will take the action necessary to close those loopholes.

There are two separate "domestic only" provisions applicable to federal construction projects. On the surface, these provisions require using American materials. One set of provisions applies to bridge construction and is contained in the Federal Highway Administration (FHWA) and Federal Transit Administration (FTA) Buy America statutes, which, in turn, are derived from the Surface Transportation Assistance Act of 1982. The other set of provisions is contained in the Buy American Act, and applies to non-transportation federal construction projects.[1] (Note the subtle difference: "Buy America" for bridges and "Buy American" for buildings.)

In application, neither guarantees that American public works projects will be built exclusively with American material and American labor.

Bridge Construction

The current FHWA and FTA Buy America provisions were enacted 1978 when Congress sought to expand domestic procurement coverage to the federally funded highway construction projects. The Buy America provisions provide that federal-aid funds may not be used on federal-aid highway construction projects unless the iron and steel used on the projects are manufactured in America.

FHWA Buy America Statute and Regulations

The Federal Highway Administration Buy America statute and regulations apply to federally funded FHWA projects.[2] Essentially, this statute requires that all steel and/or iron materials that are permanently incorporated into a FHWA project must be manufactured and fabricated in the United States. Here is the first loophole: If a state DOT determines that a bridge structure (even a bridge structure that is to remain in place for years and possibly then moved for a secondary, continued use at another location) is temporary rather than permanent in nature, then the Buy America protection does not apply. Then there is a second loophole: Buy America protection does not apply to bridge structures funded totally from state revenue, even if application of federal funding to another state highway project freed state funds to be applied to build a bridge through loophole number two.

The FHWA Buy America statute also does not apply if: (1) the State accepts alternate bids from both foreign and domestic steel mills or fabricators and the foreign company's bid is lower than the domestic company's bid by more than 25%, or (2) the use of foreign steel and iron does not exceed 0.1% of the total contract value or $2,500, whichever is greater.[3]

A state may apply for a waiver of the FHWA Buy America statute if: (1) the application is felt to be inconsistent with the public interest, (2) it is claimed that needed materials and products are not produced in America in sufficient quantity or quality, or (3) the

[1] 41 U.S.C. §§10a -10d.

[2] 23 U.S.C.S. §313 and 23 C.F.R. 635.410.

[3] 23 C.F.R. 635.410(b)(1-4).

inclusion of domestic material will increase the cost of the overall project by more than 25%. Herein is loophole number three. Does the 25% rule apply to the total cost of the entire project (in the case of a bridge, the entire span—including approaches—from shore to shore) or can it be applied to separate contracts for individual project components? Some states have broken bridge projects down into individual components, contracted separately for those components, and applied the 25% rule only to the individual contract component and not to the project as a whole.

The Buy America Act applies to bridges, while the Buy American Act applies to buildings.

Also, certain trade agreements may waive the applicability of the Buy America statute.

FTA Buy America Statute and Regulations

The FTA Buy America statute applies to FTA federal-aid highway construction projects.[4] The FTA Buy America statute is substantially similar to the FHWA statute. Of importance, however, is that the FTA Buy America statute provides that a waiver may also be obtained if, when procuring rolling stock, the cost of components and subparts produced in America is more than 60% of the cost of all components of rolling stock and the final assembly of the rolling stock has occurred in America.

Building Construction

The Buy American Act ("the Act") was enacted in 1933 in an effort to stimulate the domestic economy. It was designed by its drafters as a device "to foster and protect American industry, American workers, and American invested capital."[5] It provides that certain American materials, such as steel, must be used on any federally funded construction project where the federal agency makes a direct purchase or awards a contract. (Remember, "Buy America" applies to federally funded transportation projects; "Buy American" applies to everything else.)

The Act applies unless: (1) it is inconsistent with the public interest, (2) the cost is unreasonable, (3) the material will be used outside the U.S. (say, an offshore DOD or DOS facility), (4) the material is insufficient and not reasonably available in commercial quantities and of a satisfactory quality, or (5) the contract award value is less than or equal to $2,500. Additionally, trade agreements, such as NAFTA and the Trade Agreement Act, waive the requirements of the Buy American Act for construction materials purchased from certain countries if the estimated value of the construction project exceeds certain amounts.

Because of the many waivers and exceptions that have found their way into the Buy American Act, impacting building construction over the years, it has become riddled with loopholes. The Buy American Act notwithstanding, there are many instances where federal funds purchase steel from foreign mills and foreign fabricators for domestic federal construction projects.

Objections to Enforcement

Over the years proponents of incorporating foreign steel products into domestic public works projects have relied upon a common theme to press for progressive weakening or removal of domestic preference provisions in federally funded construction projects. Their argument normally contains the following theme: "Domestic steel producers and fabricators are not as efficient as their foreign competition. They cost too much, they run up the price of public works, and the public has no assurance that they are not hiding behind domestic preference provisions to artificially inflate their prices."

This argument is strongly contested by the domestic steel industry. Domestic producers and fabricators argue that when competition is fair and grounded on a level, legal playing field (including application of fair and competitive structural design and fair application of international trade laws and environmental considerations) the American steel industry can compete with anyone in the world. Domestic mills and fabrication shops argue that they lead the world in efficiency and have not asked for a penny in government subsidies. Domestic producers consistently ask only for a level playing field.

However, the domestic industry contends that the playing field is not level, and that some foreign governments allow their industries to operate under advantages that are simply not shared by their American competition. All of this can be rectified by our government, and sufficient safeguards (teeth) can be brought to bear by our government to safeguard the American public against price gouging.

But rectification of international trade abuses takes time, and, simply stated, the American economy is under stress—and American workers and companies believe that they do not have time to wait for diplomacy and the international courts to rectify what they perceive as the current imbalance.

The Buy American Act notwithstanding, there are many instances where federal funds purchase steel from foreign mills and foreign fabricators for domestic federal construction projects.

Added Provision

Congress and/or the president have the inherent authority to strengthen the Domestic Preference provisions in federal procurement law and/or to temporarily close the current loopholes in the law during periods of national emergency. Participants in the domestic industry claim that we currently find ourselves in a period of national emergency and that strong action by government is required to maximize the benefits of the Economic Stimulus Package for American companies and American workers.

Many organizations, like AISC, have passed resolutions and asked members of Congress to include a "domestic only" provision in the 2009 Stimulus Package that would ensure that federal funds are being given to American workers and American companies. You can join these efforts by contacting your member of Congress and ask that he or she supports legislation that will close the loopholes in the current Buy America and Buy American provisions and/or add a "domestic only" provision to any stimulus packages. MSC

Angela R. Stephens is a civil engineer and lawyer with Stites & Harbison, PLLC, counsel to AISC. Angela has concentrated her practice in construction law. She is active in the National Association of Women in Construction (NAWIC) and will be speaking at the 2009 North American Steel Construction Conference in Phoenix this April. The views expressed here are those of Ms. Stephens and not necessarily those of either AISC or Stites & Harbison.

[4] 49 U.S.C.S §5323(j) and 49 C.F.R. 661.1 - .21.

[5] 76 Cong. Rec. 1896 (1933) (remarks of Rep. Eaton), cited in *Textron, Inc., Bell Helicopter Textron Division v. Adams*, 493 F. Supp. 824, at 830 (D. D. C. 1980).

Historic stadiums, such as the University of Illinois' Memorial Stadium, are undergoing renovation work to keep the seats full and the fans happy.

Photos by Brad Feinknopf, courtesy of HNTB

Exposed trusswork in the concourse complements the brick cladding and imagery of former Illini football greats.

Big Draw

BY ROBERT HYLAND, P.E., AND JEFF ADAMS, P.E.

THERE'S NO DOUBT that Big 10 alumni and students are passionate about their athletic teams. Football is a particularly big draw at most Big 10 schools, and many of the conference's stadiums are beloved icons for the universities and surrounding communities. Many of them are also almost a century old and in need of renovation.

The University of Illinois' Memorial Stadium in Champaign is one such stadium. Built in 1923, the structure had simply become outdated. The restroom and concession facilities appeared crowded, the press box didn't have the technology and space found in more modern venues, and the stadium lacked the hospitality facilities for top-flight viewing and entertainment. In short, the stadium was showing its age.

As such, the university embarked on a project to make improvements to Memorial Stadium so it could better compete with other Big 10 schools. These involved providing student-athletes with state-of-the-art facilities and adding a high-end club level for recruiting and entertaining and add revenue-generating luxury suites. The renovation was completed in time for the Illini football team's first home game of the 2008 season, and the $120 million project used about 3,300 tons of steel in all to make it happen.

Architectural Tradition

Memorial Stadium is a unique example of an architectural stadium within collegiate athletics. Built in a classical revival style, the stadium was designed as a memorial dedicated to the 189 students and alumni of the University of Illinois who died in World War I. A set of colonnades run the length of the east and west façades. Two hundred columns complete the colonnades, and 189 of the columns are inscribed with the name of an Illini soldier who died in the war. Intricate carved stone panels on the exterior of the facility commemorate the war and pay tribute to the athletic games.

To honor this rich architectural tradition, the existing building elevations, colonnades, great halls, ramp towers, and all

A night game at newly renovated stadium.

The renovation project kept the stadium's historic façade intact, including the signature columns.

historic details needed to remain intact during the renovation. All new renovation work planned for the west and east sides of the stadium had to occur within the historic façades.

Working within those confines, HNTB Architecture, Inc., joining forces with associate architect Isaksen Glerum Wachter, LLC, developed a plan that included:

- Increased restroom and concession capacities
- A new 1,200-seat outdoor club and 200-seat indoor club
- 45 climate-controlled suites
- Enhanced functionality of press and game-day operations
- An expanded concourse with new secured entry portals
- Addition of a mechanical mezzanine on the west side of the stadium

A Tight Construction Plan

A short construction deadline required the engineers, architects, and construction team to develop a unique scheduling plan. Work on the west side of the stadium began in early 2007 and the east side broke ground in the spring of 2008. Again, all work had to be completed in time for the first home football game, on Sept. 6.

To meet this tight schedule, the west stadium project, where the bulk of the construction occurred, was divided into thirds. Before the 2007 season began, about two-thirds of right and left wing structures were constructed to match the height of the existing building. Although construction wasn't completed on these wings, the structure had to meet IBC 2000 load requirements so that spectators and members of the media could pass through those areas while heading to their seats in the lower bowl and to the press box in the center.

At the end of the 2007 season, selective demolition and construction immediately began on the center section of the west stadium. At the same time, crews worked on completing the erection of the structural steel on the left and right wing structures. Interior work began in the wings while the center section was being erected. The center structure reached its maximum height in the months following and work began on its interior. This "divide-and-conquer" planning enabled the construction team to meet the relatively short schedule while still enabling the 2007 Illinois football season to go on without interruption.

Building from the Inside Out

The architectural and engineering team considered structural steel, precast, and cast-in-place systems to complete the renovation. Structural steel was selected because of the complexity of the design, the height of the proposed structure, the speed of construction, and to match the structural framing of the existing stadium—which was also structural steel.

While the material properties of the 1920s-era steel are different from the steel of today, testing showed that the more than 80-year-old existing structure had no deterioration and was strong enough to withstand new construction, including modern welding; in the 1920s, riveting was the standard way to connect steel parts.

The primary challenge of marrying the old 1920s-era steel construction with the new steel structure was the confines in which we had to build. In most stadium renovations where you are adding suites and additional levels, you build from the outside. This stadium is unique in that we had to build from the inside, adding to the existing structure while being vigilant to not tear it apart or compromise the existing façade.

The project plan called for the interior of the west stadium structure to be removed while shoring and bracing the remaining structure until the new interior structure could be completed. To prevent damage to the historic façade and colonnades, the existing structure had to be shored, jacked, selectively demolished, re-jacked, and supported while minimizing any movement. The solution was to provide shoring columns and beams to support the existing trusses. The existing trusses were supported on a new transfer truss. Foundations were designed to support the shoring columns and temporary loads.

Because the new foundations would experience small settlements and the support trusses would be subjected to deflection under load, the existing trusses were jacked up and continuously monitored. The historical masonry façade and other brittle elements also were monitored during the process to verify they were not damaged.

Marrying Two Different Structural Grids

Project plans created a second challenge of transferring from a structural grid—defined by the regular spacing of the suites, press area, and club spaces that splayed with the curve of the façade—to the existing grid of the lower bleachers and historic façade. The lower half of the building matched the orthogonal grid of the existing building, whereas the new suites followed a radial grid. This caused the columns to not be in line with each other, so transfer girders and trusses were designed to provide a load path for the columns. As a result, no single column continued directly from the roof to the foundation.

The main structural support system for the existing structure was a series of transfer trusses. The new design required the existing trusses to be cut in half while they were still supporting the upper half of the building. Where existing trusses were cut, an 8-ft-deep perpendicular transfer truss constructed of 12-in.-wide-flange sections was erected to support the existing trusses. Transfer from the 14-ft to 16-ft grid spacing of the existing stadium to the 30-ft grid of the upper levels occurred two levels up using a 40-in.-deep beam. Approximately 30 ft east of the west transfer truss, another 15-ft-deep transfer truss was built to support the lower bleacher framing and the upper suite, club, and press framing, while matching the existing column grid below.

In addition to the transfer trusses and members, the floor system used was typically a concrete slab on composite metal deck and steel-beam framing. Depending on the span and load, the typical floor framing ranged from 12-in.- to 30-in.-wide-flange beams. Heavy 40-in.-deep girders as large as 297 lb per linear foot were used to support cantilevers at the suite, club, and press seating areas.

A Landmark Stadium

Because of the inside-out renovation that took place and due to its national significance to the development of recreation in America, Memorial Stadium is eligible for both the National Register and National Historic Landmark listing, the latter of which is the highest national distinction available to historic structures.

From the 2008 season forward, the Fighting Illini football tradition will continue from a stadium that maintains its historical integrity on the outside while providing a state-of-the-art experience for players and fans on the inside. MSC

Robert Hyland is a senior structural engineer and Jeff Adams is a structural project engineer, both with HNTB Corporation.

Owner
The University of Illinois, Urbana-Champaign

Architect and Structural Engineer
HNTB Illinois, Inc., Kansas City, Mo.

Associate Architect
Isaksen Glerum Wachter, LLC, Urbana, Ill.

Construction Engineer
Roecker Consulting Engineers, Inc., Morton, Ill.

Steel Fabricator and Detailer
Blattner Steel, Cape Girardeau, Mo. (AISC Member)

Construction Manager
Hunt Construction, Indianapolis

West Stadium General Contractor
Williams Brothers, Peoria, Ill.

Structural Analysis Software
RISA3D, RISAFloor

Steel Detailing Software
StruCAD

Memorial Stadium: A Timeline

Nov. 3, 1923: First game played in Memorial Stadium.

1967: Installed press box atop the west balcony; constructed Ray Eliot Varsity Room, a training table, and trophy display area at the southeast corner of the stadium.

1972: $1 million stadium renovation, which included the addition of aluminum seating.

1974: Installed the first artificial turf field and a new lighting system.

1977: Renovated the varsity locker rooms and training facilities.

1985: $7 million renovation, which featured new artificial turf and expanded football headquarters in the northeast corner of the stadium. Also in 1985, an air-tight vacuum dome completely covering the field—commonly known as "The Bubble"—was inflated for the first time. The Bubble allowed for practice during the winter months.

1989: Replaced a portion of the AstroTurf field after vandals burned a 40-yard swath in the middle of the field.

1991-1992: $18 million renovation project included replacing all the concrete bleachers in both upper decks, as well as the top 25 rows of the main stands. The stadium's electrical and drainage systems were brought to code, and new restroom facilities were installed in the corner towers and great halls.

1994: Added new color matrix scoreboard to the north end zone.

2000: Replaced The Bubble with the Irwin Indoor Practice Facility.

2001: Replaced AstroTurf with AstroPlay, an artificial surface featuring a grass-like, nonabrasive, polyethylene fiber matrix filled with special rubber granules.

2002: While Soldier Field was under renovation, the Chicago Bears played all of their 2002 home games in the friendly confines of Memorial Stadium. In anticipation of the Bears' arrival, locker rooms and meeting rooms were expanded, and a new sports medicine facility was built on the building's first floor. In addition, a new video-replay scoreboard was installed in the north end zone. (For an article on Soldier Field's own structural renovation/expansion, see "Field Goals" in the 7/04 issue of MSC, available at **www.modernsteel.com**.)

2007: Added a 5,200-seat bowl to the north end of the stadium.

2008: Renovation project completed in time for first home game of 2008 season.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Beyer Blinder Belle

Fan Favorite

BY KEVIN C. POULIN, PH.D., P.E., AND FILIPPO MASETTI

Thanks to a structural renovation in lower Manhattan, a new sports museum comes to life and an historic edifice lives on.

COLLEGE FOOTBALL'S 2008 SEASON ended last month with its traditional plethora of bowl games, culminating in the national championship game in which Heisman Trophy winner Sam Bradford, quarterback for the University of Oklahoma, fell short of victory against the University of Florida and last year's Heisman winner, Tim Tebow.

In America, as soon as one season ends, another begins—or is already in progress. In recognition of this love affair with athletic pursuits, the Sports Museum of America last May opened its doors in lower Manhattan as the nation's first museum dedicated to all sports—and as the new home of the Heisman Trophy.

The museum occupies 80,000 sq. ft on the bottom three floors of 26 Broadway, a site with a rich history. It was in this building that John D. Rockefeller made his millions at the helm of Standard Oil, the powerful firm that monopolized America's oil markets and set prices for petroleum for decades. Rockefeller constructed the building in several phases. In 1885, he started with a ten-story building designed by Ebeneezer Roberts. In 1895, he expanded the building through the construction of six additional stories and an addition to the northern section, design by Kimball and Thompson. Finally, in five phases over six years in the 1920s, he built the 32-story tower, designed by Thomas Hasting of Carrere and Hastings, the firm renowned for its design of the New York Public Library.

Worthy of a Museum

Decades later, in May 2006, the building began a structural renovation project to prepare the bottom three floors for their new role as a museum; the rest of the building is used as office space, and another portion of the building has been renovated to house a new public high school. The structural scope of this most recent project included an increase of the live load capacity of the bottom three floors to 100 psf, for museum occupancy, and the addition of both a new elevator and a new stair.

After conferring with the architect, Beyer Blinder Belle (BBB), we knew that the older portions of the building had no original structural drawings, but that the drawings for the Carrere and

The Sports Museum of America (housed in the above building) pays tribute to the nation's sporting history and is also the new home of college football's Heisman Trophy.

Simpson Gumpertz and Heger

Manhattan's 26 Broadway began as a 10-story office building in 1885. It was expanded by six stories and also received a northern addition in 1895. A 32-story tower was added in several phases during the 1920s. A structural renovation to the building was just completed last year.

Hastings portion of the building were available, and we started our structural work with a field investigation program. We systematically probed the older portions of the building for which we had no drawings and we spot-checked the Carrere and Hastings portion to determine whether the structure adhered to the drawings in our possession.

In most of our probes into the 1885 portion of the building, we observed wood sleepers and wood flooring bearing on the top of wrought-iron beams. Between the beams, cinder fill rested on 10-in., terra-cotta tiles that span 4 ft as a flat arch between the beams. The bottom flanges of the beams support the tiles. Thus, the bottom flanges of all the beams are aligned while the top flange elevations vary by the depth of the section. The wrought-iron beams are either supported on 4-ft-thick exterior bearing walls or frame into girders that are supported by cast-iron columns.

When we investigated the 1895 portion of the building, we found similar construction with wrought-iron beams, cast-iron columns, and thick bearing walls. We made extensive site visits to document the steel framing exposed at probe openings, used ground-penetrating radar (GPR) to locate steel framing between probes, and obtained steel coupons for analysis in our Boston lab. We analyzed the live load capacity of the floor system and found that, in general, it was not sufficient for museum occupancy.

To strengthen the beams, we chose to weld WT sections to the top flanges because we were concerned that reinforcing them from below would potentially damage or collapse the brittle terra-cotta tiles. We removed the 4-in. topping slab, which helped to reduce the dead-load stresses in the beams prior to welding the WTs and creating composite action. The contractor, Structure Tone, cast new concrete against the WTs, replaced the topping slab, and coated the WTs with intumescent paint to achieve the required three-hour fire rating.

For the Carrere and Hastings addition—again, from the 1920s—we reviewed the existing structural drawings and made site visits to confirm and update as-built structural information. Here, extracted concrete cores revealed that the floor system consisted of 5 in. of cinder fill above a 5-in. cinder-concrete slab, with a draped mesh spanning 6 ft between concrete-encased steel beams. Analysis proved that the cinder-concrete slab was insufficient for the new load but that most of the steel beams were adequate. The solution was to remove the cinder fill and pour a new structural slab in its place, using the cinder-concrete slab as formwork. Removing the cinder fill and replacing it with structural concrete of a similar density allowed us to strengthen the floor slab without increasing the load to the beams.

Another task was to install a new elevator between the basement and the third floor. Since there are two sub-basements below the basement level, it was not possible to use the typical soil-supported pit. Instead, we designed an elevator pit that hangs from the ground floor steel from a series of five hangers and one building column. At the ground floor, we reinforced most of the existing beams with either WTs that stop short of the columns or with new beams below the existing ones, that span to the columns. We were also challenged with designing reinforcement for the existing beams and hanging the pit in this location while threading between a tangle of the building's utilities and infrastructure.

Façade

By the summer of 2007, when construction was underway and the floor-framing strengthening had been substantially completed, the architect asked us to assist with the remodeling of the building's storefront along Beaver Street and New Street. The existing storefront had hosted a series of restaurants, banks, and shops, which had modified the façade over time with limited architectural coordination. The museum wanted to reestablish the appearance of the structure by removing the existing storefront and replacing it with smaller windows surrounded by limestone piers that matched the original stone above. The Landmarks Preservation Commission was deeply involved in the restoration of the façade and held the team to strict standards.

Although a new concrete masonry unit (CMU) back-up wall could be built to the underside of the spandrel beams, the limestone would have to bypass the spandrel beams to create a typical joint with the existing stone above. Thus, we had to make the new stone cladding fit into the existing framing. When the new stone was selected, limited exploratory openings were made to expose the existing spandrel beams, and it was difficult to determine if interference was an issue. Upon interior demolition, we observed spandrel beams installed at an elevation lower than the original floor framing. These beams appeared to be of the same vintage as the storefront modifications. We also found that brick masonry was placed in the gap between the top flange of these spandrel beams and the underside of the existing limestone blocks above.

The renovation included structural probes into the older parts of the building, including the steel—still holding up—in the section built in the 1920s.

Simpson Gumpertz and Heger

Simpson Gumpertz and Heger

At some of the exterior bays, which were highlighted with limestone blocks, a temporary shoring system was used to support the limestone.

Sports Museum of America

The Heisman Trophy in its new home at the Sports Museum of America. Besides displaying sporting paraphernalia and artifacts, the museum also features several interactive exhibits.

During several site visits, we used a laser level to determine the interference between the back of the new stone with the spandrel beams and/or with the brick masonry, depending on the location. One of the possible solutions was to notch or cut the back of the new limestone blocks, but the stone subcontractor opposed this as it would have affected the integrity of the stone.

The team decided to locally remove the existing brick and/or cut the part of the bottom flange of the existing lower spandrel beams. The removal of part of the existing brick was a very risky operation, since we were not sure whether the load path for the support of the original stone above had been altered during the prior renovations at the storefront. The enigma was solved when we found valuable information in the original architectural drawings, which showed two beams located side by side at the second floor. The interior beam supports the second-floor slab and the exterior one supports the façade. In all but three bays, the contractor confirmed the existence of the upper spandrel beam through exploratory probes. At these locations we were able to temporarily support the original limestone, reinforce the existing steel to provide a new load path, and cut the steel and/or brick interference.

Three Bays

At the three remaining bays, establishing a new load path required a Herculean effort. We had to devise a temporary shoring system to support the limestone, but because of building infrastructure on the floors below grade, we could not place shores to the footings. At one bay, we cantilevered a shoring system from the spandrel beam. At the façade end we installed a post up from the cantilever beam to the underside of the stone, and at the backspan end we installed a post from the shoring beam to the underside of the floor framing. Once the load was redirected, we removed the brick masonry, installed a series of posts to the underside of the stone, and reinforced the spandrel beam.

At the second bay, the lower spandrel beam was below the elevations of the new windows and had to be removed. To temporarily support the 30-ft limestone piers at this location, we bracketed off the columns and installed an outrigger system. We designed needle beams that penetrated the masonry above the existing spandrel beam and redirected the load to the temporary shoring system. Once the contractor installed the shoring with needle beams, they removed the existing spandrel beam and installed a new spandrel below the needles. At the third bay, the lower spandrel beam was only slightly below the elevation of the new windows, and we were able to strengthen the beam and cut the bottom end that interfered with the window line.

The Sports Museum of America reinforces and preserves this country's history with sports—and by renovating the building that houses it, a piece of American architectural history has been reinforced and preserved as well. MSC

Kevin C. Poulin is a senior project manager and Filippo Masetti is a staff II engineer, both with Simpson Gumpertz and Heger.

Architect
Beyer Blinder Belle, New York

Structural Engineer
Simpson Gumpertz and Heger, New York

General Contractor
Structure Tone, New York


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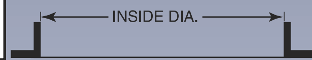
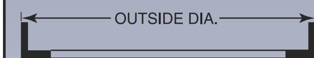


10"x10"x1" Angle

2 **Angle Rings Leg In**

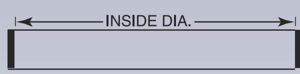


10"x10"x1" Angle

3 **Flat Bar Rings The Hard Way**

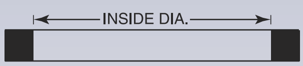
24"x10" Flat

4 **Flat Bar Rings The Easy Way**



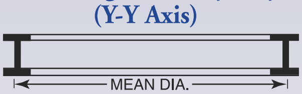
36"x12" Flat

5 **Square Bar Rings**



18" Square

6 **Beam Rings The Easy Way (Y-Y Axis)**

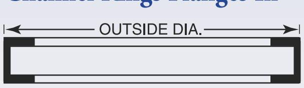


44"x 285#, 36"x 848#

7 **Beam Rings The Hard Way (X-X Axis)**

44"x 285#

8 **Channel Rings Flanges In**

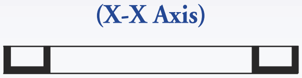


Any Size

9 **Channel Rings Flanges Out**

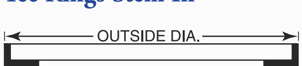
Any Size

10 **Channel Rings The Hard Way (X-X Axis)**



Any Size

11 **Tee Rings Stem In**



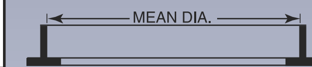
22"x142 1/2# Tee

We bend ALL sizes up to:

12 **Tee Rings Stem Out**

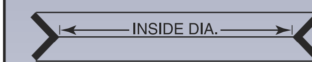
22"x142 1/2# Tee

13 **Tee Rings Stem Up**



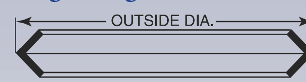
22"x142 1/2# Tee

14 **Angle Rings Heel In**



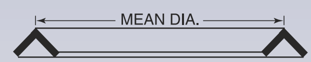
8"x8"x1" Angle

15 **Angle Rings Heel Out**



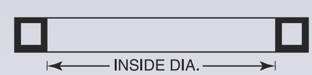
8"x8"x1" Angle

16 **Angle Rings Heel Up**



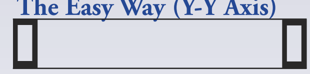
8"x8"x1" Angle

17 **Square Tube Rings**



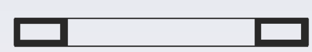
16" Square Tube
20"x12"x1/2" Tube

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



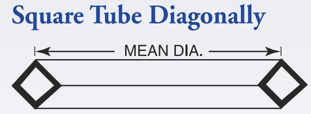
20"x12"x1/2" Tube

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



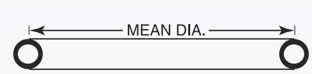
20"x12"x1/2" Tube

20 **Square Tube Diagonally**



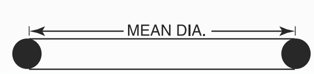
12"x5/8" Square Tube

21 **Round Tube & Pipe Rings**



20"Sched.80 Pipe

22 **Round Bar Rings**



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All Aboard

BY ASHLEY G. PARKER, P.E.

Photos: Jonathan Medlin/Design Development

A trackside structural renovation breathes new life into weathered warehouses in Raleigh, N.C.

DURING THE 1940s AND 1950s, WAREHOUSES built adjacent to the Seaboard Railroad Station in Raleigh, N.C. were bustling centers of commerce that served local textile mills and the busy Seaboard Railway. But as the textile industry and rail traffic flagged, the buildings were abandoned and fell into disrepair.

From a redevelopment and reuse standpoint, the brick warehouses had a lot going for them. At a total of 120,000 sq. ft, the three buildings sit on a 5.7-acre tract that spans three city blocks near downtown Raleigh and the popular Glenwood South entertainment district. Peace College and several mixed-income residential neighborhoods are close by, as are governmental buildings and several busy thoroughfares.

These characteristics prompted developer Trammell Crow to breathe new life into the structures. The proposal involved converting the boxy, vintage industrial buildings into the Shops at Seaboard Station, which would become Raleigh's only downtown shopping center.

The Challenges

Of course, converting three aging warehouses into modern retail space was no cakewalk.

"We were brought into the project early for a feasibility study to determine whether the buildings could be renovated to comply with current building codes and to support the new loads the developer anticipated," said Banning J. Reed, P.E., a principal at the Raleigh-based structural engineering firm Fluhrer Reed. "Though we determined a renovation was feasible, we knew going in that structural steel would be required to strengthen the existing building."

Steel was an important factor throughout the project, as the interior and exterior walls were reconfigured to accommodate one- and two-story shops as well as the large expanses of glass that would let light stream into the formerly dingy spaces. That meant punching holes through the existing brick walls both for windows and to accommodate pedestrian traffic.

"Steel was obviously the best solution for the project," Reed said. "We used it throughout the buildings to retrofit, strengthen, and repair. As we cut new openings through existing masonry walls, we created steel frames consisting of columns and beams to support the structure's weight."

To protect shoppers from the weather, the architect created a covered pedestrian walkway by recessing new storefronts behind the existing warehouse walls. That meant large openings would need to be cut in the exterior of each building to expose the new shops. It also meant significant changes to interior roof joists, and the design of a new system to resist the loads to be carried by the relocated storefronts.

"When the storefront was loaded, mainly due to wind pressure, the new lateral load had to be resisted," Reed said. "We designed a system of hanging steel angles and kickers, which were supported by the existing joists. The joists were not originally designed for this load condition, and based upon our analysis, required

A new two-story entry to the complex (shown from the interior, left, and the exterior, right) showcases trusses and a curved roof, hinting at the bow-truss roof inside the converted buildings.

strengthening. The resulting system consisted of L4×4 hangers and diagonal L4×4 kickers. The joists were analyzed and reinforced with steel plates on both the top and bottom chords, based upon the procedures and suggested details in the 2005 *Engineering Journal* article 'Strengthening Open-Web Steel Joists.'"

Similar issues were faced when the architect removed interior walls and reconfigured the space to split one of the warehouses into two separate buildings. Steel braced frames had been used for lateral resistance, and the existing long-span steel bow trusses required a new structural support. After reviewing several alternatives, structural steel was determined to be the best solution for the renovation as well.

In addition to steel's use as a structural element, it also became an important aspect of the look of the shops. The architect used exposed steel beams both inside and outside the buildings to preserve an industrial feel that harkens back to the site's original use. New exposed steel bow trusses were first designed for strength. However, larger sections were required by the architect to provide a more industrial appearance.

Oversized porches were added to the buildings to reduce the scale for pedestrians and to create outdoor common areas for dining and merchandise display. Each new covered entry area features exposed structural steel and bowstring trusses that mirror the materials and geometry of the historic Seaboard Railroad Station located nearby. Similarly, a new two-story entry to the

Fast Facts:

- The buildings: three 1940s/1950s-era warehouses on a 5.7-acre site
- Space: 120,000+ sq. ft
- Structural system: structural steel and reinforced masonry
- Lateral resisting system: reinforced masonry shear walls

Steel used:

- Columns: hollow structural sections (HSS) and W-shapes
- Bow trusses: HSS, steel rods, rolled WT members
- Steel lintels: W-shapes
- Other: HSS tubes, L-angles

complex showcases trusses and a curved roof, hinting at the bow-truss roof inside the converted buildings.

From Blight to Rebirth

Upon completion, the Shops at Seaboard Station renovation was immediately singled out for a community appearance award. An independent jury for the City of Raleigh's annual Sir Walter Raleigh Award competition recognized the project for its contribution toward making the city more attractive and livable.

Transformed from dark and dingy to bright and airy, today the Seaboard Station warehouses feature specialty shops, restaurants, a fitness center, and a grocery to serve nearby residents in what is now a vibrant and growing community.

"The project has had a tremendous impact," Reed said. "The area was really dead before, and now it's an important community hub teeming with people who come to shop or to have dinner on an outdoor steel mezzanine overlooking downtown Raleigh. We couldn't have asked for a better outcome." MSC

Ashley G. Parker is director of business development with Fluhrer Reed.

Developer
Trammell Crow

Architect
Design Development Architects, Raleigh, N.C.

Structural Engineer
Fluhrer Reed, Raleigh

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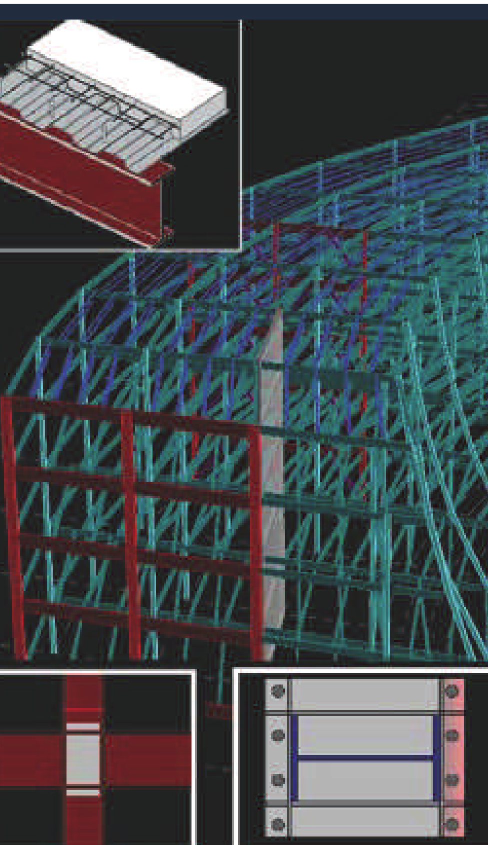

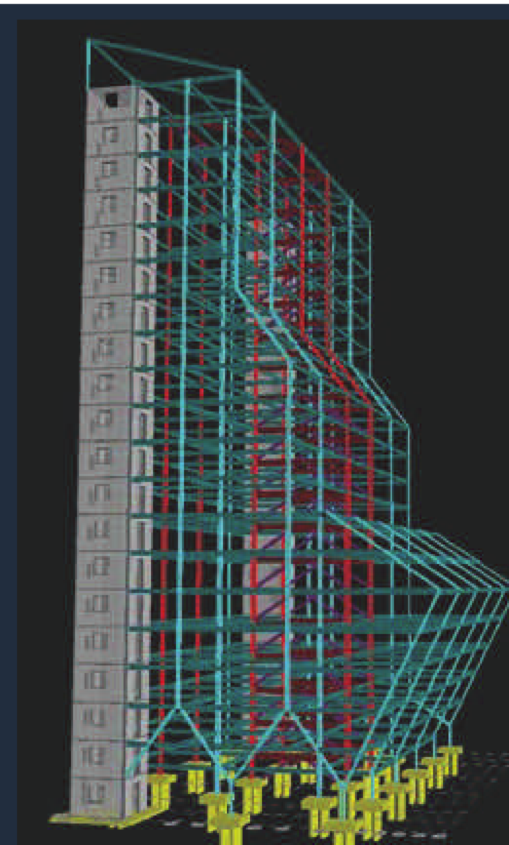

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Keeping Corrosion Contained

BY WING HO, P.E.

Corrosion doesn't need to mean the end for a steel parking garage.

THE SEPTEMBER 2006 MSC STEELWISE ARTICLE "Are You Next?" (available at **www.modernsteel.com**) suggested steel-framed parking garages built with a cast-in-place concrete slab on metal deck is suitable for less atmospherically corrosive regions. In fact, many steel-framed parking structures have been built in regions where corrosive de-icing salts are used and freeze-thaw cycles are present. As with all parking garages, an effective maintenance plan is the key. But what about a garage where maintenance has not kept up?

A program of repair, or a combination of repairs and partial reconstruction, often can be implemented to extend the service lives of steel-framed garages and avoid demolition. Such a rehabilitation program, completed mid-last year, was the case with a 25-year-old steel-framed garage in New Jersey.

The Existing Conditions

The framing of the garage was similar to that shown in Figure 3-2 of the AISC *Design Guide 18*. It had two 60-ft structural bays in the short direction and several 25-ft bays in the long direction. Heavy wide-flange girders spanning 60 ft connected the wide-flange columns in the short direction. Wide-flange filler beams and open-web bar joists at 4 ft on center spanned between the girders. The 4-in.-thick floor deck consisted of 3 in. of cast-in-place concrete over a 1-in. metal deck, reinforced with welded wire fabric. The slabs were built compositely with the beams, joists, and girders. Slopes were built into the slabs to drain water away from the exterior walls toward floor drains adjacent to interior columns.

All corrosion was typically initiated by water and de-icing salts entering cracks in the slabs. The salt and water trapped in the cracks then corroded the welded wire fabric and the metal deck. After the metal deck was corroded through, salt and water trickled down and affected the beams, joists, girders, and columns. The thin-gauge metal decks typically suffered the most severe corrosion, with the heavy steel girders and columns sustaining corrosion on the surfaces only; the filler beams and bar joists exhibited various degrees of corrosion. As a result, only the corroded slabs, beams, and joists needed to be replaced or repaired, while the girders and columns only required cleaning and repainting.

The Rehabilitation Program

Located at the high points of the slabs, the exterior walls and the adjacent floor areas had less contact with moisture and were in better condition than the interior floor areas. Therefore, only the slab areas and framing away from the exterior walls were repaired or rebuilt. During demolition, "picture-frame" slab areas along the exterior walls were maintained to preserve the diaphragm action of the slab to stabilize the exterior walls. Temporary bracing was also provided to limit the unbraced lengths of the girders and columns before the new slabs were installed.

Alternative slab systems were considered, including a cast-in-place concrete on Filigree system and a post-tensioned system. However, the increased dead load of these alternatives made them unsuitable for the replacement of the corroded framing. The only feasible option was a similar steel-framed system with cast-in-place concrete on metal decks. Since the minimum uniform design live load under the 2006 International Building Code is 40 psf and the existing structure was designed for a 50-psf live load, the replacement slabs could be 10 psf

Wing Ho is a senior project manager with TNW Engineering in Manalapan, N.J. He can be reached at wingho_pe@hotmail.com.

heavier without overstressing the existing girders, columns, and footings. This allowed a thicker replacement slab to be used. In the final design, a 5-in. replacement slab consisting of 3.5 in. of cast-in-place concrete over a 1.5-in. metal deck was selected. This thicker replacement slab was more cost-effective, as it required fewer filler beams. The filler beams were spaced at 8 ft, 6 in. on center. The thicker slab also provided adequate clear cover for the reinforcing steel.

When the corroded slab areas were saw-cut and removed, the typical cut edge was made at 3 in. from an existing bar joist, leaving a 3-in.-long slab overhang. During the erection of the new framing, a new filler beam was installed 3 in. away from the cut edge, or 6 in. from the existing bar joist. After the new slab was poured, the existing bar joist was connected to the new filler beam so that they would act in unison under live loads. Located directly over this combined steel member, the joint between the new and existing slabs was kept tight because it only experiences minimal stresses and movement. However, these joints were further protected with sealant and waterproofing coating as recommended by AISC *Design Guide 18*.

Methods and Materials

To maximize the durability of a rehabilitated steel garage structure and minimize future corrosion opportunities, the following methods and materials were used to keep water from entering the slabs, weep water out of the slabs, and make all metal parts more corrosion resistant:

- G90 galvanized metal decks were used as forms only. The slabs were reinforced with low-carbon, chromium reinforcing steel bars (ASTM A1035).
- Vented metal deck or holes in the bottom of the metal deck were provided to weep water.
- Galvanized wide-flange shapes were used to replace corroded filler beams and joists.
- Shear connectors for composite action were mechanically attached.
- Decks were attached with mechanical fasteners.
- Conduits were eliminated from slabs; cracks tend to form along embedded conduits.
- Details were configured to prevent water from accumulating on the structure.
- All joints in slabs were sealed with a waterproofing coating, following the recommendations in AISC *Design Guide 18*.
- Existing structural steel was cleaned and painted, following AISC *Design Guide 18*.

All structures can experience corrosion problems in harsh environments, and steel-framed parking structures are no exception. However, modern methods and materials are readily available for their rehabilitation, and new construction can be designed and built with much less maintenance required. For this 25-year old steel-framed garage, the majority of the structural components were suitable for reuse. A program combining repairs and partial reconstruction was easily implemented to restore the structure and extend its service life, and this project serves as an example for other steel garages requiring the same kind of attention. MSC

What to Fix First? Prioritizing Repairs

Very often, the construction budget and the requirement to maintain a certain number of available parking spaces combine to demand that repairs to a garage be performed in phases. The following are some ideas to consider when setting the priorities of repair items:

- First, close off heavily corroded areas. Stabilize these areas with temporary shoring if the damage is so severe that the capacity is insufficient. Perform repairs of these areas.
- Second, remove all overhead loose materials that may fall and inflict bodily injuries or property damage.
- Third, repair the joints and waterproofing coating on the top-level deck. Also, ensure that the drainage system captures the water from this level. Water intruding through or conveyed by the top-level deck could trickle down and affect all other levels. If the top-level deck is watertight and draining properly, there is much less water left to deal with, the building and the new repairs will be subject to a less corrosive environment, and the garage will enjoy a longer service life.
- Lastly, concentrate repair efforts on what is essential to safety and extending the service life of the building. Generally, it is not necessary to repair everything!

Holding On

BY BENJAMIN R. BAER, P.E., S.E.

You may not notice them, but you probably use them all the time: handrails and guardrails.

HANDRAILS AND GUARDRAILS are very often just another orphan component of buildings, like stairs, light-gage metal framing and other non-structural steel elements. But almost all buildings, from houses to factories to skyscrapers, have them. Yet there is often confusion about what the design criteria should be, who should be responsible for their design, and what materials should be used.

Handrail vs. Guardrail

The terms handrail and guardrail are often used interchangeably, although they have two different definitions. According to most building codes, guardrails (or guards) are required at the open side of elevated walking surfaces to prevent a fall to the lower surface. The 2006 International Building Code (IBC 2006) generally requires guardrails when the difference in elevation between the upper and lower surfaces is 30 in. or more. Handrails, on the other hand, are something that can be grasped for guidance or support while walking, usually on a stair. The biggest difference between a guardrail and a handrail is that the area below the top rail of a guardrail is infilled with additional components such that there is no opening large enough for a 4-in.-diameter sphere to pass through; this approximates the size of a small child's head. Openings should be small enough to prevent a child's head from entering, where it could become trapped with disastrous results.

The Occupational Safety and Health Administration (OSHA) has requirements for handrails and guardrails that apply to all permanent places of employment, except where only domestic, agricultural, or mining work is performed. OSHA generally requires a guardrail when the walking surface is elevated 4 ft or more above the lower surface. For guardrails, the OSHA standards require one intermediate rail approximately halfway between the top rail and the walking surface (as opposed to the closely spaced infill required by the IBC). Jurisdictions that do not use a model building code, or have adopted an older version of a model building code, may have less restrictive requirements than the OSHA standards, in which case the OSHA standards would govern the design.

Design Responsibility

The project architect usually shows handrails and guardrails on the architectural drawings. Sometimes, just a schematic representation of the desired architectural profile is shown; other times, all of the members' sizes are provided. Even in this case, project specifications very often require signed and sealed calculations from a specialty structural engineer (retained by the fabricator). It is important that the drawings and specifications be consistent and compatible. If there are specific member sizes or details required by the project design team, they should be shown on the design drawings. However, once specific member sizes or details are shown on the design drawings, the licensed design professional who signs those drawings—i.e., the architect or structural engineer of record—retains full responsibility for those member sizes or details, even if delegation language is included in the project specifications. If the project design team wants the fabricator's structural engineer to be completely responsible for the design of the handrails, only schematic information should be shown on the design drawings.

Structural Design Criteria

The 2006 IBC requires that handrails, guardrails, and their supports be designed for 50 lb per linear foot, applied in any direction at the top of the top rail, and a concentrated load of 200 lb applied in any direction at any location along the top of the top rail. The uniform load and concentrated loads are not to be applied simultaneously. Other components, including guardrail infill and bottom rails, are to be designed for 100 lb acting on a projected area of 1 sq. ft, including the open space between components. The effects of this load are not to be combined with the load on the top rail. One- and two-family residences need only be designed for the 200-lb concentrated load, and certain low-occupancy areas not accessible to the general public need only be designed for 20

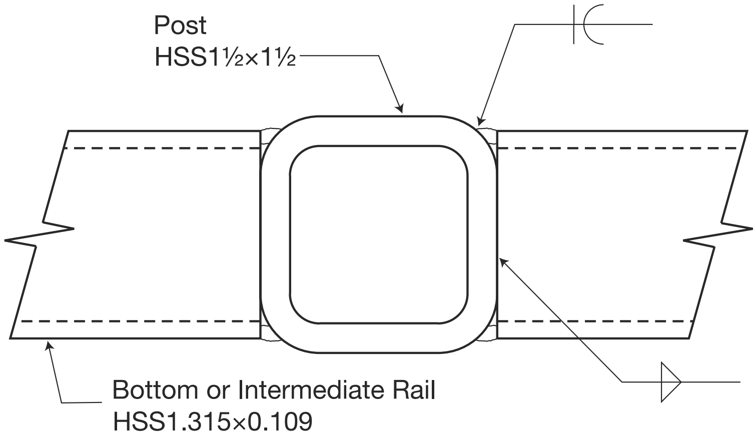


Figure 1.
Connection of bottom or intermediate rail to post.

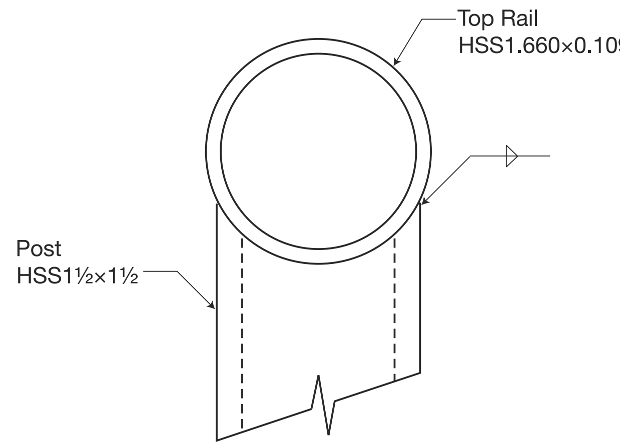


Figure 2.
Connection of top rail to post.

lb per linear foot, in addition to the 200-lb concentrated load.

OSHA standards require both guardrails and handrails be designed for a concentrated load of 200 lb applied in any direction at any location along the top of the top rail. These standards also include specific member sizes for railings constructed of wood, steel pipe, and steel angles. Other sizes and configurations are equally acceptable, as long as they comply with the strength requirement and provide at least the same level of protection as the stated sizes.

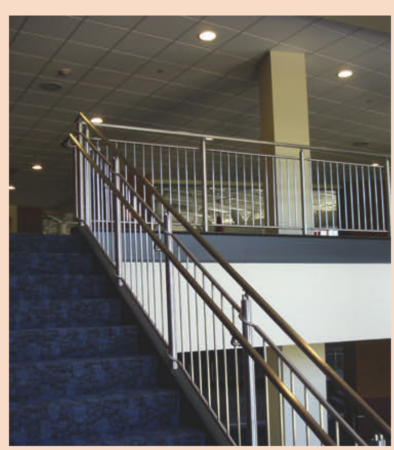
Since its inception in 2000, the IBC has permitted the allowable stresses for handrails and guardrails to be increased by one-third when the design is based on working stress. This provision, which does not appear in any other codes or specifications, is based on a perceived disparity between allowable (working) stress design (ASD) and load and resistance factor design (LRFD) for both steel and wood, and on the lack of widespread use of LRFD for wood. While this provision actually results in non-conservative and potentially unsafe design for critically important components, it has been continued in the 2006 IBC. Informally, there are efforts to remove this provision from the 2009 edition. Engineers are strongly urged *not* to use this stress increase.

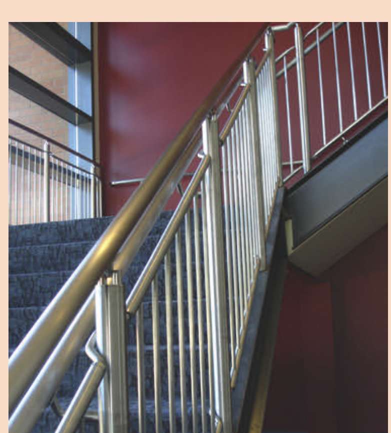
Handrail Size

The biggest source of confusion for handrails and guardrails is the diameter of the member to be gripped. When the Americans with Disabilities Act Accessibility Guidelines (ADAAG) were enacted in 1992, they specified a diameter of 1¼ in. to 1½ in. for the handrail, and the corresponding figures clearly showed this to be the outside diameter of the handrail. However, standard industry pipe and hollow structural section (HSS) sizes are not based on the outside diameter (or the inside diameter), and confusion arose almost immediately.

According to one source, the original ADAAG were based on an outdated version of the underlying American National Standards Institute (ANSI) A117.1, *Accessible and Usable Buildings and Standards*. At the time the ADAAG became effective in 1992, it was based on the 1986 version of ANSI A117.1, which stated that handrails were to be between 1¼ and 1½ in. in diameter. However, ANSI 117.1 had been revised in 1990 to clarify that the intention was to allow for nominal pipe sizes of 1¼ in. to 1½ in.

The ADA is a civil rights protection law (not a building code), and as such, enforcement of the pertinent sections is by the





Photos: Livers Bronze Co.

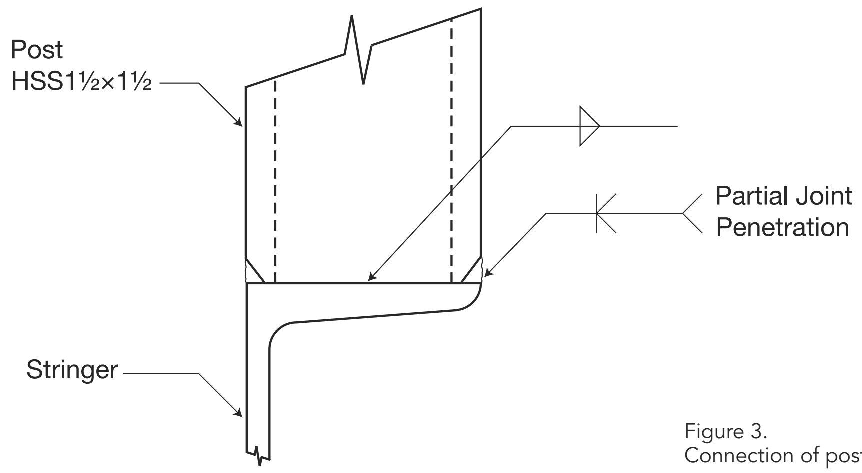


Figure 3.
Connection of post to stringer.

U.S. Department of Justice (DOJ). In 1993, DOJ issued a letter clarifying that 1¼-in. to 1½-in. standard pipe sizes (1.660-in. and 1.900-in. outside diameter, respectively) are acceptable for compliance with the ADA.

In 1998, the Access Board, a Federal agency that administers the ADA, published an explanatory manual on the ADAAG. It states that "standard IPS pipe designated as 1¼ to 1½ in. is acceptable." Further, the manual actually recommends the use of 1¼-in. pipe, because the diameter of 1½-in. pipe approaches 2 in., which is a bit too large to be comfortably gripped. To this day, the Access Board provides the same clarification among the "Frequently Asked Questions" on its website.

An updated version of the ADAAG was issued in 2004 and amended in 2005. This latest version changed the language on handrail size to eliminate the confusion, and only specifies a minimum outside diameter of 1¼ in. and maximum outside diameter of 2 in. This language is the same as that in IBC 2006, and in fact, earlier editions of the other model building codes—e.g., UBC 1991 and BOCA 1993.

Recommendations

There is no single handrail or guardrail design that will work for all situations. There are different functional code requirements, different load requirements, and different aesthetic requirements. Each handrail is unique, and each requires architectural and structural design by licensed professionals. Nevertheless, there are a few general recommendations that can simplify design, fabrication, and installation and result in a more economical solution.

To comply with the accessibility guidelines and strength requirements, it is recommended that the top rail be HSS1.660×0.109 (equivalent to the size of a 1¼-in. nominal Schedule 10 pipe). This material is commonly available as A500, Grade C (F_y=46 ksi), and the cost per lineal foot is about the same as the slightly heavier standard (Schedule 40) A53 pipe. There are no accessibility requirements for the bottom rail of guardrails, and they do not have the same load-bearing requirements of the top rail. Therefore, a slightly smaller, HSS1.315×0.109 (equivalent to the size of a 1-in. nominal Schedule 10 pipe) can be used. This too, is commonly available as A500, Grade C. These rail sizes are usually sufficient for most common post spacings.

It is recommended that posts be HSS1½×1½ to simplify the fabrication. This square hollow section is commonly available in 0.145-in., 3⁄16-in. and ¼-in. wall thicknesses as A500, Grade B material. The difference in cost between a round post and a square post is offset by the easier fabrication with square posts. When using a square post, the ends of the bottom rails do not need to be cut to fit around a circular section. The bottom rail can be fillet welded to the flat face of the post. The top rail fits well on top of the profiled post (Figure 1). Welds on the top rail provide structural strength and seal the top of the post (Figure 2). Also, the bottom of square post fits on the flange of common stair stringers members, or to the side of plate stringers. When attached to the top flange of stringer channels, the base of the post can be fillet welded on two sides and partial-penetration welded on two sides (Figure 3). The common stair stringer channel (MC12×10.6) has a flange width of 1½ in., which is too narrow for 1.9-in.-diameter HSS or pipe. One steel mill has begun producing a channel specifically for stair stringers with a 2-in. flange to accommodate 1.9-in.-diameter HSS or pipe.

For guardrails, there can be a wide variety of choices for the infill, such as individual pickets, glass panels, solid or perforated metal panels, or wire mesh. The simplest, easiest, and usually most economical choice is solid round or square bars for individual pickets. The diameter will depend on the distance between the top rail and the bottom rail, but will generally be ½ in. to ¾ in. in diameter. Nominal ½-in. pipe could be used, but it usually costs more than solid ½-in. or ¾-in. rod.

Wire mesh is an alternative for the infill in guardrails. While it would seem the installation should be easier than individual vertical pickets, this may not always be the case. Even though there are many more pieces to fabricate and install, individual pickets are usually less expensive than wire mesh. To be most effective, wire mesh should be manufactured from 6 or 7 gage wires (approximately 3⁄16 in. in diameter) to provide sufficient strength, and sufficient resistant to impact loads—i.e., kicking. The mesh should be lock-crimped or welded to keep the wires in place, and the openings should be no more than 2 in. square to prevent people from climbing on the mesh. When using wire mesh in high security applications such as correctional institutions, each wire has to be secured—i.e., welded—to a "U-shaped" perimeter steel frame to prevent removal of the wire, which could then become a weapon.

In 1993, the BOCA Code introduced a new provision for guardrails, stating that they could not have an ornamental pattern that would provide a ladder effect. A common guardrail design is a series of horizontal pipes as the infill. However, the horizontal pipes can be used as a convenient ladder, defeating the purpose of the guardrail. While this provision does not appear in the IBC or other codes, it is a good practice not to use infill that could be used as a ladder, especially in uncontrolled public areas. Aside from making for a safer barrier, it can help limit potential liability.

Specific Condition, Specific Design

Although there may be confusion about the responsibility or design of handrails and guardrails, a structural design is required for each specific condition. As with any component, the design must consider strength and serviceability, which includes ADA requirements.

Code requirements, material availability, and labor and material costs can affect efficiencies in design. (Note that the welding featured in this article is done to meet National Association of Architectural Metal Manufacturers standards and not necessarily those of the American Welding Society.) As always, it is good to check with a local fabricator to get the best information on feasibility and costs. MSC

Benjamin R. Baer is the president of Baer Associates Engineers, Ltd. in Skokie, Ill.

History of Standard Pipe Sizes

A better understanding of handrail size comes from a little background on pipe sizes. Standard industry pipe sizes are based on a system of nominal pipe sizes. Standard 1¼-in. pipe has an outside diameter of 1.660 in., and standard 1½-in. pipe has an outside diameter of 1.900 in. There is also "mechanical grade" tubing available with an outside diameter of 1½ in. However, this tubing is not manufactured to the material specifications referenced by the building codes for load-bearing components. The governing standards for steel components specify that handrail material must comply with ASTM A53 (pipe), A500 (HSS), or A501 (HSS), and there is no 1¼-in. or 1½-in. outside diameter material available that complies with these standards. Only standard industry pipe sizes are manufactured to meet these material requirements.

The exact origin of pipe size designations is lost to history. It is known that nominal pipe sizes were first tabulated around 1862 by Robert Briggs, superintendent of Pascal Iron Works in Pennsylvania. To this day, nominal pipe sizes are sometimes referred to as "Briggs Standard." The basis for Briggs' standardization is not known, but it is thought that his standard was based on the size of the dies used by Pascal Iron Works. One method of producing seamless pipe is by piercing a hot solid round bar or billet with a die. The bar is then worked with increasing sized dies to achieve the desired diameter and wall thickness.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Park Life

BY JEFFREY S. LEE, FAIA

An outdoor performance venue doubles as a modern, visual focal point in a revitalized city park.

IN SPITE OF LIMITED VENUES, the performing arts have long been embraced by the citizens of Fayetteville, N.C. Based on this love of the arts—and the subsequent need for more entertainment options—the city conducted a Performing Arts Needs Assessment in 2004. The findings indicated substantial community demand for an outdoor, multi-use performance space, and a plan was hatched to build such a venue.

The result is the Performance Pavilion at Fayetteville's new Festival Park; it is the major architectural element in the overall plan of the park. The park itself is near downtown on a decontaminated brown field, a site that had been used by a coal de-gasification operation in the 1930s. (From the 1940s until the late 1960s, the site housed a USO facility; it has been vacant since the 1970s.)

Multiple Materials

The structure is a layered composition of materials including concrete masonry units (CMUs), wood, concrete, cement board, and exposed structural steel. It consists of two components: a covered elevated stage and an enclosed rectangular volume housing back-of-house functions such as dressing rooms, restrooms, electrical and sound equipment rooms, and loading/storage. The back-of-house building is actually over to one side—stage left—allowing open views through the performance area to the backdrop of existing trees. Opaque panels on overhead tracks can be retracted from behind a wood scrim wall to serve as a backdrop and crossover when performances are taking place.

The use of structural steel was critical to meeting our design objectives. It was important that sightlines to the stage be completely unobstructed and that the architecture of the pavilion expresses a sense of excitement; columns could not be used to support the stage canopy. The solution to these two objectives in the end became mutually dependent—i.e., one informing and directly impacting the other. Keeping the front of the stage completely open to sight lines was achieved by suspending the butterfly-formed stage canopy with a system of steel masts and high-strength steel cables. The canopy itself was fabricated from tapered wide-flange sections and steel tube purlins and was designed to complement the lightness and translucency of the canopy roof, which is made from extruded polycarbonate. The high-strength steel cables connect to each end of the bent beam butterfly roof and terminate at steel brackets embedded in large

Photos: James West/JWest Productions

James West/JWest Productions

The Performance Pavillion project filled in an outdoor performance space gap in Fayetteville, N.C. The open-air venue, with exposed materials, sits in front of a backdrop of trees, connecting audiences with the natural beauty of Festival Park.

concrete footings beneath the stage. To resist uplift and high winds due to the threat of occasional hurricanes, the thin profile of the leading edge of the canopy is actually a steel plate. The plate is 2 ½ in. thick by 5 ft wide by 15 ft long and spans between the tapered bent beam assemblies. A total of 45,000 lb of plate load resists uplift. Water is channeled off the roof by a welded, galvanized steel gutter discharging into a receptacle at stage right.

Hollow structural sections were used primarily to provide diagonal bracing. The steel assembly tolerances, craftsmanship, and finish meet AISC criteria for architecturally exposed structural steel.

Maximum Exposure

Great attention was given to the detailing and fabrication of this project due to the

The canopy was fabricated from tapered wide-flange sections and steel tube purlins.

high percentage of exposed structural materials. Working collaboratively with the structural engineer, we were able to achieve a fairly delicate and refined structural assembly. For example, the bent roof beams are tapered toward their ends in response to loading conditions. Whenever possible, lighting and sound equipment conduit runs were coordinated and concealed within the structure; performance, work, and architectural lighting were thoughtfully incorporated within the steel structure. Architectural uplighting accents the underside of the canopy roof, while tightly focused spotlights on steel outriggers highlight the tops of the steel masts. Plates for making connections were water-jet cut. Bolt heads and nuts are oriented in uniform directions. Welds are continuous. And painted finishes were carefully specified for longevity and appearance (the paint used is a high-performance industrial enamel).

The result is a venue that has been widely accepted by the community, and requests for its use have exceeded the expectations noted in the earlier needs assessment. The project has also been noticed by the design community, having received local and state level awards from the American Institute of Architects. On top of all this, the unique steel structure of the stage canopy has become the defining, iconic image of Festival Park. MSC

Jeffrey S. Lee is a principal and the design director with Pearce Brinkley Cease + Lee Architecture.

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Fleming and Associates, Fayetteville

Steel Fabricator and Detailer
North State Steel, Greenville, N.C. (AISC Member)

General Contractor
Ellis Walker Construction Co. Fayetteville


From advanced aging...


To advanced engineering.

Miscellaneous Metals: The Devil is in the Details

BY TED HAZLEDINE

Miscellaneous steel is an intricate but necessary component of buildings—and requires intricate and necessary communication and documentation.

"ALL REQUIRED HANGARS, BRACING, SUPPORTS, and related metals, whether shown on drawings or not, shall be furnished by this contractor."

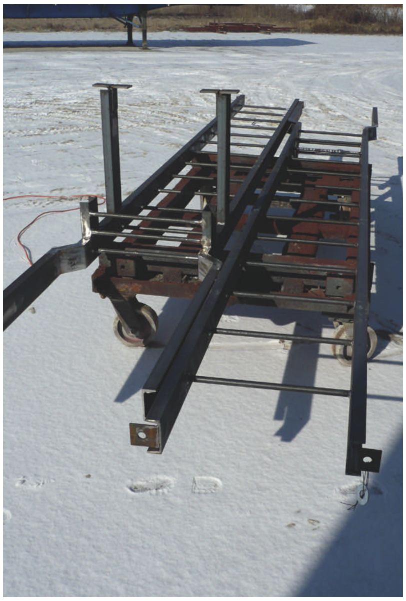
This and similar specification language has actually appeared in contract documents. Couple this potentially disastrous requirement with the occasional stipulation that the "contractor's bid shall conform to the prepared contract documents with no qualifications allowed" and you have a catastrophe-in-waiting. One attorney I've spoken with commented, "If you sign a contract with those terms and conditions, you don't need a lawyer—you need a psychiatrist."

Welcome to the everyday world of "Miscellaneous Metals." During the development of the architecture and structural frame of a building, additional framing, embedded items, and other metal items are added to complete the details of the project. These include steel items such as stairs, handrails, curb angles, hangars, ladders, mansard frames, and supports for mechanical units.

These items define the scope of work that will forever be known as miscellaneous steel or miscellaneous iron or miscellaneous metals. Regardless of the name, this scope of work includes the details sometimes identified and sometimes not, sometimes real and sometimes imagined, and can appear on any construction sheet of any document at any time throughout the project. Very often, the quoted scope is several pages long and usually includes the phrase "including and limited to."

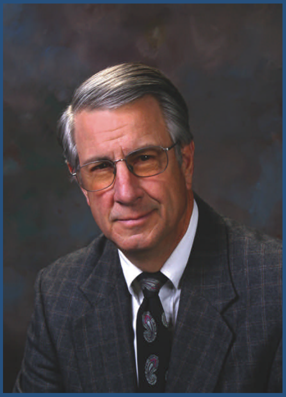
Miscellaneous History

The miscellaneous metals specialty has been in existence as long as construction in general but began in earnest with the development of cast iron at the beginning of the industrial revolution. Indeed, the first iron bridge built in the world, in 1779 in Coalbrookdale, England—which still exists today and is a national monument (now called Ironbridge)—is a large ornamental iron structural frame comprised of castings produced by the Darby Iron-

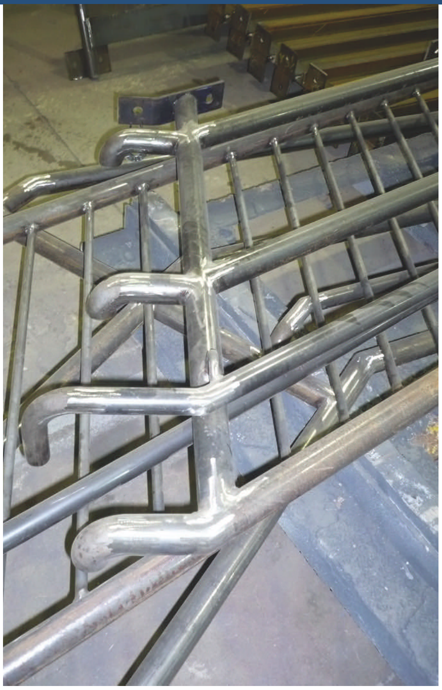


The word "miscellaneous" encompasses several types of steel, including shop-assembled stairs (left) and custom ladders (right).

Photos by Ted Hazledine



Ted Hazledine is president of Benchmark Fabricated Steel, a Terre Haute, Ind.-based fabricator of miscellaneous metals and structural steel.



Four-line handrails and picket rails for stairs also fall under the miscellaneous banner.

works. These craftsmen, artisans known as blacksmiths, also developed their forgings into handrails, gates, ladders, stairways, structural columns, and related ornamental metals. This craft, while shrinking, is still in existence and produces magnificent structures and artistic creations very much in evidence in virtually every city in the world.

As technology improved from iron to steel, the craftsman was now able to provide a wider range of structural materials, and many of the ornamental iron shops developed into providers of miscellaneous metals. Architecturally exposed structural steel (AESS) is an extension of the ornamental concepts that are now being applied to large structural frames.

Miscellaneous steel fabricators can probably claim to have the most widely varied experience of any construction professional. They touch virtually every aspect of the construction project, from embedded items in footings and slabs, to supports for doors, frames, and countertops, to supporting members from the framing system for overhead doors and mechanical and electrical units—plus, roof opening frames and miscellaneous materials required for the roof and the myriad of structural and bracing members required for mansards and other architectural creations as well. The list is considerable.

Miscellaneous Challenges

Very often, poor construction documentation places a large burden on the miscellaneous fabricator. Construction details are often lacking and it is apparent, in coordinating the scope of work for the structural and miscellaneous packages, when the engineer and architect did not coordinate the details and intent. Often, architectural details show a structural member or bracing component with a reference to the structural drawings that does not appear on those drawings or is different from the architectural detail.

Specifications are often vague and redundant. Specific directions on finishing are usually generic in nature and sometimes have no relevancy to the project at hand. Also, the language of specification in miscellaneous steel often refers to the need to provide supports, holes, and accommodations for other construction specialties whether directly indicated or required, even if not shown on the drawings. Clearly, this adds to the burden and risk of the miscellaneous fabricator. The quoted and defined scope of work and subsequent detailing can serve to identify where conflicts occur and the proposed solution.

Miscellaneous steel detailing can also be a challenge—as well as a huge expense, whether planned or unplanned. It is good construction practice to develop placing drawings (aka erection plans) showing the fabricator's understanding of intent, as well as solutions to conflicts for submittal and review by the designers. At the very least this generates discussion, which should lead to conclusions and decisions. Once approval of the placing documents is provided, piece detailing may commence. Sometimes, this is delayed by the need for field dimensions, which may be required to protect the fabricator as well as establish any conditions that were unknown.

An equal burden is placed on the erector of miscellaneous materials. Miscellaneous steel erection can be a risky and often complicated affair, and the erector must understand the intent and scope to accommodate the subsequent construction. The erector must be in the loop early in the project, including during shop drawing review. This advance knowledge will expedite erection and help avoid delays, inefficient use of site labor, and expensive multiple mobilizations.

Miscellaneous fabricators must understand and interface with virtually all of the contractors on the project if miscellaneous framing is required (a situation that can contribute to the depth of knowledge of miscellaneous fabricators). Like any other construction specialty, the level of expectation must be established between the miscellaneous fabricator and his or her customers—the architect, engineer, and owner—to avoid and hopefully eliminate misunderstanding and conflict.

Frankly and fortunately, the future is very bright for quality miscellaneous metal providers, as there will always be a need for the skill and knowledge required to provide this specialty. It is up to the industry to embrace the technology and innovations that have been developed—and those that will be implemented in the future—in order to compete in the market and provide the materials required. MSC

Out in the Open

BY KEITH A. GRUBB, P.E., S.E.

Weathering steel in architectural applications.

MENTION THE TOPIC OF WEATHERING STEEL to a group of designers, and two things usually come to mind: COR-TEN and bridges. COR-TEN is a trade name developed by U.S. Steel to market weathering steel. And bridges—well—they're the most common application for weathering steel today.

So what is this stuff? Weathering steel is a steel alloy containing quantities of copper, chromium, nickel, and other alloying elements that enhance corrosion resistance. When the steel rusts under normal atmospheric conditions, it forms a protective patina that bonds with the surface of the steel. Over a relatively short period of time, the patina forms into an impervious layer that precludes further corrosion. Minor damage to the coating is self-healing. In its early stages, the coating is a reddish-orange brown color. Over time, the coating thickens, the texture becomes a bit rougher, and the color deepens to a rich purple-brown. With the patina protecting the steel from further rusting, there is no need for the expense of painting the steel to protect it from the weather. Its low maintenance requirements and rustic appearance make it a popular choice for highway bridges.

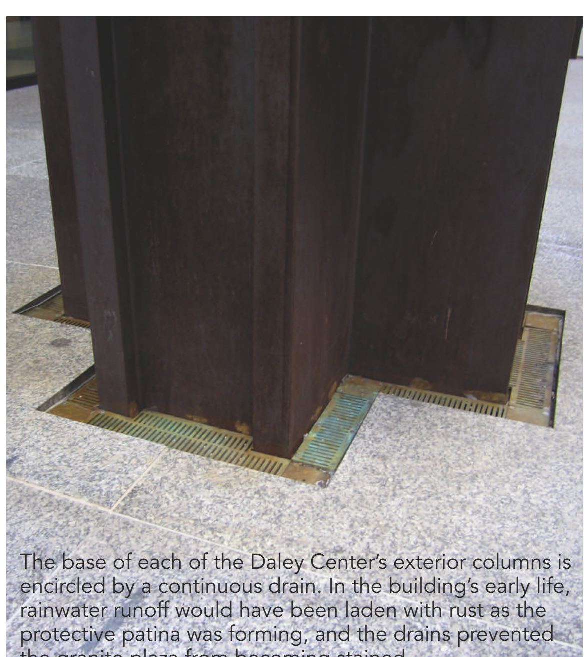
In the 1960s, the novelty of weathering steel (and its then-new 50 ksi yield stress) led to its application in buildings. Chicago's Richard J. Daley Center (1965) was the first building to be entirely built with exposed weathering steel. Interestingly, the plaza outside the Daley Center features a Pablo Picasso sculpture also made entirely of weathering steel.

Specification Specifics

ASTM A588 covers the majority of rolled structural shapes produced in weathering steel and can be considered the "base" specification for weathering steel for building applications. ASTM A709 is used primarily in bridge applications. Among its various grades, Grades 50W and HPS 50W are available in rolled shapes. Other grades such as HPS 70W, cover plates of various thick-

Photos by Keith Grubb

Chicago's Richard J. Daley Center, as well as its iconic Pablo Picasso sculpture, was the first building to be entirely built with exposed weathering steel.



The base of each of the Daley Center's exterior columns is encircled by a continuous drain. In the building's early life, rainwater runoff would have been laden with rust as the protective patina was forming, and the drains prevented the granite plaza from becoming stained.

Keith is AISC's senior engineer for research. Contact him directly at grubb@aisc.org.

ness ranges. ASTM A242 is the original COR-TEN specification, which varies in yield strength from 42 ksi to 50 ksi depending on the shape or plate thickness. HSS with weathering steel characteristics are available as ASTM A847.

Buying Basics

Because of the "exotic" nature of using weathering steel for building applications, AISC's Steel Solutions Center often gets questions about the availability of weathering steel. Usually, relatively small quantities are required for specific architectural features, such as pedestrian bridges or canopies. An informal survey of AISC-member steel service centers found that many had at least some ASTM A588 material on hand for immediately delivery. Some had extensive inventories (angles, channels, W-shapes, bar, sheet, and plate), and those that didn't stock it would source it or could recommend another supplier. For a complete list of AISC-member service centers, visit **www.aisc.org/servicecenter**.

HSS in weathering steel grades are somewhat more difficult to come across. According to Jim Collins, vice president of marketing for Metals USA, weathering steel HSS may only be available from one or two specialty service centers in the U.S. (See "Rare Shapes," next page.)

Keep in mind that the weathering-steel-for-buildings market is extremely small: The most extensive inventory at any one service center was in the 200- to 300-ton range, and that total includes *all* shapes stocked. For projects of any size, getting into a mill's rolling schedule is definitely something to consider and discuss with a local fabricator or service center.

Location, Location, Location

Frequent wet/dry cycles are key for the protective coating formation. Moisture from precipitation and dew, dried by the wind and sun, is essential for the formation of the patina. Because of this, weathering steel isn't a good choice in environments that are constantly wet or humid—where the steel can't dry. Also, weathering steel is not recommended for subsoil applications because the chemistry of some soils can corrode the steel.

Applications where the steel would be subject to salt spray, salt splashing,

On the Road

Short-span bridges are ideally suited to weathering steel. Jim Collins of Metals USA notes that his company stocks W24, W27, W30, W36, W40, and W44 beams. They have supplied steel for bridges in the 150-ft to 200-ft-long range, with girder lengths of 60 ft to 80 ft. ASTM A588 is the most common specification he sees, and Metals USA supplies Charpy testing upon request. Collins has noticed a trend towards the use of W40 and W44 sections in the bridge market. For more information about using weathering steel for bridges, visit **www.aisc.org/weathering**.

The Box Elder Creek Bridge in eastern Colorado (a 2007 National Steel Bridge Alliance Prize Bridge Award winner; see 11/07 MSC) employs W-shape weathering steel.

or salt-laden fogs from de-icing salts or coastal conditions are not good candidates for weathering steel. Salt precludes the development of the protective patina and dramatically accelerates corrosion.

Devilish Details

The success of Chicago's Daley Center, from an aesthetic perspective, is largely due to the control of rainwater runoff and good maintenance. For example, the base of every exterior column is encircled by a continuous drain. In the building's early life, rainwater runoff would have been laden with rust as the protective patina was forming, and those drains prevented the granite plaza from becoming stained. Rust stains on the stone plaza from the façade of the building appear to be minimal, probably due to periodic stone maintenance. Also, the good condition of the columns is a sign that corrosive de-icing chemicals have either not been used on the plaza or have been kept away from the steel.

Other Details to Watch for

Design for drips: Pay attention to drainage details by controlling rust-laden runoff. Drip pans and overhangs can keep water away from stainable surfaces below. Detail exposed slab expansion joints (such as in pedestrian walkway slabs) with troughs below to catch runoff if the joint fails. Masonry surfaces subject to runoff can be sealed or coated to minimize stain penetration. After the steel's initial weathering process, staining is much less intense, so often the stained coating can be sandblasted off (taking the majority of the rust stains with it) or left to weather away (with the rust stains slowly fading over time). The best way to avoid staining altogether is to positively control runoff.

All wet: Consider how rainwater or snow melt will drip, run, or pool on the structure. Uniform wetting and drying will create a more uniform patina and minimize streaks. Hollow or box members should either be sealed or designed with drainage and vent holes—and screened, if necessary.

Fastener facts: To maintain the same appearance characteristics, Type 3 (weathering steel) versions of ASTM A325 and A490 bolts, nuts, and washers, are available. Galvanized fasteners are also used when appearance does not have to match. Besides the obvious difference in color, runoff from the zinc in galvanized fasteners can leave a light-colored stain on the weathering steel. DTIs (direct tension indicator washers) aren't available in weathering grades, so they should be galvanized and epoxy-coated if used.

Weld wisdom: AWS D1.1 includes provisions for welded joints with weathering steels. Although standard welding electrodes will produce welds with adequate strength, special welding electrodes have been developed that produce welds with the same weathering characteristics as weathering steel itself. Single-pass fillet welds made with standard electrodes generally include enough infused base metal to resist corrosion but will not have the same appearance as the weathering steel. The bottom passes of multi-pass welds can be made with standard electrodes (and finished with weathering electrodes), but special attention must be paid to the ends of welds to make sure the weathering electrode pass is on the surface. Because of this—and because of appearance issues—it's generally best to use weathering steel electrodes for all passes of multi-pass welds.

Keep it clean: The surface condition of the steel has a direct bearing on the weathered appearance of the steel. For exposed areas, it's a good idea to blast-clean the steel to remove mill scale if a uniform appearance is desired early in the life of the structure. Otherwise, the mill scale will weather away eventually, with no adverse affect on the strength of the member. Commercial blast-cleaning (SSPC-SP6) removes oil and grease and most of the mill scale and rust, producing a relatively uniform weathered appearance.

Handle with care: Any weathering steel that will be exposed should be handled carefully to avoid unsightly scratches and gouges. Keep weathering steel away from dirt and debris, and during construction protect the surface from concrete spills, mortar spatter, and other foreign substances. Wax crayon markings should only be used in inconspicuous locations but can be cleaned off with suitable solvent cleaning. Solvent cleaning will also remove oil and grease. None of these appearance issues have any affect on the performance of the steel. MSC

Resources

More detailed information on all of these tips is available online at **www.aisc.org/weathering**. Posted resources include:

Steel Bridge Design Handbook, Chapter 23: **http://www.steelbridges.org/pages/designhandbook.html**

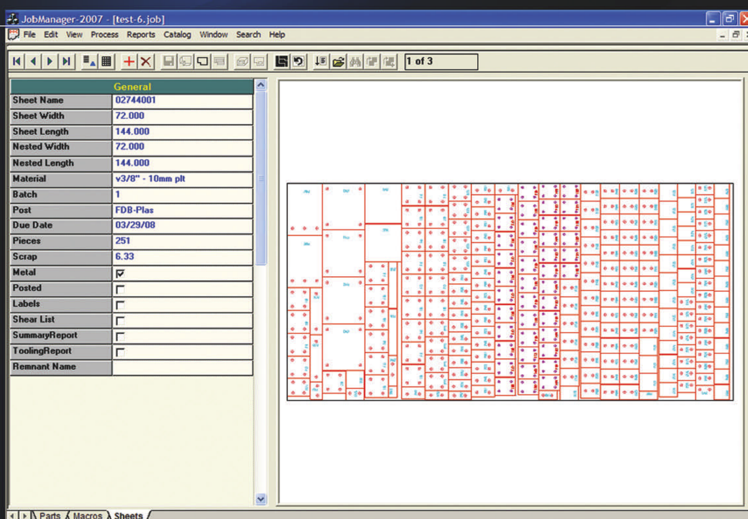
NSBA White Paper: *A Primer on Weathering Steel*: **http:www.steelbridges.org/pdfs/Weathering.pdf**

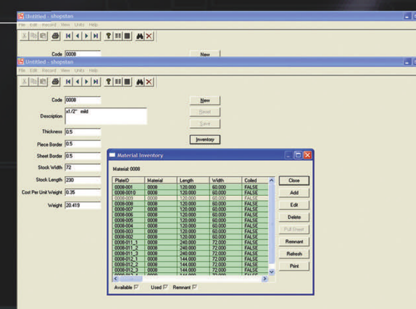
Arcelor-Mittal: "A Technical Overview of Weathering Steels for Bridges and General Construction"

Rare Shapes

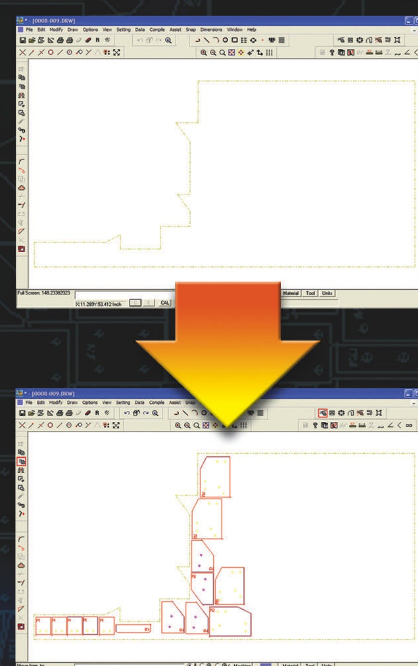
For hard-to-find weathering steel shapes, one source to try is the aptly named A588 and A572 Steel Company (**www.a588a572steel.com**), which has locations in Birmingham, Ala. and Sewickley, Pa. According to Rhonda Heatherly, sales manager, A588 Co. stocks weathering steel varieties of just about all common connection materials: rolled angles from ¾-in. legs up through 8-in. legs; channels; and flat bars up to 8-in. wide. Sheet steel is available in thicknesses starting at 16 gauge up to 6-in.-thick steel plate.

Automatic EdgeStart Nesting





Remnant Tracking



Remnant Nesting

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Business Velocity: An Introduction to Lean Six Sigma

BY LARRY MARTOF

Is your business moving in the right direction?

EVERY BUSINESS WANTS TO ACCOMPLISH THREE KEY BUSINESS GOALS: lower costs, increase profits, and exceed customer expectations. If you can meet and sustain these three goals, then you have built a successful business—but is it moving forward and is it sustainable?

Enter the concept of "Business Velocity." To best describe this term, let's break it apart. "Business" is obviously what you do, whether that is steel fabrication, erection, manufacturing, design, servicing, or some other element of the steel world. "Velocity" is defined basically as speed and direction. When we combine them, we have a company or business with speed and direction, or velocity. Now you may be asking, "How do we obtain speed and direction?" By deploying advanced, proven improvement tools found in the methodologies of Lean Six Sigma.

Lean (aka Lean Manufacturing, Toyota Production Method, Throughput Design, and some other monikers) is defined as the continuous systematic pursuit of the elimination of waste. This waste (or "muda," in Japanese) takes on many forms, which can be described by the acronym DOWNTIME, as follows:

- **D**efects resulting in rework and scrap.
- **O**verproduction resulting in cost and space burden of excess inventory.
- **W**aiting, such as one process waiting for another process to complete before it can begin.
- **N**on-utilized talent—the waste caused by having the wrong person in the wrong position.
- **T**ransportation waste, which occurs when product is moved around without any value-added activities.
- **I**nventory waste—excess raw materials that are not being processed.
- **M**otion, the wasted human movement—not having what is needed where it is needed.
- **E**xtra processing as seen in redundant steps, duplicated work, or data and energy waste.

This "leaning" of the business is accomplished by targeted improvement efforts, which eliminate or reduce any of these areas of waste. By eliminating waste the process becomes more efficient or faster, and hence speed is added to the business. It is important to look for waste across the business, not just in the production areas. Waste occurs in the front office, design, detailing, project management, scheduling, bookkeeping, purchasing, and even in the conference room. (When was the last time that you couldn't find that dry-erase marker when you needed it?) Waste in these areas is often referred to as the "Hidden Factory." It is not obvious unless you are actually looking for it. Before we explore the Hidden Factory and its counterpart, the "Visual Factory," let's first look at the concept of Six Sigma.

As we mentioned earlier, we need speed and direction to have velocity. The Six Sigma methodology provides the direction. Now, you might be thinking that Six Sigma doesn't fit your process; you don't make thousands of widgets that are identical. I always hear folks say that steel construction is unique; every project is different and requires different things.

Although it is true that every project may be different, every project uses our processes and every project has one thing in common: Every project has a customer. Actually, every project has many customers. There is the customer that owns the project and is paying for it, there are the customers that will use the project (i.e., those who drive across our bridges, climb our stairs, occupy the offices we build, etc.), and there are the customers all across the supply chain whom we must interact with and satisfy. This idea of "customer" is what Six Sigma is all about. It's not about statistics, green belts, black belts, and hugely expensive training and capital investments that only large corporations can afford. It is about customers throughout the building process.

Six Sigma is defined as the scientific and systematic approach to quality-based improvements driven by the voice of these customers. The use of statistics or statistical process control (SPC) is just one of the tools in the Six Sigma toolbox that you may or may not use.

We have just stumbled upon a really good analogy: this idea of a toolbox. When we really look at Lean and Six Sigma, we are looking at two sets of tools. Think about the last time you attempted to do some maintenance on your car. You needed some standard SAE fractional-sized wrenches and you probably needed some metric tools too. Then there is the ever-handy adjustable wrench that can work with both. Think of Lean as your SAE wrenches and Six Sigma as your metric wrench set. As for that adjustable wrench, well, some tools can be used for Lean- *and* Six Sigma-based improvements. So by putting all of our tools in one toolbox, we get Lean Six Sigma, which in turn gives us the power of speed and direction: velocity.

There are a lot of tools in the Lean Six Sigma toolbox, and finding the right tool to fit your needs is important. Sometimes, we have to try a couple of different tools before we find the one that fits. Earlier, we mentioned the Hidden Factory that is everywhere in our companies. We need to transform this Hidden Factory into a Visual Factory where we can see and eliminate the waste and hear the voice of the customer.

In Part Two of this article, we will look at a few of the basic tools that we need to uncover the Hidden Factory and provide for a Visual Factory that is focused on reduced costs, increased profits, and total customer satisfaction. Keep watching Quality Corner for this second installment, where we reach into our Lean Six Sigma toolbox and discover how others have used these tools to achieve improvements. MSC

Larry Martof is president of Process Improvement Solutions and is an ASQ Manager of Quality/Organizational Excellence and ASQ Certified Quality Auditor; a RAB/QSA Lead Auditor—ISO9001, consultant for TS16949, and AS9100; and a Certified Lean Six Sigma Master Black Belt.

Quality Corner is a monthly feature that covers topics ranging from how to specify a certified company to how long it takes to become a certified company. If you are interested in browsing our electronic archive, please visit **www.aisc.org/QualityCorner**.

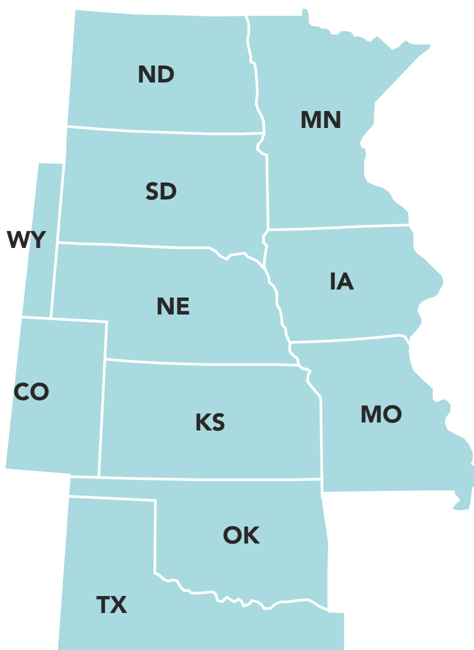
Plain(s) and not so Simple

BY ERIKA WINTERS-DOWNEY, S.E

When it comes to steel in the Great Plains region of the U.S., thoughts on its use are as wide-ranging as the region itself.

GREETINGS FROM THE MIDWEST! I'm the Great Plains regional engineer for AISC.

In a nutshell, the middle of the country is mine. I represent the states of North Dakota, South Dakota, Nebraska, Iowa, Minnesota, Missouri, Kansas, Oklahoma, and portions of Texas, Colorado, and Wyoming.



As a regional engineer I am the face of the steel industry in my region, a liaison between the design community and the steel production and fabrication community, and a resource for designers when it comes to project-related inquiries regarding structural steel. Do you want to know the current price at which structural wide-flange beams are trading? Find out the current backlog and inventory of your local service centers? Learn about architecturally exposed structural steel or LEED credits relating to steel? That's what we regional engineers are here for!

Another task of AISC's regional engineers is to give presentations at conferences, meetings, and individual firms. I usually have the opportunity to give about one a week, to individual firms or to associations regarding the above topics. At the 2009 NASCC: The Steel Conference in Phoenix (April 1-4; visit **www.aisc.org/nascc**), I will give a presentation on the rules of thumb for cambering beams. I hope to meet many of you there!

HSS, BIM, etc.

I recently took over the duties of organizing AISC's HSS Producer Committee. If you have project-related questions relating to HSS use, the committee's site has a number of resources for the design and construction community (**www.aisc.org/hss**). Or you can always contact the AISC Steel Solutions Center (call 866.ask.aisc)—and/or me directly. In 2009 we will be sponsoring tours at several HSS production facilities around the country and giving an accompanying presentation on the production, uses, and design of HSS members (when available, the schedule will be posted on the AISC website).

I'm also involved with my local U.S. Green Building Council chapter as the liaison to university USGBC chapters in the greater Kansas City area. I am involved with a Kansas City area-based building information modeling (BIM) collaborative, which meets monthly to discuss ideas and questions relating to this exploding technology. As most designers look to the steel industry to lead the way in this technology, I will be seeking out other similar BIM groups in my region so that attendees can have a face and name to contact with steel-related BIM questions. If you're involved with one of these groups, I'd love to hear from you.

My region is large and diverse (and snowy this time of year). Some areas tend to favor steel construction and some favor other materials. This can be due to local politics, labor supply, and even designer experience and preference. Presenting developers and designers with current and local information on design practices and steel supply—and connecting them with local fabricators—has been, in my experience, the best way to be of value to design teams. Your regional engineer, whether it's me or one of my colleagues, can make sure you have the most up-to-date picture of structural steel options on your project.

Please check out my page via the "My Region" channel on AISC's updated website (**www.aisc.org**) to view my upcoming travel schedule. I will be including photos of steel construction in my region, as well as a short blog about my recent and upcoming activities. MSC

*Erika Winters-Downey is the AISC's Great Plains regional engineer. She can be reached at **wintersdowney@aisc.org**. She has a Bachelor of Science in Architectural Engineering and a Master of Science in Civil Engineering from the University of Kansas. Prior to joining AISC in 2005, she worked for Wallace Engineering in Kansas City and Halvorson and Partners in Chicago.*

Keeping Candidates Interested

BY TIMOTHY R. JOHNSON

The economy won't stay down forever, so it's a good idea to maintain relationships with potential employees who are waiting on-deck for when work picks up.

WHEN WORK SLOWS DOWN, firms subsequently slow down hiring. No surprise there; it's simple business math. Less work equals not only fewer projects to keep employees busy and productive, but also less money in the budget to pay new hires. So, yes, even though there are benefits to recruiting when work is slow, many companies hold off on hiring new staff members.

Sometimes a slowdown in work is foreseen well in advance. But sometimes it happens all at once. And sometimes it happens when in the midst of actively recruiting new top-talent employees. When that occurs, firms are faced with a tough decision. Let's say you have a great candidate whom you've recruited for a key position in your firm, one who is both highly qualified and seriously interested in joining your organization. Then your firm loses a big project unexpectedly. Work dries up faster than anticipated, as the scorching rays of a slow economy beat down from every angle. Do you hire the candidate even though the work and the finances are no longer there? Do you turn down a top-notch prospective employee and let him or her stay on board with your competitor, or even lose the candidate to yet another competitor? Though this may seem like an "A" or "B" decision, the best approach is option "C." That approach is to keep the candidate interested in the opportunity with your firm—without seeming to simply string him or her along—until work picks up again and you can safely make that key hire. Here are some things to consider:

Schedule additional interviews.

If an initial interview has already taken place, set up a day and time a week or two out to have the candidate come back and meet with you again. Include additional decision makers in subsequent interviews and allow the candidate to meet one-on-one with peer employees as well. Not only will this keep the candidate in the process and interested, it will also allow the candidate to learn more about your firm in a rewarding fashion—and allow you to learn even more about the candidate.

Keep in regular contact with the candidate.

One of the biggest mistakes that I've seen many firms make is to let too much time lapse between communications with a candidate. This gives the impression to the candidate that he or she has been forgotten, suggesting that the company is not interested in him or her, even when that is surely not the case. The easiest way to avoid this is to maintain regular contact. Place a call or simply send an email to the candidate every week with an update or just to touch base. This lets the prospective hire know that you're still thinking about him or her, and thus are still interested. Do this in a professional but friendly approach, and don't be afraid to, as some say, "show some love" in letting the candidate know that his or her time and patience are greatly appreciated. Quite simply, this will help to keep the candidate interested, as well.

Give the candidate further information to review.

During an additional interview or in an e-mail, give the candidate more information about your firm for his or her perusal. This information can be an outline of your firm's benefits package, notes on an exciting project your firm is currently handling, details on your strategic plan, or simply results from a client or employee survey. Again, this helps to keep the candidate well informed and maintains his or her interest as time passes.

Offer an approximate timeline.

If trying to buy time, be sure not to waste any, be it the candidate's or your own. If you anticipate your firm will win a new job and allow you to make the new hire in a month, let the candidate know that he or she could expect an offer within a month's time. If you honestly don't know when you will be able to make the hire, be honest with the candidate. Usually, gainfully employed recruits will not be in any rush to jump ship, so make it clear that you are still interested but also not in a rush.

Explain the importance of the hire.

Let the candidate know that the position for which he or she is being considered is of high importance to your firm—as every key hire should be. Make it clear that while you do want to see the position filled, you want to assure that due diligence is followed to be certain that both sides are satisfied.

Following these steps can go a long way in maintaining the interest of a top-talent individual who would surely benefit your firm. Beyond that, it can also help to create a positive image of your firm within your industry. When firms ignore recruits whom they've interviewed or try to rekindle forgotten relationships with prospective hires, this can eventually create bad feelings. Understandably, when work dries up, companies focus their time and efforts on winning new jobs, as they should. Just don't neglect promising recruits during such situations or you may lose great potential employees once you win new work. MSC

Timothy R. Johnson is a principal at GCA International, an executive consulting firm serving the green building and design industry. He can be reached at tjohnson@gcaintl.com.

Different Angles

BY EDDIE WILLIAMS

Reducing fabrication and erection costs of shelf-angle supports.

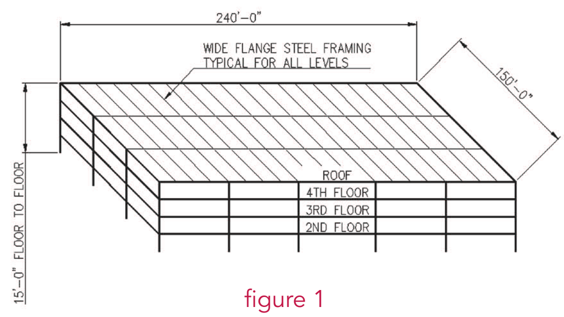


figure 1

A VARIETY OF DETAILS can and have been used for external brick support framing on multi-story buildings. The Steel Erectors Association of America (SEAA) recently conducted a survey of five erectors and six fabricators to determine how fabrication and erection costs compared for a few common details. Each firm was given a sample building plan and asked to provide their assessment of the various details.

The sample building (see Figure 1) is 240 ft by 150 ft in plan and has three framed floors plus a roof. All bays are 30 ft by 30 ft, beams and columns are W-shapes, and the floor construction is concrete on metal deck. The roof construction is insulation on metal deck. Suitable access exists for lifts and hoisting equipment around the entire perimeter.

Each firm compared three systems, as follows:

System 1: Conventional L3×3×¼ angle hanger and diagonal at 4 ft on center with L6×6×½ shelf angle. Shipped cut to length with slotted erection holes. Field welded after alignment. (See Figures 2 and 3.)

System 2: Similar to System 1, except with a vertical frame shop welded in 30-ft sections and diagonals shipped loose. (See Figures 4 and 5.)

System 3: Horizontal HSS14×6×½ shop fabricated in 30-ft sections with shop-welded L6×6×½ shelf angle. HSS is supported at columns with provision for vertical and in-out adjustments. Optional hanger and diagonal at center. (See Figure 6.)

Each firm was asked to estimate the work hours per linear ft for each option. Following is the average of the 11 estimates:

	System 1	System 2	System 3
Fabrication	0.32 hours/ft	0.63 hours/ft	0.16 hours/ft
Erection	0.65 hours/ft	0.47 hours/ft	0.14 hours/ft

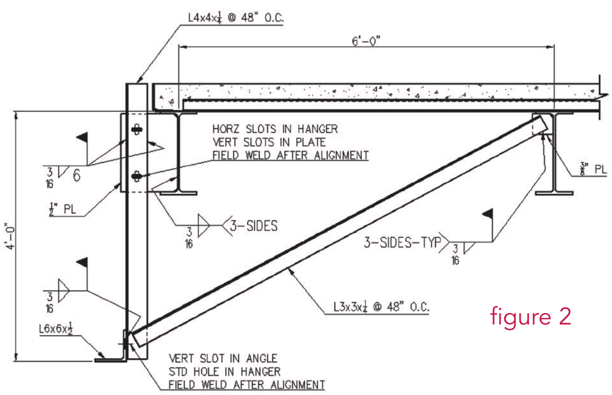


figure 2

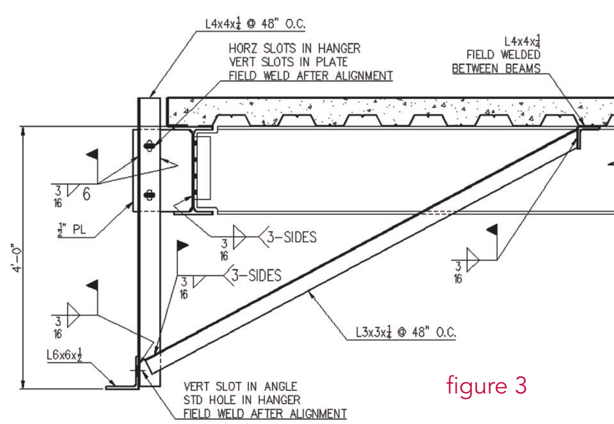


figure 3

For cost in dollars wage rates with overhead, profit, etc. for different geographic areas can be applied.

Material costs also must be considered. At the time of this study, even after allowing for the greater weight of the material used in System 3, its cost was at least 25% less than Systems 1 and 2, which were very close in cost. (While cost was about equal for Systems 1 and 2, it should be noted that System 2 requires less installation time than System 1 and can be a useful approach when this conventional detail is used.)

Eddie Williams is the CEO of Buckner Companies (an AISC Member Erector) in Graham, N.C.

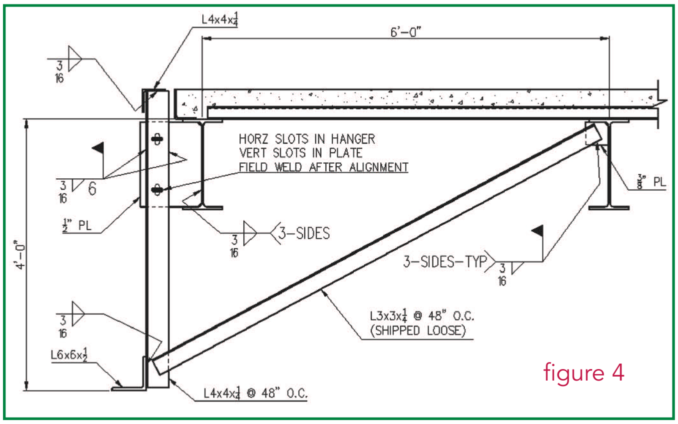


figure 4

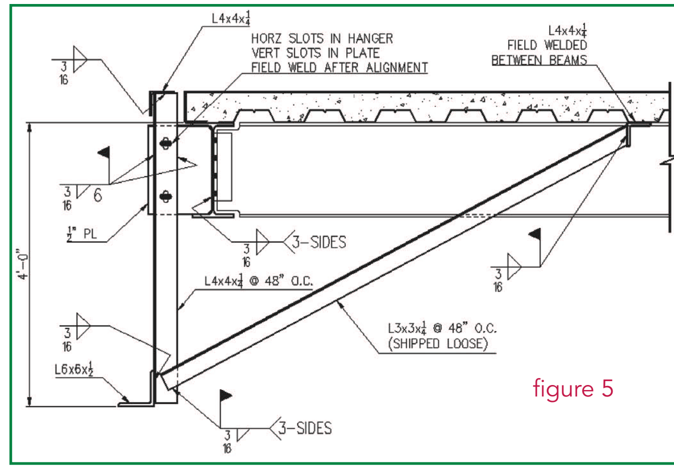


figure 5

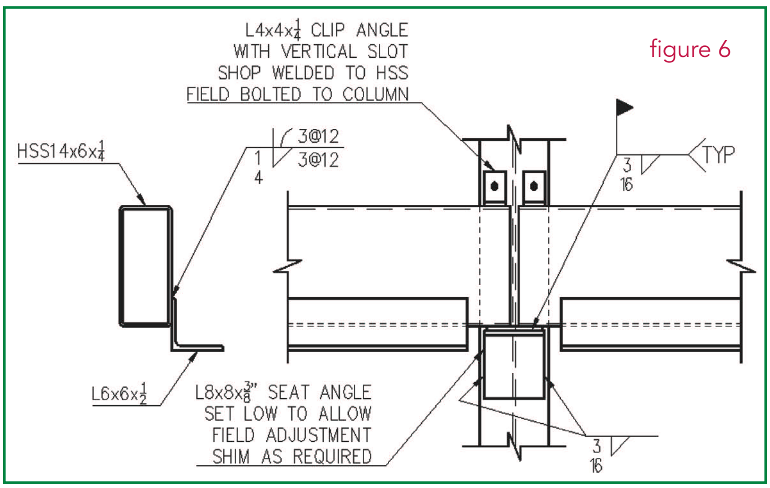


figure 6

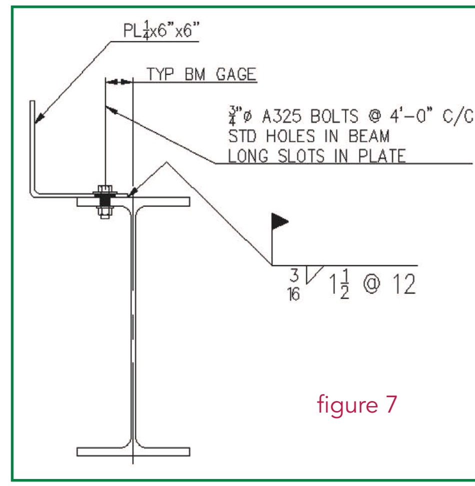


figure 7

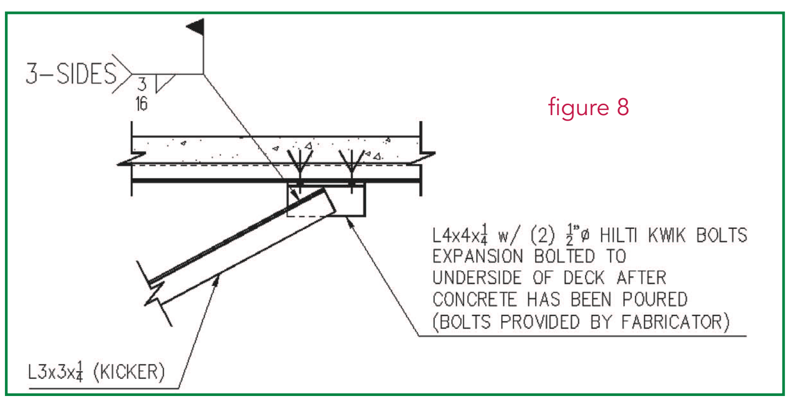


figure 8

All details were provided by Frank Bland with SteelFab, Inc. (an AISC Member Fabricator).

In addition to the potential for lower labor and total cost, System 3 offers several advantages over Systems 1 and 2, including:

- Shorter installation time
- Earlier start for masonry trades and other related material installation
- Lower exposure to safety hazards
- No need to wait for floors to be poured and camber in beams to adjust prior to alignment
- Significant improvement in overall project schedule

Some other comments that may help improve economy in perimeter details:

- Tolerances generally mean that shop attachment of perimeter angles or bent plates is not a viable approach. Instead, consider the use of angles or plates that are temporarily shop bolted with slotted holes that provide for the necessary field adjustment. If required, field welding can be performed for the final connection after field adjustment. (See Figure 7.)
- Field welds should be shown for actual weld required, not as "weld all around."
- Attachment of diagonal braces to the underside of the deck with post-installed anchors can be very expensive. It may be less expensive to provide an angle or other suitable framing element between beams (see Figures 3 and 5) for attachment of diagonals when the diagonal frames parallel to the beams.

So, what should you do on your project? Send this article to a steel fabricator in your area and ask them how this study compares to the results you might achieve. For further discussion, consider the details and guidance provided in AISC Design Guide No. 22, *Façade Attachments to Steel-Framed Buildings*. There is great information in this guide for a variety of façade systems and support details, including those covered in this article. Should your fabricator agree that the HSS shelf angle support detail is the most cost effective, more extensive details for this option also will be included in the revised NISD/SEAA detailing manual, which will be published later this year. MSC

Each month MSC's product section features items from all areas of the steel construction industry. In general, these products have been introduced within the past six months. If you're looking for a specific product, visit MSC's online product directory at **www.modernsteel.com/products**. You can browse by product category or search on any term to help find the products you need, fast.

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All products submitted are considered for publication, and we encourage submittals related to all segments of the steel industry: engineering, detailing, fabrication, and erection. Submit product information via e-mail to Geoff Weisenberger (weisenberger@modernsteel.com). To be included in MSC's online products directory, contact Louis Gurthet (gurthet@modernsteel.com).

Stacker Crane

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For more information, visit: www.diamondphoenix.com

continued from page 74

The final, simple interaction formulas were developed in a 1996 paper published in the ASCE *Practice Periodical on Structural Design and Construction*. The formulas to solve for coefficient "*C*" follow:

C=1/ [(1/γN)^2+ (1/δZ)^2] – Equation 4a

or the yet simpler:

C=1/ [(1/N)^2+ (1/Z)^2] – Equation 4b

When considering high eccentricity connections, this can be further simplified as:

$C=Z/e$ – Equation 5, where e is the eccentricity.

The interesting conclusion is that bolted connection capacity can be directly solved without iteration. As an example, a single column of connectors can be tabulated as:

N # of bolts	γN	*Z*	δZ	*h* inches
2	1.96	3.00	3.00	3.0
3	2.89	6.00	6.00	6.0
4	3.77	12.00	11.94	9.0
Etc.				

This easy formula allows intuitive simplification of bolt connection analysis, and Equation 5 allows a quick preliminary rule-of-thumb check. Even capacity improvement to existing connections can be obtained by merely drilling larger holes and installing larger bolts.

One of those old Illinois professors I mentioned above said that engineers should "be lazy" and do the least amount of good work. I'd update that saying to "be efficient"; it's more politically correct today to focus on productivity rather than sloth. Plus, I like to think that formulas like the one above don't encourage laziness, but rather efficiency.

I've posted a spreadsheet that solves this formula at **www.steelutilitiesonline.com** (search for "Bolted Connection Design), an awesome tool that AISC created as an open (but unmanaged—check anything you get before you use it) location for engineers and others to share their spreadsheets and programs. The forum also allows for inquiries and discussions between engineers. It's a good resource that helps users wade through the difficulties of structural design, and helps them verify that the software—and their understanding of what it does and how it works—is correct. MSC

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Making Simple Connections in Engineering

BY THOMAS W. HARTMANN, P.E.

Part of good engineering is good, old-fashioned intuition.

IT IS EASY TO RECOGNIZE that the world of codes and analysis is getting more complex. New codes, with increasingly intricate provisions, often require more and more computer analysis. It is perhaps ironic that the computer has served a pivotal role in making this possible; without computing power, the simple rules of yesterday would still be required. While a computer also can be used to simplify analysis, most "old-time" engineers can create an appropriate scheme "on the back of a napkin," as they say; the rest is detail.

While no modern engineer really wants to go back to the "good old days" before computers, it seems increasingly difficult to teach engineering interns that "statics" still live somewhere in that big pile of computer output. My engineering professors at the University of Illinois wouldn't grade a problem if it didn't have an accompanying sketch, and usually expected a second sketch summarizing the results. Sketching reveals a thought process and frames a problem graphically.

Change is not just happening in engineering either. As a dad, my daughter and I are challenged by "new math." New math is "old math" in a new wrapper of more conceptual thinking. My daughter, Kelsey, and I can sketch out our new math of how many cow feet and how many chicken feet there are in her barnyard problem from math class, and we sometimes solve the problem just in our discussion of the picture.

So it still remains that structural engineering relies on a combination of test results, design rules, experience, intuition, and common sense to foster the creation of simple solutions from complex problems. The practice of engineering is a combination of both "art" and science; experienced engineers know solutions "by feel." Calculations and analysis often prove that intuitive feeling is correct.

Thomas W. Hartmann is lead structural engineer of the Power Group with CH2M Hill in Englewood, Colo.

A while ago, when working on a master's degree at Colorado State University, I used my thesis research to develop a simple formula that can be used to efficiently determine the coefficients *C* for eccentrically loaded bolted connections. My advisor (another Illinois alumni, Dr. Daniel Vanderbilt) challenged me to get creative. He suggested that, from an engineer's view towards simplicity, a useful, practical connection design approach can be much like the classic stress interaction formula:

$P/A + M/S < 1$?

Or for bolts, something simple like:

$P/N + (Pe)/Z < 1$?

Taking the creative part a step further, consider the use of geometric parameters γN and δZ as follows:

$P/\gamma N + (Pe)/\delta Z < 1$

This is my "napkin sketch" of design for a bolt group that reflects the interaction between the direct axial force (parameter γN) and moment due to eccentricity (parameter δZ). As I will now illustrate, this geometric formula can work for *any* bolt configuration, including arbitrary layouts as well as mixed connector sizes.

The factor "γN" takes into account the non-linear distribution of force to each bolt in a long connection. Correlating it to long-lap testing with A307 bolts by Bendigo in 1963:

$\gamma = (1\text{-}0.0062{*}h)$ – Equation 1

The variable "h" is the greatest dimension (normally a diagonal between corner bolts) of the connection. For a connection with h = 36-in., γ = 0.88, which is generally consistent with the AISC reduction for long lap connections tested.

The variable "δ" represents the effect of load-deformation distribution of shear, based upon the distance of the connection with respect to the load center. The load-deformation factor $\delta = (1\text{-}e^{-10\Delta})^{0.55}$ (AISC *Steel Construction Manual*, Figure 7-3), is applied to each bolt within the connection group. Here is the ugly formula, but fortunately you only need to do it once per geometry, and it is "scalable":

$\Delta Z = \Sigma \delta_n A_n d_n$ – Equation 2

where A_n is the bolt area and d_n is the distance from the centroid of the bolt group to the center of the nth bolt. The torsional capacity of the connection, without consideration of the bolt load-deformation reduction, is really easy:

$Z = \Sigma A_n d_n$ – Equation 3

If you want an even more simple approach, I'd suggest that you forget the "δ" and the "γ" and just use the "Z" and the "N." The formula for the coefficient is based upon the combined interaction of the axial and eccentric shear loads on each bolt.

continued on page 69

Have an opinion you'd like to share in "Topping Out"? Send your feedback to Geoff Weisenberger, senior editor, at weisenberger@modernsteel.com.