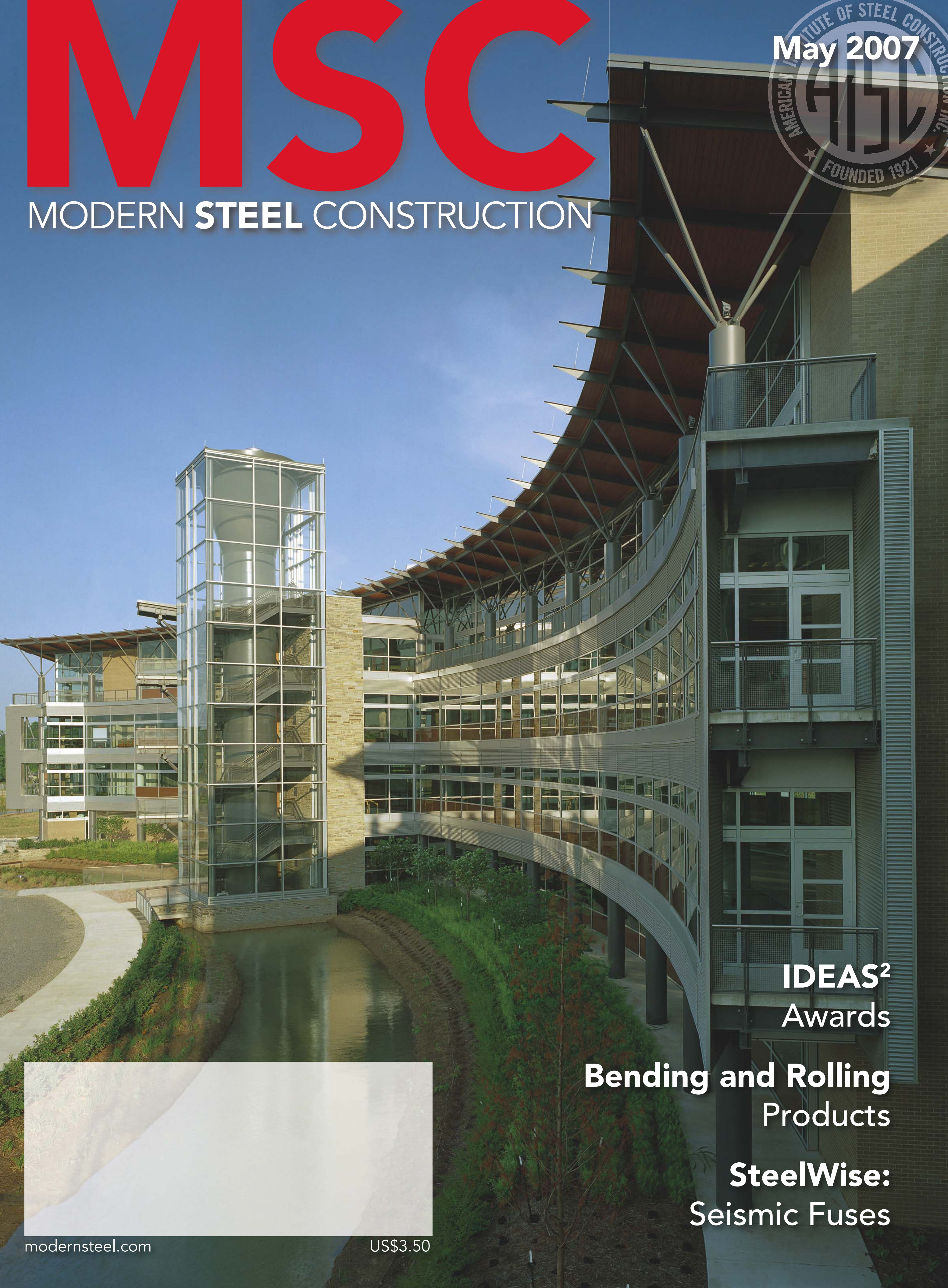

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May 2007

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DECK DESIGN DATA SHEET #45

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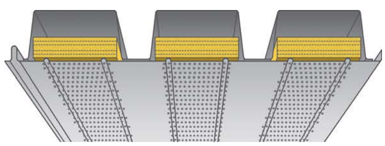
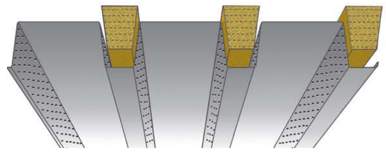
SUMMARY OF ACOUSTIC TEST DATA FOR STANDARD DECK CONSTRUCTIONS


CELLULAR TYPE (NCAS SHOWN)


STANDARD TYPE (NSA SHOWN)

ASTM C423 ACOUSTIC TEST REPORT	PRODUCT	FREQUENCY/SOUND ABSORPTION COEFFICIENT						NRC
		125	250	500	1000	2000	4000	
A76-125 (Non-Polyencapsulated)	BA, BIA	0.47	0.93	1.06	0.96	0.56	0.23	0.90
A76-124 (Non-Polyencapsulated)	NSA, NIA	0.59	1.00	1.05	0.95	0.60	0.34	0.90
A02-246 (Polyencapsulated)		0.84	1.08	1.03	0.79	0.44	0.35	0.85
A79-181 (Non-Polyencapsulated)	JA	0.83	0.99	0.97	0.78	0.53	0.43	0.80
A02-245 (Polyencapsulated)		1.09	1.14	1.12	0.78	0.56	0.50	0.90
A02-239 (Polyencapsulated)	HA6	1.15	1.10	1.02	0.61	0.52	0.40	0.80
A00-94 (Non-Polyencapsulated)	HA7.5	1.12	1.03	0.87	0.63	0.58	0.63	0.80
A02-241 (Polyencapsulated)		1.39	1.16	0.94	0.58	0.46	0.44	0.80
A02-237 (Non-Polyencapsulated)	BCAS	0.44	0.58	0.71	0.96	0.87	0.58	0.80
A03-108 (Polyencapsulated)		0.40	0.58	0.79	1.08	0.80	0.55	0.80
A02-238 (Non-Polyencapsulated)	NCAS	0.89	0.67	1.12	1.04	0.83	0.67	0.90
A03-107 (Polyencapsulated)		0.65	0.74	0.89	1.05	0.73	0.46	0.85
A04-007 (Non-Polyencapsulated)	JCAS	1.00	1.00	1.09	0.94	0.78	0.74	0.95
A03-129 (Non-Polyencapsulated)	HCA6S	1.23	1.01	1.10	0.88	0.84	0.75	0.95
A03-127 (Non-Polyencapsulated)	HCA7.5S	1.35	1.04	1.08	0.77	0.83	0.71	0.95

NOTE:
This table presents the acoustic test results for our Standard Products & Insulation Systems. Non-standard system test results are available for some products and normally include a variation in either insulation density or thickness, or deck perforation pattern. The standards are preferred. Contact the Summit, NJ office if greater performance is necessary.

The noise reduction coefficient (NRC) is the average of the sound absorption values for the 250, 500, 1000, & 2000 Hertz frequencies. The average is rounded to the nearest .05.

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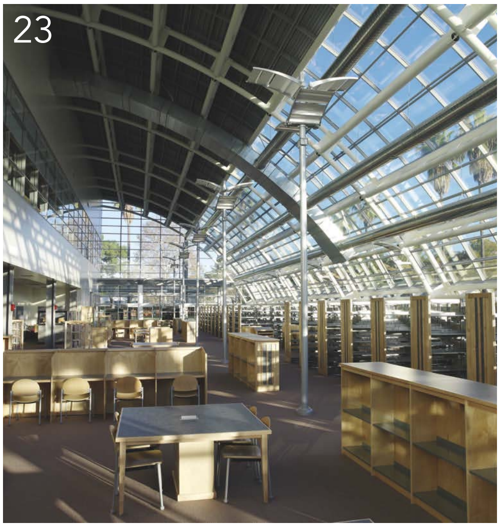

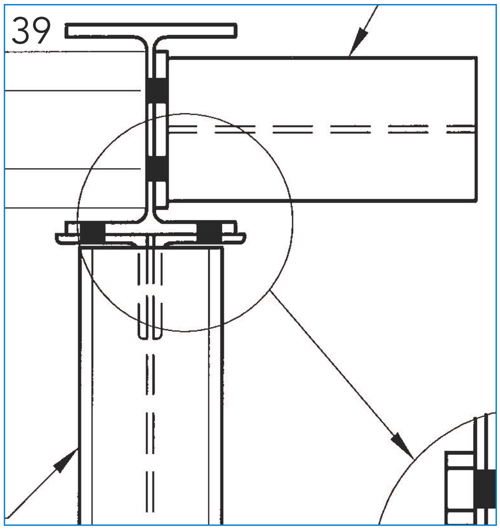

ON THE COVER: Heifer International Headquarters, Little Rock, Ark. Photo by Timothy Hursley, The Arkansas Office.

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editor's note

AS I LAZED ABOUT ONE SUNDAY MORNING, READING THE PAPER AND GENERALLY IGNORING THE HAVOC MY KIDS WERE CREATING (yes, my wife was out or I'd have never gotten away with it), I was rendered thoughtful by a story from Blair Kamin.

Kamin is the *Chicago Tribune's* Pulitzer Prize-winning architecture critic, and I often find him a bit too strident. In this article he was complaining about the increasing trend towards "façade-ectomies" in Chicago. This trend in preservation simply keeps the façade of a historic building and attaches it to a new structure behind. And often the new structure towers over the historic portion.

While Kamin doesn't out-and-out condemn the practice, he is hostile to it since too often merely preserving a façade creates a record of a city that never existed and destroys the community fabric it was intended to preserve. I kind of like the trend, though. The first time I saw it done well was up in Toronto at BCE Place, a modern steel temple where a strip of historic façades are preserved not on the exterior of the building, but rather inside the main atrium. It creates amazing visual interest while preserving at least a slice of the past. Yes, there are bad examples too. But there are also a lot of poorly designed buildings out there in general—both being built today and designed decades ago.

And I do agree with at least one thing Kamin said, at least once I got past the first two pages of his rhetoric: "The city is a living museum of architecture, not one frozen in time." But I would add that it's the new that adds vibrancy.

This same need to adapt the past to the present is behind AISC's online continuing education program. We've toyed with online continuing education in the past, but now we've relaunched it in a bigger way.

Last summer we presented four of our most popular continuing education seminars during one week in Chicago. But this time, we digitally recorded the presentations. And now we've put the four programs online. When you take the course online, you see the same PowerPoint presentation you'd see if you attended the course in person. And you hear (and see) the presenter. (In the near future, seven lectures from the recent NASCC: The Steel Conference will be added.)

We also thought about how to price these programs. In keeping with AISC's philosophy of making information as readily available as possible (for example, everyone can download current AISC specifications at no charge), we've decided to allow everyone to view these courses for free. That's right. If all you're interested in is expanding your knowledge, feel free to enjoy all four courses at no charge. However, if you also want your CEU certificates, then you need to pay a fee (there really is no free lunch). Each of the programs offers 0.6 CEUs (or 6 PDHs) and costs just $100 for AISC members or $200 for non-members. (Of course, if you're a structural engineer and plan on taking one or more courses, you should join AISC and save some money.)

To access these courses, simply visit **www.aisc.org**, click on "Learning Opportunities" and then click on "Online Seminars."

To join AISC, visit **www.aisc.org** and click on "Join AISC!"

Welcome to the vibrant new future!

Scott Melnick

SCOTT MELNICK
EDITOR

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

Backstepping

I just saw the word "backstep" in reference to a welding note on a structural drawing. What exactly does this mean?

Backstepping is a welding technique where the direction of welding is reversed over segments of the weld length to help avoid rotational distortion. For example, butt-welding two pieces of plate along a seam may induce rotational distortion as a result of transverse shrinkage, causing the joint to either open up during welding or close tight, and may possibly cause overlapping in thin plates.

While the backstepping technique can be successful in controlling rotational distortion, it provides little or no assistance in minimizing other types of distortion. The subject of backstepping is discussed in AISC *Design Guide 21: Welding Connections – A Primer for Engineers*. Design guides are available as free downloads for AISC members at **www.aisc.org/epubs** or can be ordered from the AISC Bookstore at **www.aisc.org/bookstore**.

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

Slip-Critical Bolt Values

Has Table 3, "Allowable Load for Slip-critical Connections," which appeared in the 9th edition AISC manual, not been included in the 13th edition?

Slip-critical bolt values are covered in Part 7 of the 13th edition AISC manual. There you will find two tables, one for slip prevented at service loads, and another for slip prevented beyond the service-load range up to the strength-level loading. All previous AISC specifications were based upon slip in the service-load range as a serviceability criterion. The latter provision has been added for specific (and rare) cases in which the factor of safety against slip must be higher. These two options, including specific cases for which the latter criterion might apply, are discussed in the AISC specification in Chapter J and also in the Commentary, available as free downloads at **www.aisc.org/2005spec**.

Sergio Zoruba, Ph.D., P.E.

Holes in Base Plates

On one of my projects, it was reported by the inspector that holes in some of the column base plates were enlarged in the field to accommodate anchor rods that were misplaced. Some of the holes were enlarged significantly, and some of the plate edges were notched out around bolts. The columns are part of a moment frame, so the bases were designed for the lateral forces. Is it possible to repair the plates by welding an angle or plate on top with drilled holes to receive the anchor rods? If a new plate is added on the top, the anchor rods may not have adequate projection. The rods are A307 material. Is this weldable, or would a coupler be required?

Many things are possible, including welding plates with standard holes over the enlarged holes in the base plate to the existing plate. However, the requirements for the base anchorage will largely depend on the type and magnitude of force to be resisted by the anchor rods. Major considerations are the method assumed to transfer the shear forces from the column to the foundation, and the magnitude of any tensile force in the rod. For guidance on this evaluation, refer to AISC's *Design Guide 1: Base Plate and Anchor Rod Design*, second edition (**www.aisc.org/epubs**). The recommendations therein can be applied to your modified column bases with proper engineering judgment applied based upon proper strength and stiffness of the actual modifications you need to make.

And yes, ASTM A307 is a mild carbon steel and is generally considered weldable. There are also coupler solutions that may be appropriate in some cases. Both of these options are discussed in the design guide.

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

I_y and J for Double-Angles

In attempting to calculate the lateral-torsion buckling of double-angles per the AISC manual, I cannot find properties such as I_y and J. Are these tabulated in the 13th edition manual?

These are not specifically tabulated for double angles in the 13th edition manual. However, they can be determined from the single-angle properties. J for a double angle is always twice the value for a single angle. J values for single angles are listed in Part 1 of the manual. When looking at the Y-Y geometric axis, the moment of inertia can be determined from the radius of gyration, r_y, and area, A, which are tabulated in Table 1-15. That is, $I_y = Ar_y^2$. You didn't ask about I_x, but in this case, the neutral axis goes through the center of gravity of both angles, and the moment of inertia about that axis is twice the value for a single angle.

Sergio Zoruba, Ph.D., P.E.

Slip-Critical Bolts used in Shear Tabs

I had the impression that we could not use slip-critical bolts with extended shear plates because the flexibility of shear plate connection is achieved by the plowing of the bolts against the main material. Based on the 13th edition AISC manual, it seems we can use slip-critical bolts with the extended configuration. What makes the connection flexible in this case?

It is rare that a single-plate connection would require the use of slip-critical bolts. But, if a slip-critical joint were used, the rotational demand would first cause slip and then proceed just as it would for a single-plate connection that had been designed as a bearing-type connection. This is why all high-strength bolted connections, including slip-critical and bearing-type connections, must be designed as if the bolt will eventually go into bearing—even if that does not occur at a service-load level. When the bolts do go into bearing, it is some combination of the plowing of the bolt and the yielding of the plate (and or beam web) that provides for the rotational flexibility of the connection. In the extended configuration of single-shear plates, the plate thickness is limited such that the plate flexural strength does not exceed the "flexural" strength of the bolt group in shear.

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

Filler Metal for High-Seismic Applications

Where can I find the filler metal requirements for high-seismic design?

Refer to the 2005 AISC *Seismic Provisions* (**www.aisc.org/2005seismic**). Section 7 addresses weld requirements, as does Appendix W. Note that Appendix W provisions are also consistent with provisions that subsequently have been released in AWS D1.8, a seismic addition to AWS D1.1.

Sergio Zoruba, Ph.D., P.E.

Knifed Connection

What is the definition of *knifed connection*? I have looked in several textbooks without any success.

The term *knifed connection* is usually used in reference to a double-angle connection that is shop attached to the supporting member (usually a column) and where the bottom flange of the beam is coped away or blocked out on both sides of the web. A small increase (1/16 in. or so) in spacing between the angles is provided to ease erection. The flangeless section of the beam web is then "knifed" down between the outstanding legs of the support angles during erection, and the bolts are inserted through the mating angles and beam web. The bolts easily pull the plies together, eliminating the small gap that was allowed in fabrication to ease erection.

This detail may be less common today, as one-sided connections such as single-plate connections are used with increasing frequency. Nonetheless, a knifed connection is sometimes considered when the attachments to the column are shop welded and other connection types are not feasible.

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

SCBF Brace Reinforcement

The 2005 AISC *Seismic Provisions* for SCBF states:

Where the effective net area of bracing members is less than the gross area, the required tensile strength of the brace based upon the limit state of fracture in the net section shall be greater than.... $R_yF_yA_g$ (LRFD).

For an HSS brace, F_y = 46 ksi; F_u = 58 ksi; R_y = 1.4; R_t = 1.3

The required tensile strength of the brace based upon the limit state of fracture is $0.75R_tF_uA_e = 56.55A_e$ and the required tensile strength is $R_yF_yA_g = 64.4A_g$. Setting the required tensile strength of the brace greater than $R_yF_yA_g$ results in $A_e = 1.14A_g$, which is not possible. It seems that you cannot stiffen the member to increase A_e without also increasing A_g. How can the requirement of 13.2b(a) can be met?

One can increase A_e by adding reinforcement (plates, for example) at the ends of the HSS brace member. Since the reinforcement does not run along the entire length of the HSS brace (just at the ends), A_g for the brace is not increased. This means using the A_g from the non-reinforced length of the brace rather than from the reinforced ends.

Sergio Zoruba, Ph.D., P.E.

Heat-Straightening Columns

A two-story column on our project was erected approximately 1⁷/₈ in. out-of-plumb. The erector would like to heat one face of the HSS column and then cool it quickly in order to bend the column back to plumb. All other issues aside, what will this heating and cooling process do to the material properties of the column? It seems as though there will be some residual stresses in the column as well that may present a problem.

Controlled application of heat can be used to effectively to straighten or curve members. The mechanical properties of the structural steel material are generally unaffected by such heating applications as long as the procedures described in Section M2.1 of the AISC specification are followed. The AISC specification is available as a free download at **www.aisc.org/2005spec**.

The use of heat bending is as much of an art as it is a science, and significant experience is generally required to control the process and to achieve the desired results. Also, depending upon how much of the rest of the structure is present to restrain the column, there may be little actual movement induced by heating.

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

Kurt Gustafson is the director of technical assistance, and Sergio Zoruba is a senior engineer in AISC's Steel Solutions Center. Charlie Carter is AISC's chief structural engineer, and Lou Geschwindner is AISC's vice president of engineering and research.

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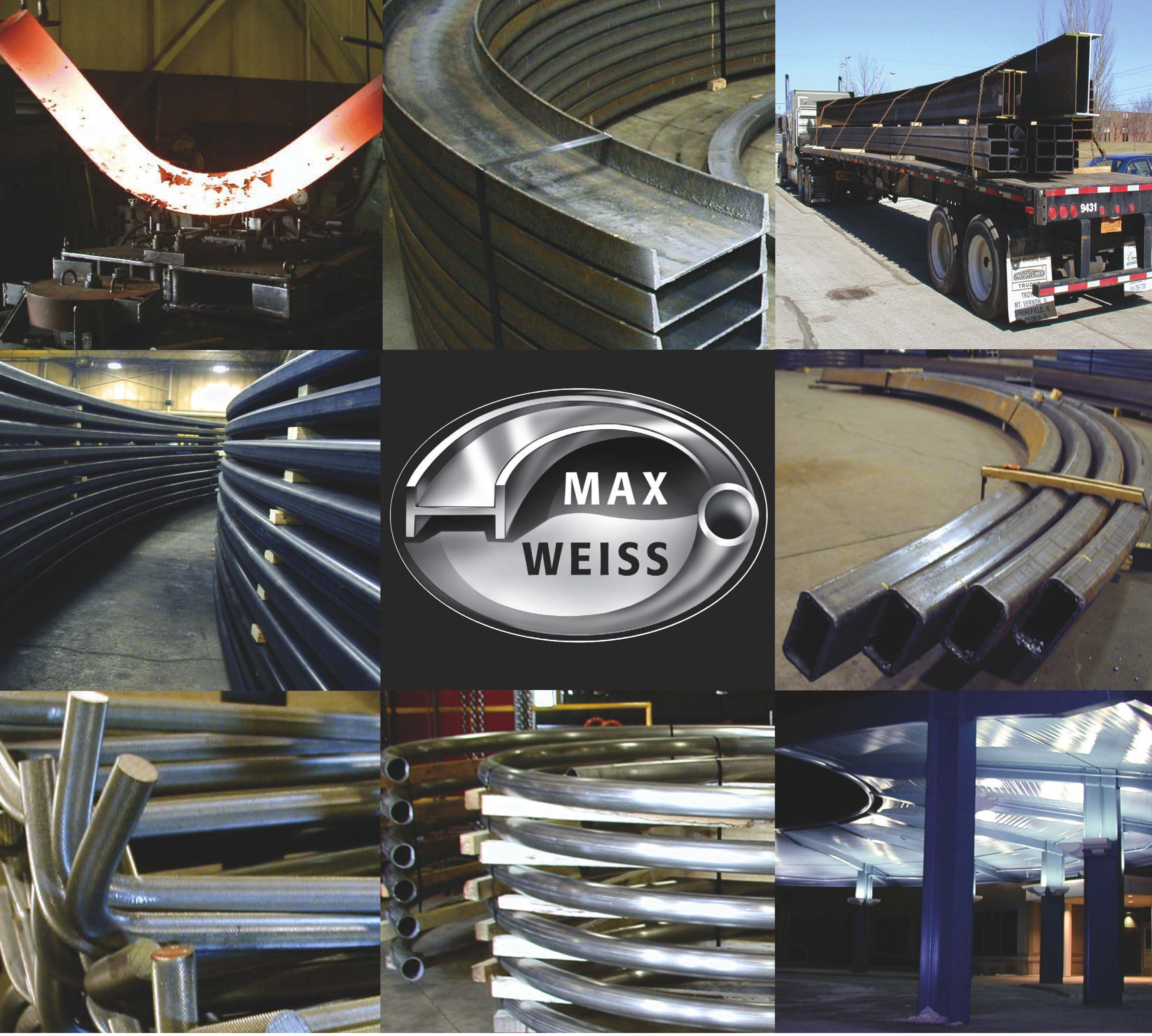
MAX
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LOOKING FOR A CHALLENGE? *Modern Steel Construction*'s monthly Steel Quiz tests your knowledge of steel design and construction. Most answers can be found in the 2005 *Specification for Structural Steel Buildings*, available as a free download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

This month's Steel Quiz was developed by AISC's Steel Solutions Center. Sharpen your pencils and go!

1 Which of the following is not considered a thermal cutting process?
- **a.** gas
- **b.** plasma
- **c.** laser
- **d.** punch

2 Which of the following are structural nut material standards listed in the AISC specification?
- **a.** ASTM A193
- **b.** ASTM A194
- **c.** ASTM A563
- **d.** ASTM A325

3 **True/False:** Lateral-torsional buckling is a concern for an I-shaped member under weak-axis flexure.

4 Which limit state would be incorrectly assigned to a member?
- **a.** lateral-torsional buckling in a flexure member
- **b.** flexural-torsional buckling in a flexure member
- **c.** tension yielding in a tension member
- **d.** tension rupture in a tension member

5 **True/False:** Drift is evaluated at service loads.

6 Planing or finishing of sheared or thermally cut edges of plates and shapes is:
- **a.** mandated by the *Specification*
- **b.** required only if called for in the contact documents
- **c.** required only if called for by the inspector
- **d.** not required

7 **True/False:** The length of a slotted hole is measured from center-to-center of the circular ends of the slot.

8 **True/False:** Inelastic deformation is permitted in simple shear connections.

9 What is the shear lag factor, *U*, for the case where a tension load is transmitted directly to each of the cross-sectional elements by fasteners or welds?
- **a.** 1.0
- **b.** 0.9
- **c.** 0.6
- **d.** 0.5

10 **Yes/No:** Are the compact limiting width-thickness ratios (λ_p) applicable to uniform compression limit state checks for flanges of rolled I-shaped sections?

TURN PAGE FOR ANSWERS

steel quiz

ANSWERS

1 The answer is **d**, punch. Refer to the definition of thermal cutting in the glossary of the 2005 AISC specification (a free download from www.aisc.org/2005spec).

2 The answers are **b** and **c**. ASTM A194 and A563 are listed in Section A3.3 of the 2005 AISC specification as nut material standards. Note that ASTM A193 is a steel bolting material typically used as threaded rod, whereas ASTM A325 is a high-strength bolting material.

3 **False.** Flexure about the weakest axis is not prone to lateral-torsional buckling, because the shape is stiffer about the strong axis than it is about the weakest axis. Referring to Section F6 of the 2005 AISC specification, two limit states are checked for weak-axis flexure of I-shapes, namely yielding and flange local buckling.

4 The answer is **b**. Flexural-torsional buckling is a limit state that may occur in singly symmetric columns or compression struts, such as single and double angles, tees and channels. It is characterized by the simultaneous flexure and twisting of the compression member.

5 **True.** Refer to Section L4 of the 2005 AISC specification for additional information. Note that serviceability load combinations are usually different than the LRFD and ASD load combinations used for design for strength. *AISC Design Guide 3*, second edition, provides discussion on serviceability design considerations for steel buildings.

6 The answer is **b**. Per Section M2.3 of the AISC specification:

Planing or finishing of sheared or thermally cut edges of plates or shapes is not required unless specifically called for in the contract documents or included in a stipulated edge preparation for welding.

7 **False.** The length of a slotted hole length is measured as the out-to-out distance.

8 **True**, provided the deformations are self-limiting. See Section B3.6a of the 2005 AISC specification.

9 The answer is **a**. The shear lag factor, *U*, is unity for Case 1 of Table D3.1 in the 2005 AISC specification. This recognizes that there is no shear lag effect in this particular case, as the effective area is equivalent to the net area of the tension member.

10 **No**. Compressive strength of a member is based on whether or not the member contains slender elements. Compact and non-compact sections are treated similarly for compression members. Therefore, λ_p is not applicable for design of rolled I-shape compression members; only λ_r is. See Table B4.1 of the AISC specification (a free download at www.aisc.org/2005spec) for limiting width-thickness ratios for compression elements.
For axially loaded columns λ_r defines the slenderness limit up to which the axial load can reach the yield capacity of the section, F_yA, if the column is short—i.e., there is no column buckling. If the slenderness exceeds λ_r, the cross section is slender, and a "Q" factor must be applied to the yield stress.

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 Solutions Center


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CONTINUING EDUCATION

Popular AISC Seminars Now Online

AISC has furthered its commitment to providing online learning opportunities by posting four of its most popular continuing education seminars on its web site. Originally presented last summer in Chicago, the seminars were digitally recorded and are now available at www.aisc.org. The online presentations include audio and video of the actual presenters as well as the original PowerPoint presentations. The four courses are:

Field Fixes
Authors/Speakers: James M. Fisher, Ph.D., P.E., and Lawrence A. Kloiber, P.E.

Steel Design After College
Author/Speaker: Lawrence G. Griffis, P.E.

Bolting and Welding Primer
Authors/Speakers: Geoff Kulak, Ph.D., P.E., and Duane K. Miller, Sc.D., P.E.

Seismic Braced Frames
Author/Speaker: Rafael Sabelli, S.E.

The courses can be viewed free of charge. However, to obtain CEU certificates (0.6 CEUs or 6 PDHs per course), there is a fee of $100 per course for AISC members and $200 for non-members.

AISC also plans to post seven lectures from its 2007 NASCC: The Steel Conference on its site in the near future.

To access the four courses, visit www.aisc.org, and click "Learning Opportunities" then "Online Seminars."

COATINGS

Industrial Protective Coatings Course

The Society for Protective Coatings (SSPC) is presenting the course "Fundamentals of Protective Coatings for Industrial Structures" in multiple U.S. cities. The 40-hour course takes place over five days, includes an exam, and is worth 3.8 CEUs. The cost is $795 for SSPC members and $995 for non-members.

The course provides a practical and comprehensive overview for those who are new to the protective coatings industry, and is applicable to contractors, engineers, inspectors, consultants, facility owners, technical services personnel, and sales reps. It is also an ideal refresher for reviewing the fundamentals of corrosion and the use of coatings as a protective mechanism against corrosion and deterioration of industrial structures.

The course was presented in Whitby, Ontario, Canada and Anaheim, Calif. last month, but remaining dates include:

August 20–24	**Pasadena, Texas**
October 1–5	**Chesapeake, Va.**
November 5–9	**Forest Hills, N.Y.**

To register, call 877.281.7772, e-mail boyle@sspc.org, or visit www.sspc.org/forms/trainreg/index.nclk. For full course schedule please visit www.sspc.org/training.

CERTIFICATION

Mississippi Fabricator Wins Free QMC Audit

Since October 2006, Quality Management Company, LLC, provider of quality audits for the AISC Certification program, has been administering a voluntary customer satisfaction survey of AISC Certified Fabricators and Erectors upon receipt of their certificate. Companies that complete the survey are automatically entered into a semi-annual drawing for a free QMC audit.

Ellis Steel Company, Inc., a fabricator in West Point, Miss., has won QMC's most recent drawing for a free audit.

The objective of the survey is to improve the certification process from invoicing to the audit to issuing the certificate. QMC will draw for another free audit in about six months, so keep those surveys coming in!

PEOPLE

World Loses Bending Innovator

Goran Kajrup, an engineer from humble beginnings who came to run the world's top producer of bending machines, passed away on February 20th.

While working as a design engineer at a bending company in central Sweden in the 1960s, he came up with a unique design for a bending roller. The machine was run by a single hydraulic motor driving a gear that engaged with two other gears in a planetary arrangement, which became the two lower drive rolls of a plate roll or section bending machine. This made it simple to run an additional roll off the same hydraulic motor, essentially creating a three-roll machine. This top roll was fitted with a clutch to allow for the differential speeds between the inner and outer surface of a curved member going through the machine.

With the planetary arrangement the two bottom roll shafts were able to move on a swing arm about the same pivot point, a huge step forward in bending machine design; up to this point all bending machines were of the pyramid type, with fixed bottom roll centers and only a two-roll drive. In addition, previous designs all had mechanical gear boxes driven from an electric motor.

This unique hydraulic design enabled the machine to be stopped instantly and was safer, with the use of hydraulic relief valves that keep the machine from overloading. The design was made possible by recent advances at the time in hydraulic seals, hydraulic motors, and hydraulic pumps.

In the late 1960s, Kajrup joined a small engineering company in Hassleholm, Sweden where he proposed the idea of manufacturing bending equipment to his new design. He moved forward with a management buy-out and became the owner of what became ROUNDO.

In the early years the company produced small bending machines, but in the 1980s introduced larger machines to curve large structural sections, wide-flange beams, and round and square tubes.

Karjup is survived by his wife, daughter, and son, Ola, who will continue with the company.

CRANES AND RIGGING

NCCCO Plans New Certification Programs for Riggers, Signalpersons

The National Commission for the Certification of Crane Operators (NCCCO) recently announced its plans to develop two new certification programs for riggers and signalpersons.

NCCCO will model the development of the new programs on its existing crane operator certification programs. The programs will draw on three major resources: industry support, subject matter expertise, and psychometric guidance. NCCCO will seek accreditation for the new programs, such as it has achieved for its crane operator certifications. The two new certifications will be geared toward meeting all prevailing ANSI and OSHA standards.

To optimize resources, NCCCO plans to double-track development of both programs through two Task Forces, one each for Riggers and Signalpersons. Don Jordan, Technical Lifting Authority, BP America, Houston, has been appointed chair of the Rigger Certification Task Force. The Signalperson Task Force is chaired by Kenneth Shinn, President, K.J. Shinn, Inc., Lake Como, N.J.

Experts in their respective fields will staff the Task Forces and will be guided by psychometric consultants from International Assessment Institute (IAI), the testing services company that has provided exam development and administration services to NCCCO since 1999. Other experts will serve as item writers. As with the current programs, a professional Job Task Analysis will be conducted to serve as the foundation for exam development activities.

Development for the programs will begin in the second quarter of 2007 and continue throughout the year. According to NCCCO Manager of Program Development, Phillip Kinser, the Signalperson Program could be largely complete by the first quarter of 2008, with Rigger Certification close behind.

SUSTAINABILITY & TECHNOLOGY

Ecobuild/AEC Shows Combine Sustainability and Technology Topics

Sustainability and the use of technology such as integrated 3D building information modeling (BIM) are two of the most compelling issues in building design and construction today. The two subjects will be explored simultaneously under one roof at the Anaheim Convention Center in Anaheim, Calif., May 14–17, when the ecobuild america and AEC-ST Science & Technology trade shows co-locate their conferences and exhibitions.

The structural steel industry, which has had terrific success in both environmental stewardship (structural steel is comprised of 95% recycled material) and in implementing BIM to speed delivery of steel packages, will be exhibiting via AISC's participation at the combined exhibition, held May 16–17. For more information on the shows, visit **www.ecobuildfederal.com/springhome.html**.

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IDEAS²

Innovative Design in Engineering and Architecture with Structural Steel

THE DESIGN AND CONSTRUCTION INDUSTRY RECOGNIZES THE IMPORTANCE OF TEAMWORK, COORDINATION, AND COLLABORATION IN FOSTERING SUCCESSFUL CONSTRUCTION PROJECTS TODAY MORE THAN EVER BEFORE. In support of this trend, AISC is proud to present the results of its annual IDEAS² Awards competition. This program is designed to recognize all team members responsible for excellence and innovation in a project's use of structural steel.

Awards for each winning project were presented to the project team members involved in the design and construction of the structural framing system, including the architect, structural engineer of record, general contractor, detailer, fabricator, erector, and owner.

New buildings, as well as renovation, retrofit, or expansion projects, were eligible. The projects also had to display, at a minimum, the following characteristics:

- ➜ A significant portion of the framing system must be wide-flange or hollow structural steel sections;
- ➜ Projects must have been completed between January 1, 2004 and December 31, 2006;
- ➜ Projects must be located in North America;
- ➜ Previous AISC IDEAS or EAE award-winning projects were not eligible.

A panel of design and construction industry professionals judged the entries in three categories according to their constructed values in U.S. dollars:

- ➜ Less than $15 million
- ➜ $15 million to $75 million
- ➜ Greater than $75 million

The judges considered each project's use of structural steel from both an architectural and structural engineering perspective, with an emphasis on:

- ➜ Creative solutions to the project's program requirements;
- ➜ Applications of innovative design approaches in areas such as connections, gravity systems, lateral load resisting systems, fire protection, and blast;
- ➜ The aesthetic and visual impact of the project, particularly in the coordination of structural steel elements with other materials;
- ➜ Innovative uses of architecturally exposed structural steel;
- ➜ Advances in the use of structural steel, either technically or in the architectural expression;
- ➜ The use of innovative design and construction methods such as 3D building models, interoperability, early integration of specialty contractors such as steel fabricators, alternative methods of project delivery, or other productivity enhancers.

Both national and merit honors were awarded. The jury also selected two projects for the Presidential Award of Excellence in recognition of distinguished structural engineering.

2007 IDEAS² Awards Jury

Jennifer Goupil, *Structural Engineer* magazine, Seattle

Keith Grubb, P.E., S.E., Managing Editor, *MSC*

Tom Harrison, S.E., OWP/P, Chicago

Jim Luckey, Architect and Principal, SmithGroup, Chicago

Bill Nash, Quality Assurance Director, McCarthy Building Companies, Inc., St. Louis

Ray Phillips, President and CEO, Cives Corp., Roswell, Ga.

Lindsey Purcell, Director of Operations, The Nature Conservancy in Indiana, Indianapolis

Frederic C. Hamilton Building, Denver Art Museum.

National Winner—Less than $15M

TRIPLE-S STEEL SUPPLY COMPANY SERVICE CENTER—SAN ANTONIO

All photos: Chris Cooper

The winning project for the less-than-$15-million award this year is itself a steel-related facility: a steel distribution center for Triple-S Steel Supply, a family-owned structural and ornamental steel service center in San Antonio.

The company wanted more than just a typical warehouse; it wanted an iconic building. To meet this goal, the architects chose to showcase steel detailing by devising a kit-of-parts using the structural shapes and sections found in the company's catalogue. The facility consists of three main building areas, all of which strongly emphasize exposed steel.

The office/showroom building consists of high-sloped, multi-level roofs supported by exposed steel HSS columns and framed with exposed steel beams, joists girders, and joists with extensions. The joist extensions protrude through the exterior and past the roof line in order to support the upper angle-framed shade structures on three sides of the building. In addition to the upper shade structure, there is a matching lower shade structure framed in a similar manner, on three sides of the building. The lateral bracing consists of steel tube X-bracing located outside of the main building.

The steel distribution building is supported by exposed W24x176 columns located on concrete piers that support the nearly 100-ft span joist girders for the low roof and 80-ft span joist girders for the high roof. Moment connections are utilized for the connections between the girders and the steel columns. Steel purlins are spaced at 5 ft on center and cantilevered on the ends as overhangs, beyond the last girder supports. Inside, there are three bays of W24x131 crane support beams for the entire length of the building. Similar to the office/showroom building, lateral bracing is achieved with exposed steel tube X-bracing.

The small parts warehouse is conventionally framed with simple joists and joist girders. Exterior WT sections support the angle and steel purlin shade structure on the north side of the building.

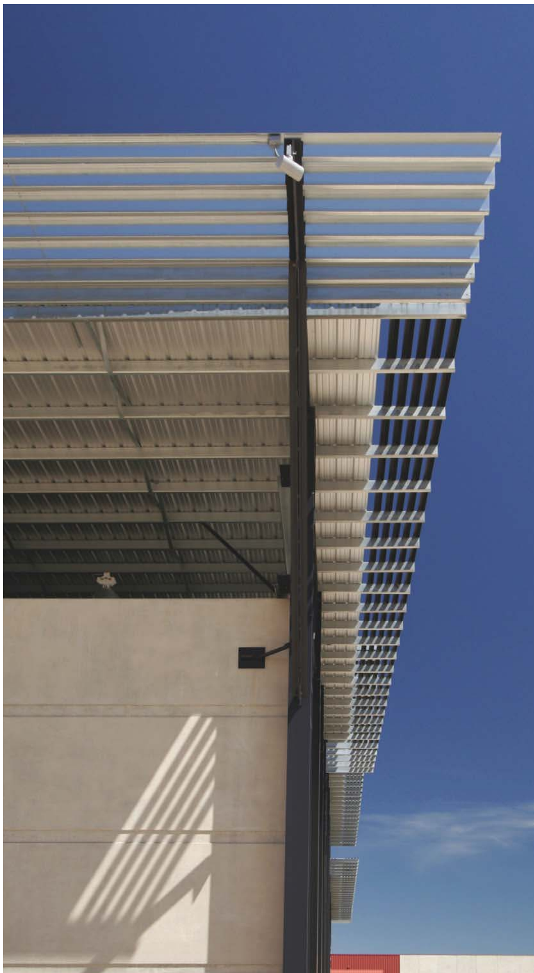
For more on this project, see "At Your Service" in our August 2006 issue at **www.modernsteel.com**.

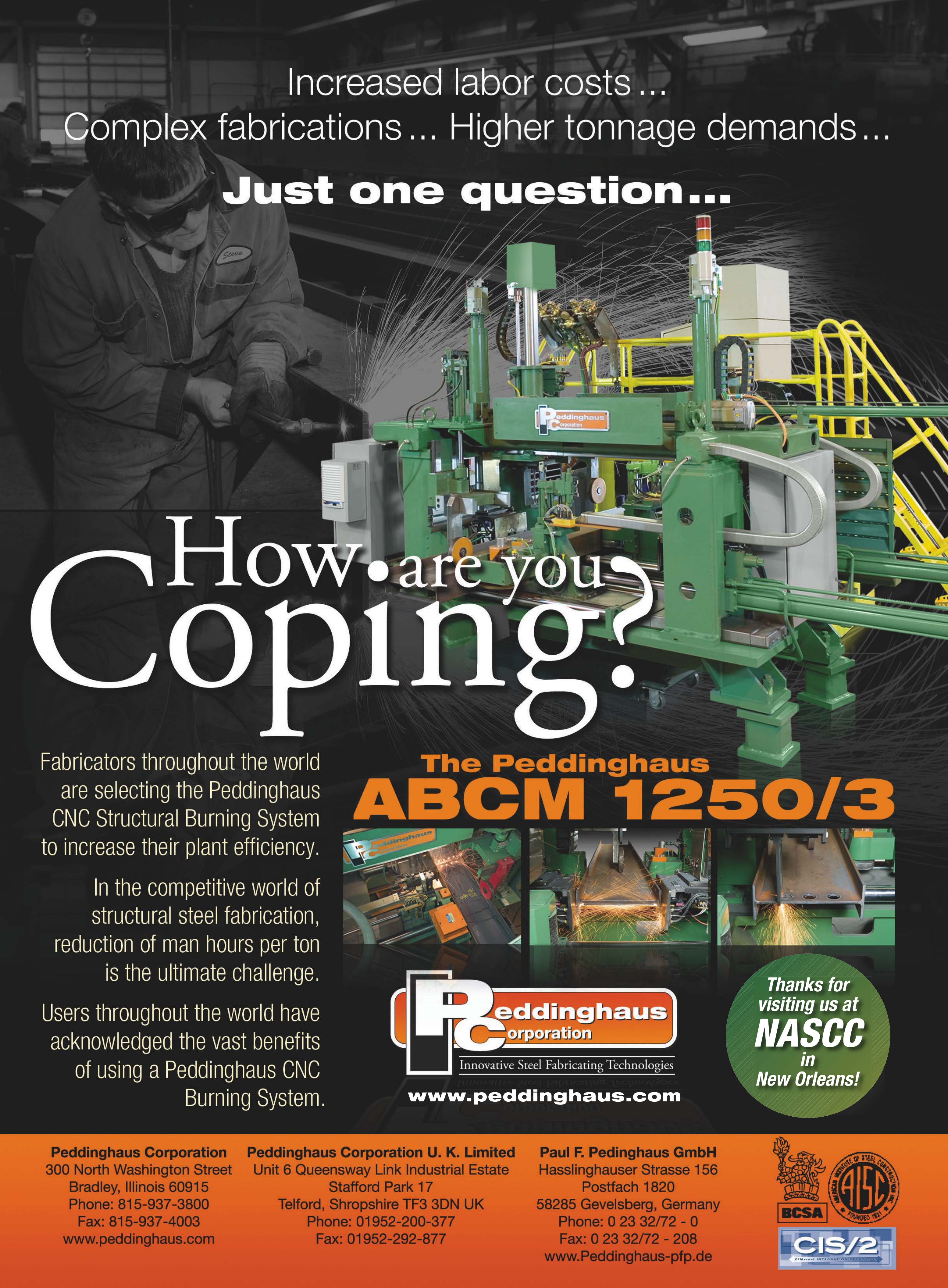
Owner
Triple-S Steel Supply Co. (AISC member)

Architect
Lake|Flato Architects, San Antonio

Structural Engineer
Steve G. Persyn, P.E., San Antonio

General Contractor
Hooker Contracting Company, Inc., San Antonio

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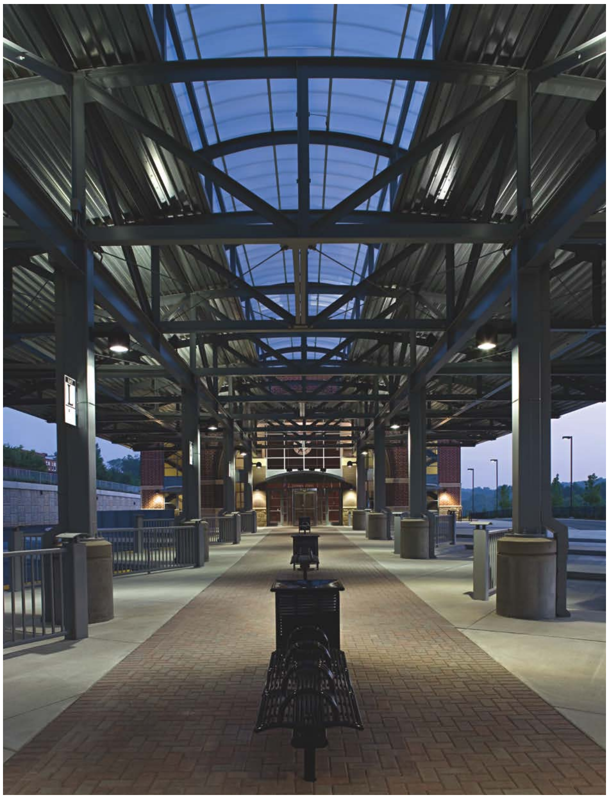
Merit Award—Less than $15M

ATHENS MULTI-MODAL TRANSPORTATION CENTER—ATHENS, GA.

The Athens Multi-Modal Transportation Center provides a new hub for various transportation modes in the Athens, Ga. area, connecting Athens Transit, Regional Express bus service, University of Georgia Transit, a future commuter rail line, Southeastern Stages bus service, and pedestrian and bicycle travel into one complex.

From an architectural standpoint, the project mixes glass, brick, wood, glass, and cast stone with exposed steel to take a contemporary approach to the traditional train station aesthetic. It is composed of three main components—the main building/waiting area, an exterior canopied bus waiting area, and a pedestrian bridge—all of which employ exposed structural steel. The exterior bus canopy shelters passengers at 17 bus bays and uses exposed steel for its long spans. Standard shapes were used for the trusses and canopies that will need to be matched for aesthetics in a future bus bay expansion. The covered pedestrian bridge uses steel trusses for its long span over an active rail line, linking the transportation center to a parking deck and Athens' central business district. The center's indoor waiting area features exposed steel arch trusses combined with wood paneling.



Exposed steel for the project is coated with intumescent paint for fire protection, provided by A/D Fire Protection Systems, and all exterior steel is protected with a high-performance finish to reduce maintenance. The finish is a three-coat system consisting of a two-component moisture-cured zinc-rich primer, polyamine epoxy intermediate coat, and aliphatic acrylic polyurethane top coat.

The engineers used STRAP software to design the canopies and RAM software for the building. Large uplift and lateral wind forces on the canopies presented the most significant loading requirements. In addition, large arched windows at each end of the building presented design and detailing challenges, but these were resolved with standard steel shapes and controlled with AESS specifications.

Steel fabrication took place during the site development phase in order to have the steel delivered to the site at the beginning of the erection phase, and the owner provided storage space for the steel during the latter stages of site development when the staging area and building pad were completed.

Supporting the bridge was a considerable design challenge, as the long bridge span rested on relatively small building columns. When it came to erecting the bridge, the design team had to coordinate with the railroad so that the existing rail line could stay functional during bridge erection. The bridge was delivered to the site in two pieces and bolted together on-site—and was hoisted into place with no impact on the railroad's schedule.

All photos: Brian C. Robbins/Robbins Photography, Inc.

Owner
Unified Government of Athens-Clarke County, Ga.

Architect
Niles Bolton Associates, Inc., Atlanta, Ga.
Cox Graae + Spack Architects, Washington, D.C.

Structural Engineer
Uzun & Case, Atlanta

General Contractor
Aldridge, Inc., Athens, Ga.

Engineering Software
RAM
STRAP

Merit Award—Less than $15M

LIBRARY LEARNING RESOURCES CENTER AT EL CAMINO COLLEGE COMPTON CENTER, COMPTON, CALIF.

RAW International, Inc.

Architecture can be catalyst for change. This was the approach that RAW International took when designing the Library Learning Resources Center at El Camino College Compton Center in Compton, Calif. The college wanted a signature building image that would not only identify the library and its growing campus as high-tech center for learning, but also change its image from hopeless to hopeful in a historically underserved area of greater Los Angeles.

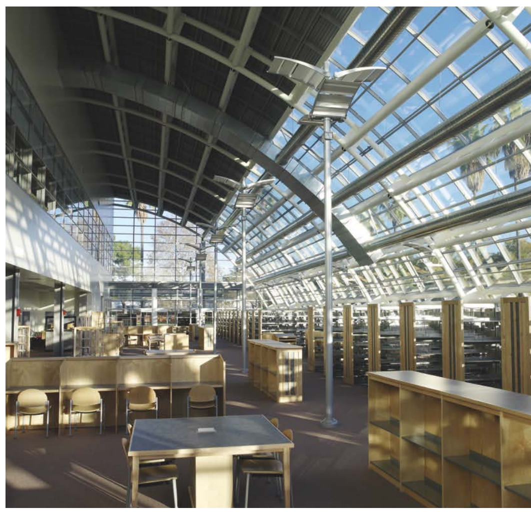
The new 45,000-sq-ft. facility's design scheme is transparent, open, and daylit. This solution is a direct response to the college's request for a program-flexible, column-free universal space for both the reading room/stacks area and the second-floor computer learning center. The unobstructed spans of the reading room, stacks area, and atrium were achieved by developing a 3-ft-deep curved tube truss, with the top and bottom chords of the truss using 8-in.-diameter curved steel tube. The two-dimensional truss vault of the reading room and atrium was designed to transfer lateral loading to a conventional moment-resisting frame.

The design required the least amount of structural obstruction and the greatest amount of design flexibility for the present, as well as future expansion. This flexibility would have been difficult to achieve with interior and exterior brace frames, which would have divided the space up into a small maze of structural-resisting elements. As such, conventional strong-column weak-beam moment frames were chosen for lateral force resistance in lieu of braced frames.

Following the 1994 Northridge earthquake, the State of California Division of State Architect's rules for the design of conventional moment-resisting frames, especially in school buildings, were reviewed and stringently upgraded. Adherence to FEMA 151 and 153 as a blueprint for approved and tested moment frame-resisting joints, beams, columns, and welding was a must. Any deviation from these standards would have required the design team to construct and test its own moment frame joints and certify the testing with an approved FEMA testing laboratory.

Because of the building's geometry and connection point complexity, the State Architect required four separate computer simulations using SAP 2000 engineering software to simulate the building's three-dimensional performance under different dynamic loading conditions—both earthquake and wind separately and earthquake and wind forces combined—to create a unified picture of the loading. The fourth simulation combined all of the design components to create a three-dimensional dynamic loading picture of how the structure would perform. The simulations revealed that in the horizontal plane, the library's length-to-width ratio reacts in a similar fashion to a high-rise building in the vertical plane under dynamic loading conditions.

Each 120-ft-long radial tube truss was shop fabricated in two sections, and each section was trucked to the job site for field erection. The layout of the steel trusses posed a challenge for the fabricator because of the sizes of the parts and also because of the tolerances required by the design for field fitting. The curved tube trusses also had to be fabricated to near-perfect tolerances, because a glass skylight was designed to be placed on top of the curved tube truss. In the end, the fabricator's attention to precision reduced erection time by an estimated 15%.



Mark Robert Halper

Owner
El Camino College Compton Center, Compton, Calif.

Architect
RAW International, Inc., Los Angeles

Structural Engineer
Farhad/Tabb Consulting Structural Engineers, Los Angeles

Software
SAP 2000

General Contractor
Douglas Barnhart, Inc., San Diego

National Winner—$15M to $75M

HEIFER INTERNATIONAL HEADQUARTERS—LITTLE ROCK, ARK.

An organization geared toward fighting world hunger, Heifer International's impact in communities starts with the delivery of one animal to one family, known as "passing on the gift." As a drop of water generates ripples that flow outward from the impact point, the gift of an animal creates "concentric rings of influence" radiating through a village, allowing sustainable methods taught to the original family to be passed on to others as the animal's offspring.

Heifer wanted its new headquarters in Little Rock, Ark. to serve as a symbol for this process. The building's gentle curve emanates from the overall four-phase master plan, conceived as a series of concentric rings expanding outward from a central commons that represents the impact point of a gift.

The four-story, semi-circular, office building, framed with steel plate shear walls, was constructed on one the largest Brownfield recoveries in the state. Roof framing consists of a wood roof deck spanning sleepers on top of steel beams spanning steel girders that in turn span steel tree columns. The tree columns consist of round pipe columns that continue from the floors below, cantilevering approximately 8 ft above the fourth floor, with steel pipe members creating the branches supporting the roof framing. The roof is inverted to provide a "valley" in the middle of the building to collect and recycle rainwater. Extended steel beams at the roof edge are capped with galvanized steel grates to extend the sun protection and lighten the edge in a crown-like fashion.

Floor framing consists of a minimum of 2½ in. of normal weight concrete on top of composite steel deck spanning between wide flange steel beams that span wide-flange steel girders and round steel columns.

Lateral stability for the building is provided by the floor deck acting as a diaphragm, spanning between steel plate shear walls from the foundation to the fourth floor. Lateral loads at the roof are resisted by the roof deck acting as a diaphragm spanning the tree columns, which cantilever above the fourth floor. The columns transfer lateral loads at the roof to the fourth floor diaphragm. The design employed extensive cantilevered floor elements to minimize the number of columns and provide a feeling of openness.

The building presented several challenges to the design team, one of which was working with round columns. The project team initially considered round cast-in-place concrete columns and a steel floor framing system, but eliminated this option due to concerns with tolerances for the concrete and connecting the steel to the concrete. It then considered round precast concrete columns, but ultimately decided on large round steel pipe columns in order to satisfy the architect's desire for round columns, as well as to ease connection of the steel framing to the columns.

The semi-circular shape of the building was another challenge, as it complicated the layout of the steel system and expansion joint; the building is more than 440 ft long, so an expansion joint was added near the center of the building. Due to building irregularities, each half of the building was analyzed for lateral loads using static and dynamic methods.

Since the structural steel system was exposed in the majority of the facility, it required closer coordination with the architectural, mechanical, and electrical details including details at windows and tree columns and up-lighting in tree columns. In addition, a raised floor system was used on most of the building to run utilities and wiring.

Because Heifer seeks attainable agricultural solutions within the parameters of each project's region, the building had to reflect this methodology as well. As such, one of the major goals for the building was to use locally sourced materials that would exceed LEED requirements for distance to site and recycled content. Steel was fabricated at a facility just three blocks from the site, and the aluminum curtain wall and skin, making up over 90% of the exterior, was fabricated directly across the street at a major glazing company. In all, 97% of the project's materials was recycled.

Architect
Polk Stanley Rowland Curzon Porter Architects, Ltd., Little Rock, Ark.

Owner
Heifer International, Little Rock

Structural Engineer
Cromwell Architects & Engineers, Little Rock

Fabricator
AFCO Steel, Little Rock (AISC member)

General Contractor
CDI Contractors, LLC, Little Rock

All photos: Timothy Hursley/The Arkansas Office

Merit Award—$15M to $75M

THE TRANSPARENT HOUSE, GULF BREEZE, FLA.

TGRWA

The coastal town of Gulf Breeze, Florida, while tiny, is home to an impressive example of modern glass-and-steel architecture. The Transparent House—so called because of its glass exterior walls—is a 20,000-sq.-ft residence consisting of a three-story main house, a 2,700-sq.-ft three-story guest house, and a pool and deck structure. The project uses metal deck composite slabs supported by a structural steel frame, which in turn is supported by stainless steel tubes dubbed "the sprouts."

Due to its location in a relatively hurricane-intensive area, local building codes required the lateral loads to be based on a maximum sustained wind speed of 110 mph. However, in order to protect the structural system of the house against a relatively moderate-strength hurricane, the design team decided to increase the base wind speed to 150 mph; this increased wind speed yielded an average lateral applied load of 58 psf. In fact, even before completion, the house was put to its first hurricane test. Toward the end of construction, Hurricane Ivan—with wind speeds reaching 130 mph—hit land directly over the house. The house suffered no structural damage.

Because residential coastal construction requires that the main living levels be elevated above the local base flood elevation, the design team positioned the first floor at 10 ft above grade. The main house is supported by 11 groupings of four columns (the sprouts) attached to a single foundation point, which gives the building the appearance of floating above the ground. The sprouts are constructed of 8-in.-diameter stainless steel pipes, support W18 girders at the first-floor level, and are supported by hubs composed of 1½-in.- to 2-in.-thick stainless steel plates.

The "floating" concept was also incorporated into the interior of the main house, as several locations of the second floor framing were held back from the main building columns. At these locations, 3-in.-diameter hanger rods support the second floor framing. These hanger rods are in turn supported by the composite steel framing at the roof level.

Architecturally exposed steel was another prominent feature of the project, and this type of steel requires greater tolerances during fabrication and erection than that of conventional steel framing. Additionally, the architect specified horizontal and vertical member proportions to achieve the desired visual appearance. For example, the superstructure columns are composed of two 5-in.-diameter HSS columns tied together with sculpted plates that match the exterior wall horizontal mullion spacing.

Architect
Krueck + Sexton Architects, Chicago

Structural Engineer
TGRWA, Chicago

Engineer (curtain wall)
Advanced Structures, Inc. Marina Del Ray, Calif.

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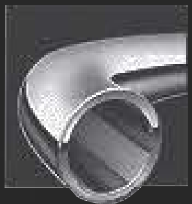

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National Winner—$75M and greater

UNIVERSITY OF PHOENIX STADIUM, GLENDALE, ARIZ.

University of Phoenix Stadium, the new home of the NFL's Arizona Cardinals as of last August, certainly stands out against the surrounding Glendale landscape. Its metal panel-clad exterior shimmers like a space-age desert flower during the day and glows like an enormous lantern at night.

While its skin makes a bold statement, its skeleton is equally as impressive. Perhaps the most interesting structural element is the 500,000-sq.-ft long-span roof structure, the backbone of which is formed by two lenticularly shaped Brunel trusses (so named because of their resemblance to I.K. Brunel's Royal Albert Bridge) that each span 700 ft. Due to the lenticular shape of the trusses, the structure behaves as a self-resolving superposition arch and a catenary tension element.

The sloping component of the top and bottom chord axial forces carry all the system's shear, and light steel rod web members resist unbalance loads, replacing the large diagonals and gusset plates typical of large roof trusses. The rods were prestressed by induced catenary action from a single rod that pinched the sets of cables on opposing faces together. As such, 15 kips introduced into the single draw-in rod produced 100 kips of prestress in four sets of rod pairs, greatly expediting the construction process.

When it came to the aesthetics of the roof, the design called for a relatively low-rise dome. The shape of the Brunel trusses allowed the externally visible rise of the roof to be only half the overall structure depth, with the lower half extending down into the building structure, but above spectator sight lines.

The central portion of the roof is retractable and opens or closes depending on weather conditions and facility use; it is the first retractable roof in the U.S. to traverse an inclined rail. For the operable roof panels, the engineers created a lenticular-Vierendeel HSS truss system—a similar principal to the Brunel truss—in order to eliminate all vertically oriented diagonal elements.

The project was also innovative from an erection standpoint. The fabricator/erector and structural engineer assembled the Brunel trusses and all framing between them—including the operable roof panels—on the ground. In the largest operation of its kind ever completed, this entire assembly was lifted into place over three days using strand jacks mounted atop four supporting supercolumns. This method both greatly enhanced safety and shortened the erection schedule, since the majority of the work was performed close to the ground.

Not only is the roof retractable, so is the field. This operable playing field can slide from its game position inside the stadium to outside the stadium though the south end in only one hour; below the field is a state-of-the-art convention floor. While there were no established playing field vibration guidelines, the engineer developed criteria to provide a suitable playing surface through a series of physical mock-up tests as well as extensive analytical work.

For more on this project, see our August 2006 issue at **www.modernsteel.com**.

Owner
Arizona Sports and Tourism Authority

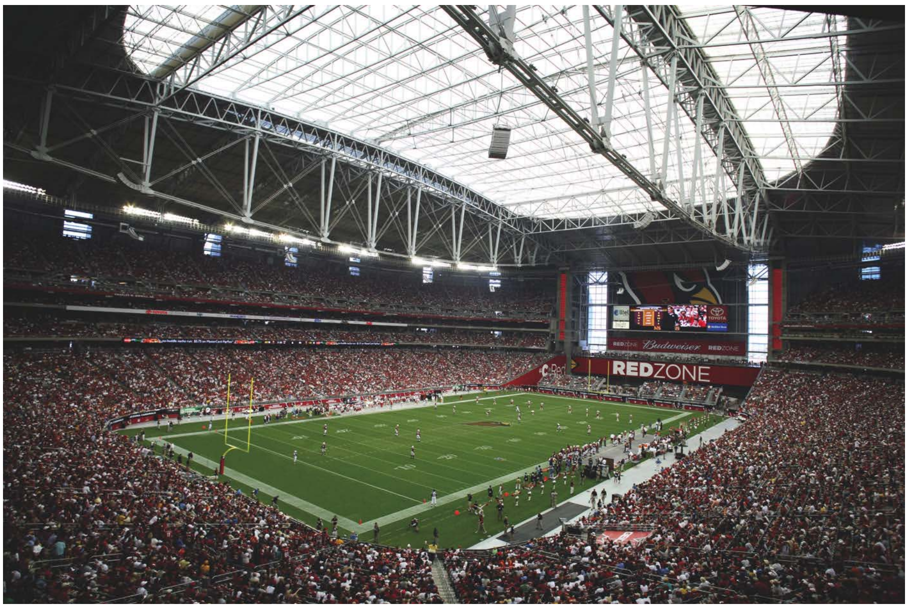
Architect
HOK Sport + Venue + Event, Kansas City, Mo.

Concept Architect
Eisenman Architects, New York

Structural Engineers
Walter P. Moore, Austin, Texas (roof; consultant for operable field)
TLCP Structural, Inc., Phoenix (bowl structure and south concourse bridge)
Crown Corr, Inc., Gary, Ind. (façade support system)

Fabricator and Erector
Schuff Steel Co., Phoenix (AISC member)

General Contractor
Hunt Construction Group (Phoenix)



Aaron Dougherty/HOK

Visions in Photography

Aaron Dougherty/HOK

Merit Award—$75M and greater

HEARST TOWER—NEW YORK

The new headquarters for the Hearst Corporation mixes old with new, with a modern skyscraper rising out of a six-story landmark art deco building. The new 46-story glass and steel Hearst Tower stands at 600 ft tall and comprises 856,000 sq ft of floor space.

Preserving the existing landmark façade was a must. The original building footprint was 200 ft by 200 ft, but the design for the new tower called for a 120-ft by 160-ft footprint. In addition, the new tower would be supported by new foundations behind the original façade.

For the upper tower, a diagrid structure system was employed, creating a highly efficient tube structure composed of a network of triangulated trusses that interconnect all four faces of the tower. The nodes for the diagrid were set on a 40-ft module and placed at four floors apart. The diagonal elements were braced at the floor level between nodal levels, necessitating a secondary lateral system connected to the common diaphragm floors. The system is inherently highly redundant by providing a structural network that allows multiple load paths, as well as inherent lateral stiffness and strength.

Besides being an effective structural system, the diagrid is also highly efficient and was constructed with 20% less steel than an equivalent moment frame structure would have used. This, coupled with the fact that more than 90% of the project's steel contains recycled material, lead to Hearst Tower receiving a LEED Gold rating. In fact, it's the first building to earn such a rating for "core and shell and interiors" in New York.

For an in-depth profile of this project, see our July 2006 and April 2007 issues at **www.modernsteel.com**.

Owner
Hearst Corporation, New York

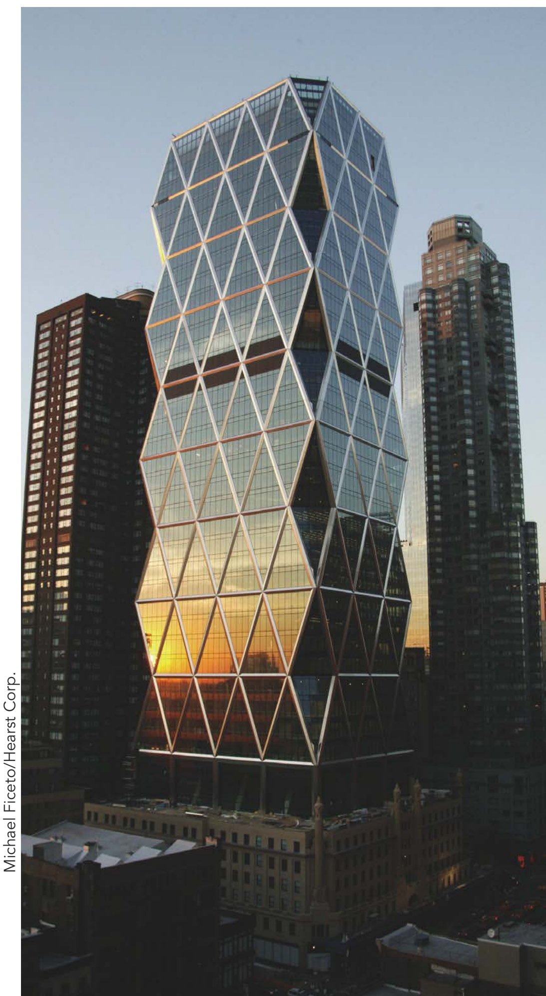
Architect
Foster + Partners, London, England

Associate Architect
Adamson Associates, Mississauga, Ontario, Canada

Structural Engineer
WSP Cantor Seinuk, New York

Fabricator
Cives Steel Company, Gouverneur, N.Y. (AISC Member)

General Contractor
Turner Construction, New York



Michael Ficeto/Hearst Corp.

Presidential Award of Excellence

DENVER ART MUSEUM—DENVER

Carole Lee; Courtesy of the Denver Art Museum

When it came to expanding its facilities, the Denver Art Museum had ambitious plans, to say the least. Not only did it wish to nearly double its size, it also wanted to create an icon for the city.

The end result is the Frederic C. Hamilton Building, a shiny, angular, abstract form that pays homage to the nearby Rocky Mountains. The building's 2,740-ton superstructure is an interwoven cluster of leaning braced frames and trusses clad in 230,000-sq.-ft of titanium shingles. More than 3,100 pieces of steel are contained within 20 sloping panes that define the structure.

None of the planes are parallel or perpendicular to each other, which required the use of 3D modeling software (SAP 2000 and Tekla Structures) and building information modeling—key to understanding spatial relationships and detecting conflicts prior to construction and component fabrication. The architect used Form-Z to create a 3D wireframe model that resulted in 3D coordination of all disciplines.

The 3D wireframe model was loaded into Tekla Structures to refine and reshape the model into an exact virtual replica of the entire structure, including every structural member, plate, bolt, and weld. Detailers dedicated nearly two months to detailing the connections specifically to ensure an accurate advance bill of materials. Multiple connection points had up to 10 members from multiple planes converging on a single point. To handle all loads and solve connectivity issues, the team fabricated columns with massive clusters of gusset plates designed to efficiently receive the field-bolted beams, braces, and struts. In addition, bolt holes were oversized in all piles, allowing for the use of full-sized fit-up pins during construction.

For a complete profile of this project, please see our April 2007 issue at **www.modernsteel.com**.

Owner
Denver Art Museum

Lead Architect Studio
Daniel Libeskind, New York

Executive Architect
Davis Partnership, Inc., Denver, Colo.

Structural Engineer
Arup, Los Angeles

Steel Fabricator
Zimmerman Metals, Inc., Denver
(AISC member)

Steel Erector
LPR Construction Co., Loveland, Colo.
(AISC member)

General Contractor
M.A. Mortenson Company, Denver

Software
SAP 2000
Tekla Structures
Form-Z

Presidential Award of Excellence

PORTLAND AERIAL TRAMWAY, PORTLAND, ORE.

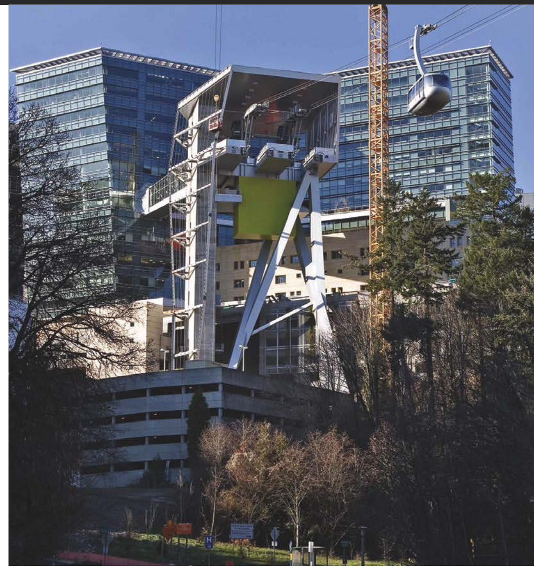
There's a new method of transportation in Portland: the Portland Aerial Tram. While by no means a citywide transit system, the tram does connect the Oregon Health & Science University Hospital (OHSU) and the Marquam Hill neighborhood, located at the top of a canyon hillside, with a new medical redevelopment neighborhood on the bank of the Willamette River, just south of downtown Portland. Passengers are transported in two tram cars with a capacity of 79 people each.

The tram project consists of three steel structures: two stations—upper and lower—and a central support tower. The upper station is an open steel structure, a covered platform on braced legs balanced on a steep site wedged amongst hospital buildings. The lower station, like the upper, is an open network of exposed steel frame construction and expanded aluminum cladding. The central tower is a steel structure whose geometric form is the result of the forces acting upon it.

The two 3,300-foot long track cables from which the passenger cars are suspended are fully tensioned at all times, therefore exerting substantial loads on the two stations and central tower; the trams are pulled by a third haul rope connected to a drive engine at the lower station. Lateral loads exerted onto the platform level at the upper station range from 500,000 to 800,000 lb, when factoring in the tension load on the tram cables, forces due to wind and temperature variations, and the weight of fully occupied tram cars.

The 200-foot tall upper station has a dual structural stability system. Lateral and vertical loads are resisted by a concrete core—which also serves as an elevator shaft and stairwell—and four diagonal steel legs. Each leg is a parallelogram measuring 6 ft by 4 ft and made with 1-in.-thick steel plates. The legs resemble two pairs of compasses and provide stiffness in all directions, providing substantial lateral and torsional stiffness.

The central tower, which provides the intermediate support for the aerial tram, measures 196.5 ft from the drilled pier cap to the highest point. The trapezoidal cross-section varies along the height of the tower, measuring 22 ft wide by 20 ft long at the base, narrowing to 8 ft wide by 8 ft long at the neck region 2/3 of the way up the tower, and expanding again 8 ft wide by and 32 ft long at the top. This variation reduced the risks associated with vortex shedding.



The lower station's structural system is simpler. The station is covered with a 45-ft-tall steel canopy supported by a reinforced concrete basement, and is subject to substantial uplift due to potential high water levels and lateral forces due to the tram loads.

The central tower was fabricated in three pieces and transported to the construction site on barges. The 90-ft-tall base piece, weighing 112,000 lb, was installed first, followed by the 60-ft-long second tier and the 45-ft-long third tier of the tower.

Owner
The City of Portland and Oregon Health Science University

Architect
agps Architecture, Los Angeles

Structural Engineer
Arup, Los Angeles

Fabricator
Thompson Metal Fabricators, Inc., Vancouver, Wash. (AISC Member)

Engineering Software
SAP 2000

General Contractor
Kiewit Pacific Co., Vancouver, Wash.

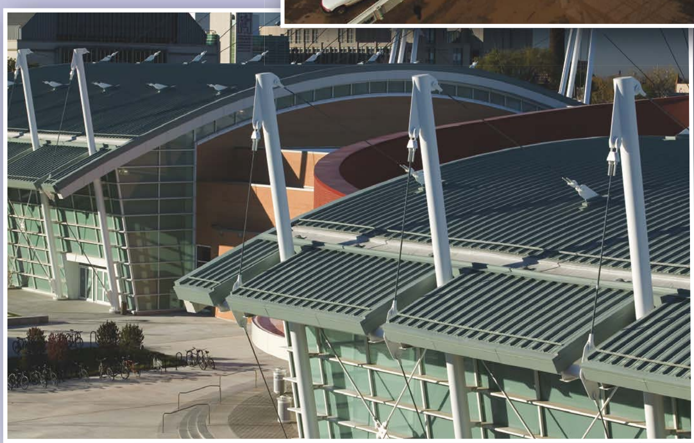
Winners Choose Chicago Metal to Curve Steel

2002 EAE Merit Award – 400 tons of 16" OD Pipe curved for JFK International Airport Terminal 4. Jamaica, NY.

2003 IDEAS National Winner – 300 tons of 5" square curved 45º off-axis for the Kimmel Center. Philadelphia, PA.

2007 IDEAS National Winner – The University of Phoenix Stadium.

400 tons of 12" square tubing curved for the retractable, lenticular roof trusses. Phoenix, AZ.



2004 EAE National Winner – 310 tons of beams bent including reverse curves for the Gerald Ratner Athletics Center. Chicago, IL.

2005 EAE Merit Award – 570 tons of 12, 14, 16, 18, and 20 inch pipe curved for the Jay Pritzker Pavilion. Chicago, IL.

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Now You See It...

BY M. THOMAS FERRELL, P.E.

Column shapes that aren't listed in the tables in the *Steel Manual* aren't off-limits, but there are important connection considerations.

KEEPING ON TOP OF W-SHAPE CRITERIA IS A MUST, as select W-shape columns have disappeared from and reappeared in the *Steel Manual's* tables from edition to edition. For example, allowable axial loads and design axial strengths for selected W4, W5, W6, and W8 column members in compression were provided in the 9th edition ASD manual and the 2nd edition LRFD manual. However, the design strengths in axial compression for these members were eliminated by the AISC Committee on Manuals and Textbooks from the tables in the 3rd edition LRFD manual. The primary reason was the difficulty and associated costs encountered when connecting W-shape members to these column sections. While W8 shapes have been reinstated in the 13th edition's Table 4-2, Available Strength in Axial Compression, these shapes do present difficulties in connecting framing members.

Conventional two-sided connections, such as double-angle and shear end-plate connections, cannot be used when connecting to the web of W4, W5, and W6 columns, due to dimensional properties of the sections. Figure 1 illustrates critical column dimensions restricting use of the conventional connections for W4, W5, W6, and W8 columns.

It's important to address the difficulties and limitations of connecting W-shape members to W6 columns, with the understanding that the connection difficulties escalate when connecting to the smaller sizes. Connections to the webs of these columns are essentially limited to extended single-plate connections. T-distances eliminate the use of two-sided double-angle and shear end-plate connections. Under limited conditions, a shear-end plate connection may be used for connecting W-shape members to the web of W6 columns. The shear-end plate width is limited to the column T-distance (4½ in.), so the bolt diameter is limited to ⅝ in. in diameter to provide adequate clearances for tightening the bolts and to provide adequate bolt edge distances. As shown in Figure 2(a), seated connections cannot be used to connect W-shape members to the W6 column webs. Column flange widths and T-distances simply do not allow access for welding the seat angles to the column webs. In essence, connections to the column webs are limited to extended single-plate connections in conjunction with conventional single-plate connections to the column flanges as shown in Figure 2(b). Extended single-plate connections can be used for both square and skewed framing.

Although W8 columns that were eliminated from the compression

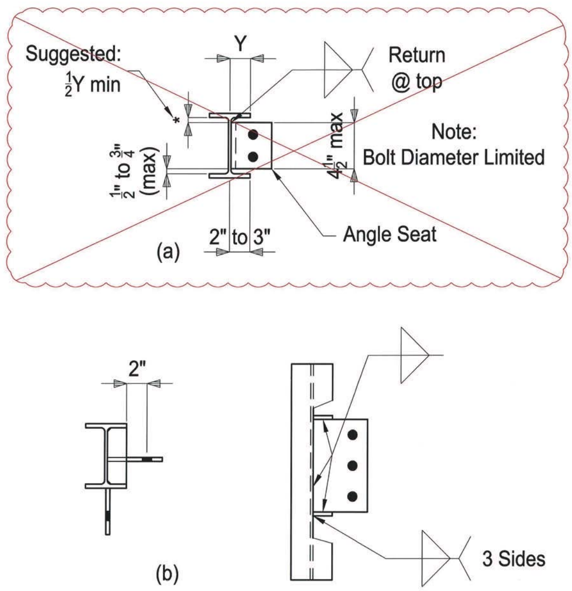


Fig. 2. W6 Columns.

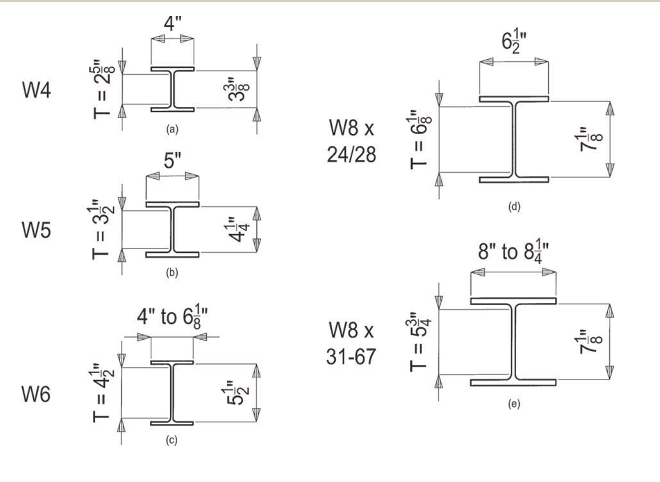


Fig. 1. Column Dimensions.

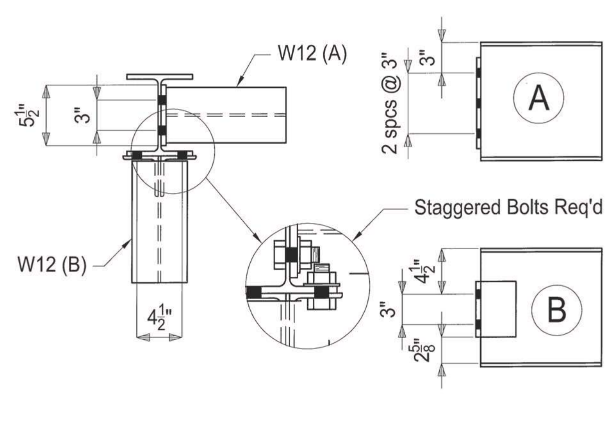


Fig. 3. W8 Columns.

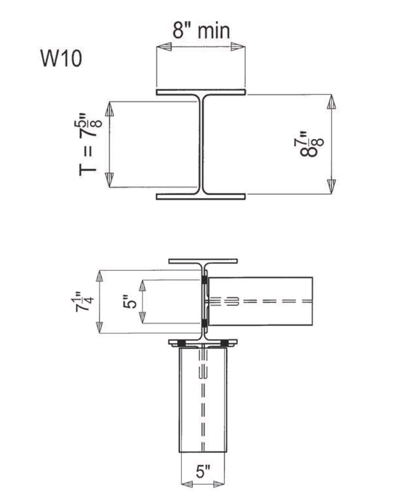


Fig. 4. W10 and Deeper Columns.

strength tables in the 3rd edition manual have been reinstated in the 13th edition, these sections also present difficulties for connecting W-shaped members. End-plate connections should be used for two-sided connections to the column webs instead of double-angle connections due to the T-distance limitations for W8 columns. Bolts must also be staggered to prevent interferences between the bolts to the column flanges and the bolts to the column webs. Staggering prevents using the maximum number of rows within the flanges of most W-shape members framing to the W8 columns. This condition decreases the available connection strengths of the framing members and is illustrated in Figure 3.

Use of W10 and deeper columns eliminates the need for special connections and allows the use of conventional two-sided double-angle and shear end-plate connections. Connection costs are decreased when these conventional connections are used. Conventional connections to W10 columns are illustrated in Figure 4.

Even though the available column strengths for W4, W5, and W6 columns have been removed from the tables, designers are not prohibited from using these sections, if necessary. However, they should be aware that using these sections results in increased fabrication costs that may substantially exceed the savings they provide in material costs. Slenderness criteria for compression elements must be determined using the 13th edition AISC *Specification for Structural Steel Buildings* Section B4 with strength reductions determined by Section E7. **MSC**

M. Thomas Ferrell is president of Ferrell Engineering, Inc., Birmingham, Ala.

We're Still Learning!

Two years into the *Certification Standard for Steel Building Structures,* we're still learning a lot about quality certification in the "real" world.

BY DAN KAUFMAN

ANOTHER YEAR OF AUDITING FABRICATORS TO AISC'S CERTIFICATION STANDARD FOR STEEL BUILDING STRUCTURES (THE BUILDING STANDARD) HAS PASSED. Last year when we examined the top corrective action requests (CARs), the big question was "What have we learned?" This year it's more like a statement: "We are still learning!"

To keep the analysis of the AISC Certification audit CAR statistics as simple as possible, we're going to look at some basic questions: What happens most often? What is the next-most frequent occurrence and how does that compare to last year? The analysis will follow last year's format, showing the top challenges facing fabricators and providing a brief explanation of how they made the list.

2006 Overview

What does the comparison of 2005 to 2006 (Figure 1) tell us? It tells us that management and detailing CARs were cut significantly. Fabricators deserve a big pat on the back for that! We hoped that fabricators would become more familiar with the *Building Standard*, and they did. In fact, almost all of the *Building Standard's* elements showed improved compliance, with one exception: process control. Why is that?

Within the process control element (Figure 2), maintenance generated fewer CARs in 2006 than in 2005, but welding and bolting generated more. Most of the welding CARs in 2006 were for inadequate records of welding personnel qualifications, followed by the handling of welding consumables such as welding rods. In the case of bolting, reviewing the most frequent cause of CARs highlighted unacceptable bolt storage: fabricators have many ways to store high-strength bolts, and many don't protect the bolts like they should—or at least they didn't in 2006. We do expect this to improve this year due to the "training effect" of the audits.

Do these process control transgressions have anything in common? Yes! When any of these items are not conducted properly, there is no immediate impact to the operation of the shop. For example, not having the proper paperwork for a welder doesn't cause him or her to start welding badly, but assigning a body to handle the paperwork can take time away from expediting a job. Likewise, having buckets of dirty bolts sitting in the shop doesn't slow down the operation. However, if you take somebody off their regular job to sort dirty bolts, now you affect the operation.

All of these items have been shown to adversely affect quality—or at least make a statement about the shop's willingness to sweat the details. The next time you see a new regulation or a tightened standard come your way, consider that it may have been prompted or justified by a similar situation that got a little bit out of hand. Those tightened regulations may be designed to ensure that unmotivated participants get in line. Before you reach for the phone to complain, you might want to take a minute to go back in your shop and see if you're living in a glass house.

Management and detailing CARs (Figures 3 and 4), while greatly reduced, are still in the most-frequent category. Can there

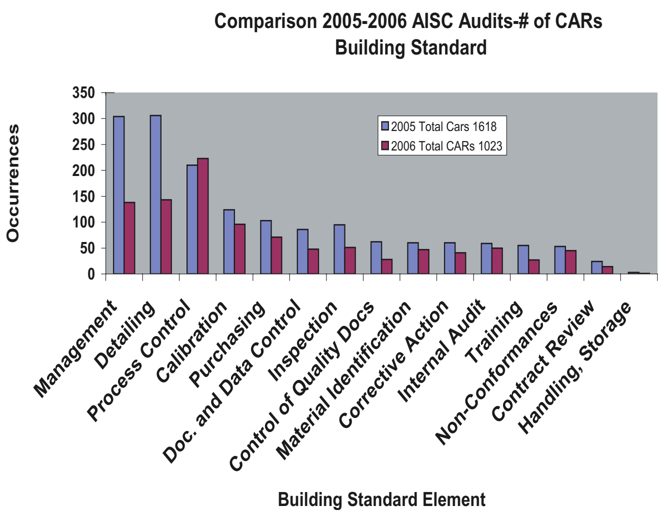


Figure 1. Element CARs by year.

Fabricators: Fear Not!

The 2006 *Building Standard*, which became effective May 1, 2007, is only an update! It includes criteria from the applicable auditing policies, auditing lessons learned, and language clarifications that make it more user-friendly. It is **not** is a revision with new requirements.

Marketing efforts by consultants may have caused fabricators to be concerned about the 2006 *Building Standard* and the audit process. If you have questions, refer to the free "Guide to the 2006 Building Standard" now available on the AISC website at www.aisc.org/2006guide. This guide shows what and where the updates were made.

You can be confident that the QMC auditing process will be performance-based and remain consistent. Please call 312.670.7520 or e-mail certinfo@qmconline.com at any time if you have questions regarding your audit.

—Pat Thomashefsky, Lead Auditor, QMC

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**.

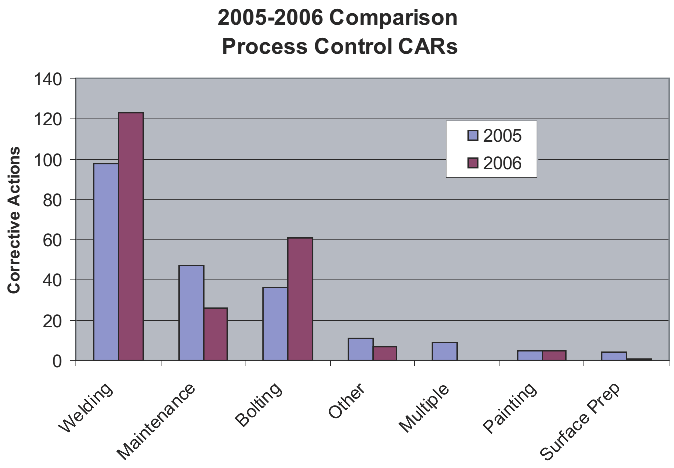


Figure 2. Process Control CARs.

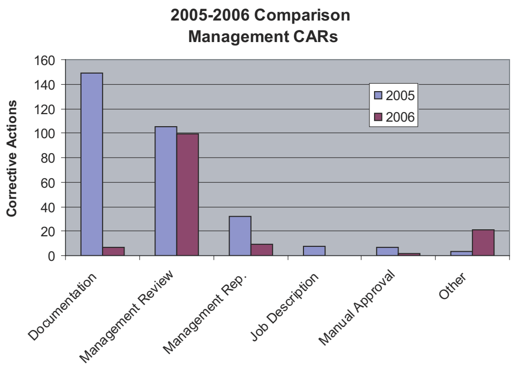


Figure 3. Management CARs.

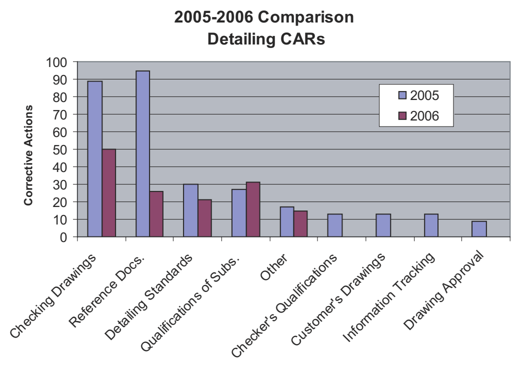


Figure 4. Detailing CARs.

be even more improvement? Of course! While management doesn't appear to be documenting quality goals as expected, I know fabricators are tracking the quality of jobs. Chargebacks and complaints cost money, and I haven't seen a fabricator yet who isn't tracking money. The point is that fabricators know if the customers are complaining or asking for money back. If it doesn't happen very often, it should be easy to document. If it happens a lot, then they might consider spending some effort on it anyway. For AISC Certification purposes, the requirement is simply that fabricators have something on paper, showing that they are aware of how well they are meeting customer requirements.

Checking drawings has improved significantly—another well-deserved pat on the back! However, it's still the number one detailing CAR. What we've seen is that subcontract detailers may be reluctant to reveal the identity of their checkers because, in some cases, they have had good people hired away from them. If that is a concern, they can assign a code to their checkers, and then supply you with a sheet showing the qualifications of the checkers using the codes. As auditors, we don't care if a checker is Bill Smith or 323, as long as the drawing gets checked and you can show us the qualification of checker 323.

Summary

The bottom line is, it's been a year of improvement, and AISC Certified Fabricators are to be congratulated! The table below shows a wrap-up of the top 10 elements generating CARs, the two-year trend, and some possible solutions. While the data collected is useful to the auditing process, it isn't the star of the show. The fabricators who are making progress—and showing off their quality systems to specifiers—are the real stars. MSC

Dan Kaufman is Manager of Operations for QMC.

Top Ten Corrective Actions

RANK	# CARs	ELEMENT	TREND	RECOMMENDED FOLLOW-UP
1	123	Welding	Worse	Welder certification documentation; consumable handling.
2	99	Management Review/Goals	Slight Improvement	Make documentation of your Quality System Goals as complex or as simple as you want, just document the goals and results.
3	96	Calibration	Improved	Use certified tapes to check weld gages and squares.
4	61	Bolting	Worse	Bolt storage cleanliness.
5	50	Checking Drawings	Improved	Use coding for checker identification.
6	50	Internal Audit	Slight Improvement	This is a critical piece of the Quality system. Take it seriously and use the feedback.
7	47	Material Identification	Improved	The *Code of Standard Practice* spells out simple identification requirements.
8	45	Non-Conformances	No Change	Define where the trigger levels are for your system, so you don't have too many—or too few—nonconformances. Zero is too few.
9	41	Corrective Actions	Improved	A "corrective action" is not repairing a defect. A corrective action is finding a solution to a repeated problem or a big issue.
10	31	Evaluation of Subcontractors	No Change	Finding that your supplier made a mistake does not mean you have to disqualify them. Can you help them improve?

Seismic Fuses

BY JASON ERICKSEN, S.E.

Structural fuses help increase the predictability of a building's behavior—and dissipate seismic energy—in the event of an earthquake.

ONE OF THE MOST DIFFICULT SETS OF FORCES FOR ENGINEERS TO ASSESS IS THAT CAUSED BY EARTHQUAKES. The base shear and distribution of forces are based on the properties of the building itself, as well as the ground motions of an earthquake, which are impossible to predict. In addition, the actual stiffness of a building is only an estimate and can change during the earthquake as members yield.

To survive a large earthquake, a building's structure must dissipate the energy imparted by the ground accelerations. Introducing a fuse into the structural frame can provide this dissipation, as well as create a predictable structural response to an unpredictable set of forces. In fact, documents such as the *International Building Code* mandate such a solution.

In terms of AISC seismic-related documents, AISC *Seismic Provisions for Structural Steel Buildings* is intended for structures with high ductility demands. This generally corresponds to Seismic Design Categories D, E, and F as determined in the applicable building code. Stated simply, the *Seismic Provisions* apply whenever the response modification factor R is taken greater than 3.

The seismic load resisting system (SLRS) is the portion of the structure that resists the forces created by the earthquake, and provides the means to dissipate energy in a ductile manner. In steel buildings the energy dissipation is largely accomplished through cyclic yielding of specific segments of specific steel members. The *Seismic Provisions* contain a series of requirements for members of the SLRS to provide stable system ductility, and have two overall goals: to force deformations to occur in specific locations (fuses); and to ensure that frames can undergo controlled deformation in a ductile, well-distributed manner.

The Fuse Concept

By forcing the ductility demand to the fuses, the behavior of the system becomes more predictable. The fuse is usually one member type of each frame system, and the *Seismic Provisions* intend for these elements to stay ductile through cyclic yielding. These members are generally required to have low width-to-thickness ratios to avoid local buckling, and eventually fractures, well into the elastic range. They must also be adequately braced to avoid member buckling at large deformations.

The remaining frame members are designed to remain essentially elastic while the fuse yields dissipate the energy. These members are often sized based on the expectation that the fuse is the overloaded element in the system.

Controlled Deformation

As the fuse yields, the force distribution in the system changes as the deformations increase. The post-yielding force distribution can be very different from the elastic and the "non-yielding" elements, and connections can experience inelastic behavior. These deformations are cyclic, which further increases the demands. As such, the *Seismic Provisions* contain requirements for members and connections of the SLRS outside of the fuse, such as limiting width-to-thickness ratios to delay or preclude local buckling, and bracing requirements to address member and global stability. The *Seismic Provisions* are also intended to result in distributed deformations throughout the frame to increase the level of available energy dissipation and the corresponding level of ground motion that can be withstood.

A Visual Summary

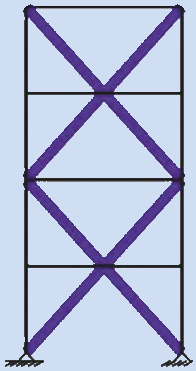
The figures on the following pages identify the fuse in four common seismic force-resisting systems: moment frames, eccentrically braced frames, special plate shear walls, and concentrically braced frames. The figures describe how the fuse dissipates energy and highlight some of the requirements in the *Seismic Provisions* that help ensure the desired behavior. For more information refer to the *Seismic Provisions* and Commentary.

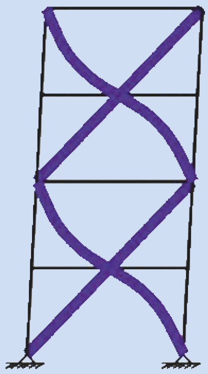
The *Seismic Provisions* include requirements for two other seismic load-resisting systems as well: Buckling Restrained Braced Frame (BRBF) and Special Truss Moment Frame (STMF). Refer to the *Seismic Provisions* and Commentary for more information on these systems.

Jason Ericksen is director of AISC's Steel Solutions Center.

Qualifying Connections for Use

It is not the intent of AISC *Seismic Provisions* to require project-specific tests for all designs. For many commonly employed combinations of beam and column sizes, there are readily available test reports in publications from AISC, FEMA, and others. In addition, connections can be prequalified. See the January 2007 issue of MSC (www.modernsteel.com) for a discussion on how moment connections are qualified, and for detailed information on the two prequalified connection types included in the standard *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications* (ANSI/AIC 358-05).





CONCENTRICALLY BRACED FRAMES

Fuse: Tension yielding of braces and compression bucking of braces for SCBF.

Special Concentrically Braced Frames (SCBF)

- ➜ Energy dissipation is achieved through tension yielding and compression buckling of the braces.
- ➜ The cumulative effect of the requirements in the *Seismic Provisions* is intended to result in braces that maintain a high level of ductility and hysteretic damping.
- ➜ Limiting the member slenderness ratio provides for a reasonable relative compression buckling strength of the brace, as compared to the tension yield strength.
- ➜ Width-thickness limits help forestall local buckling and subsequent fracture during repeated inelastic cycles.
- ➜ The connection of the brace to the beam and column must be proportioned for the expected tension and compression strength of the brace to delay a connection mechanism.
- ➜ The brace is expected to buckle in compression, and the gusset plate must be designed for the flexural strength of the brace. The gusset plate may also be detailed to accommodate the rotations of the buckled brace.

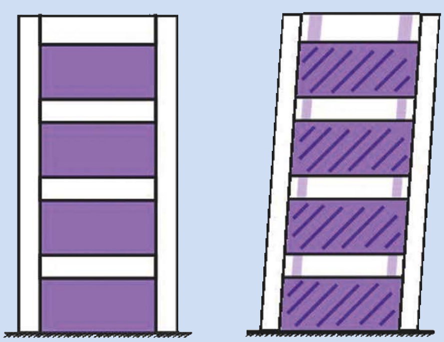
Ordinary Concentrically Braced Frames (OCBF)

- ➜ Limited elastic deformation is expected.
- ➜ The frames are designed for higher forces and use larger members to account for the limited system ductility.
- ➜ Compression buckling of the brace is not expected
- ➜ There are far fewer design requirements for OCBF than for SCBF.
- ➜ The use of this system is limited to low ductility demand structures by the applicable building code (ABC).

Note on SCBF Brace Connections

Section 13.3b of AISC *Seismic Provisions for Structural Steel Buildings* states that connections must be designed for the expected plastic flexural strength of the brace about the critical buckling axis. This satisfies the requirement of confining the inelastic rotation to the brace.

This section also contains an exception that allows connections to be designed to accommodate the rotations as opposed to being designed to force them into the brace. For a single gusset plate connection, this can be accomplished by detailing the gusset to allow the brace to buckle out of plane by terminating the brace before the gusset's line of restraint. The Commentary describes one method to accomplish this, demonstrating that where a single gusset plate connection is used, the rotations can be accommodated as long as the brace end is separated by at least two times the gusset thickness from a line perpendicular to the brace axis, about which the gusset plate may bend unrestrained by beam, column, or other brace joints. This exception is a more common method for confining the inelastic rotation to the brace.



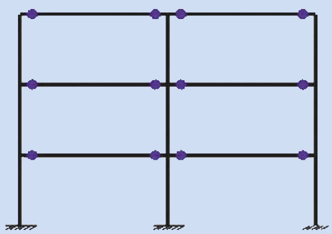
SPECIAL PLATE SHEAR WALLS

Fuse: Shear yielding of the web-plates with tension field action.

- ➜ The Special Plate Shear Wall (SPSW) is new to the 2005 *Seismic Provisions*.
- ➜ Yielding of the webs occurs by development of tension field action at an angle in the neighborhood of 45° and compression buckling of the plate in the orthogonal direction. This yielding provides the energy dissipation in this system.
- ➜ With the exception of the horizontal boundary element (beam) hinging at its ends, the boundary elements are designed to remain nominally elastic and provide enough strength and stiffness to fully yield the plates.
- ➜ The connections of the web to the boundary elements are also designed to resist the maximum force developed by the tension field action of the webs fully yielding.
- ➜ The boundary elements also have flange bracing and element width-thickness ratio limits similar to SMF to allow for the plastic mechanism of the SPSW.

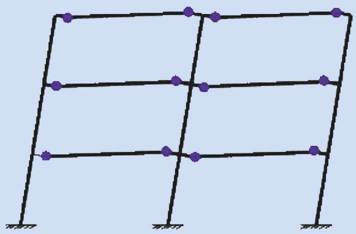
MOMENT FRAMES

Fuse: Flexural yielding of beams near ends. Panel Zones may have yielding in SMF.



Special Moment Frames (SMF)

- ➜ Connections must meet specific strength and rotation criteria, and conformance is demonstrated using either the prequalification process of Appendix P or testing per Appendix S.
- ➜ The beams have flange bracing requirements and width-to-thickness ratio limits more restrictive than the AISC *Specification for Structural Steel Buildings*.
- ➜ Columns are proportioned to preclude hinging in the column (the so-called "strong-column weak-beam" requirement). This requirement avoids a single-story mechanism in the frame and allows the yielding to progress through multiple floors.



Intermediate Moment Frames (IMF)

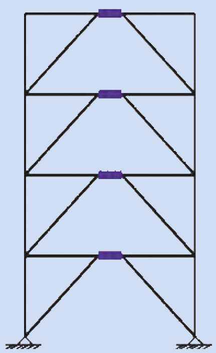
- ➜ Connections must meet specific strength and rotation criteria, and conformance is demonstrated using either the prequalification process of Appendix P or testing per Appendix S with less restrictive requirements than SMF.
- ➜ The beams have flange bracing requirements and width-to-thickness ratio limits more restrictive than the AISC *Specification for Structural Steel Buildings*, but less restrictive than SMF beams.

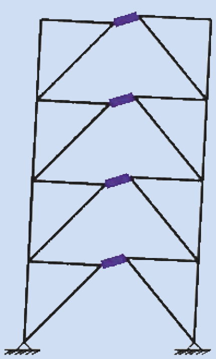
Ordinary Moment Frames (OMF)

- ➜ Intended to have little inelastic connection rotation. This system uses larger members and design forces to limit connection rotation demands.
- ➜ The beam-column moment connection design is prescriptive.
- ➜ Limited in their application as allowed by the ABC.

ECCENTRICALLY BRACED FRAMES

Fuse: Shear and/or flexural yielding of the links.





- ➜ Eccentrically braced frames (EBF) are braced frames in which at least one end is connected so that the brace force is transmitted through shear and bending of a short beam segment called the link.
- ➜ Energy is dissipated through shear and/or flexural yielding in this link.
- ➜ The braces, columns, portions of the beam outside the link, and all related connections are designed to remain nominally elastic as the link deforms and reaches its expected strength. The force in each member of the frame developed by the fully yielded and stain-hardened link is determined and replaces the earthquake load (often designated as E in the ABC) in the design load combinations.
- ➜ This system is essentially a hybrid, offering lateral stiffness approaching that of concentrically braced frames and ductility approaching that of a special moment frame system.
- ➜ System configurations other than that shown are allowed and are discussed in the Commentary to the *Seismic Provisions*.

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Stability Analysis and the 2005 AISC Specification

BY R. SHANKAR NAIR, PH.D., P.E., S.E.

Here's a brief look at the background to the stability requirements in the 2005 AISC specification.

IN TODAY'S ENGINEERING PRACTICE, THERE IS NO SUCH THING AS A "NORMAL" OR "STANDARD" STRUCTURAL ANALYSIS. Advanced analysis methods that were regarded as research tools a few years ago have entered some design offices, while other practices are still using the same (except bigger and faster) analysis tools they had a generation ago. This is especially true in the area of stability, where direct, rigorous second-order analysis is routine in some practices but not in others. This range in analysis options is especially important in the area of stability because of the close interrelationship between stability design and analysis.

The provisions regarding analysis, and especially stability, in the 2005 AISC *Specification for Structural Steel Buildings* represent a significant departure from earlier editions. The new specification recognizes the wide range of analyses in common use. It spells out the general safety- and reliability-based requirements that must be satisfied by all structural designs—giving designers the freedom to select or devise their own methods of analysis and design within these constraints—and also provides "prescriptive" methods for those (possibly a large majority of designers) who prefer that approach.

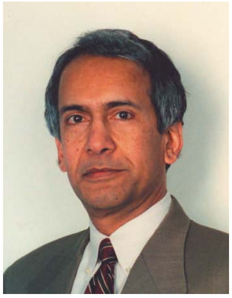
This paper discusses the logical basis of the new specification requirements for stability, and outlines the three alternative prescriptive methods that are specified.

R. Shankar Nair, Ph.D., P.E., S.E. is the recipient of AISC's 2007 T.R. Higgins Lectureship Award. Nair is a principal and senior vice president of Teng & Associates, Inc. in Chicago.

In a career that has focused on structural design of large architectural and civil engineering projects, he has developed the structural concepts for numerous tall buildings and major bridges, including the longest tied arch in the world and a 1047-ft tall building now under construction in Chicago. His work has received many awards, including four AISC/NSBA Prize Bridge awards and six Structural Engineers Association of Illinois Most Innovative Structure awards.

He has served as chairman of the Council on Tall Buildings and Urban Habitat and is, at present, a member of the AISC Specification Committee and chairman of its Stability Task Committee. He is a winner of AISC's Lifetime Achievement Award and a member of the National Academy of Engineering.

Nair present this paper as part of a recent talk at NASCC: The Steel Conference in New Orleans.



This article has been excerpted from a paper presented at The Steel Conference, April 18-21 in New Orleans. The complete paper will be available online later this month at **www.aisc.org/epubs**.

Table 1. Comparison of Analysis and Design Options.

	Direct Analysis Method	Effective Length Method	First-Order Analysis Method
Specification reference	Appendix 7	Section C.2.2a	Section C.2.2b
Limits on applicability?	No	Yes	Yes
Type of analysis	Second-Order	Second-Order	First-Order
Member stiffness	Reduced EI & EA	Nominal EI & EA	Nominal EI & EA
Notional lateral load?	Yes	Yes	Additional lateral load
Column effective length	K=1	Sidesway buckling analysis	K=1

The most versatile and powerful of these methods is the Direct Analysis Method. An appendix to this paper offers a model specification reformulated around the Direct Analysis Method alone, making it easier to understand and use. This represents the direction in which the AISC specification appears to be evolving; the stability section of the next edition is likely to resemble this model specification.

General Requirements

The chapter of the specification on "Design Requirements" (Chapter B) specifies that the design of structural components must be consistent with the assumptions made in the structural analysis used to determine the required strengths of the components. There are no other constraints on the method of analysis.

The chapter on "Stability Analysis and Design" (Chapter C) specifies that the design of the structure for stability must consider all of the following:

- ➜ Flexural, shear, and axial deformations of members.
- ➜ All other component and connection deformations that contribute to displacements of the structure.
- ➜ P-Δ effects, which are the effects of loads acting on the displaced location of points of intersection of members in the structure. (In typical building structures, this is the effect of loads acting on the laterally displaced location of floors and roofs.)
- ➜ P-δ effects, which are the effects of loads acting on the deformed shape of individual members.
- ➜ Geometric imperfections, such as initial out-of-plumbness.
- ➜ The reduction in member stiffness due to inelasticity (including residual stress effects) and, in particular, the effect of this stiffness reduction on the stability of the structure.

When the required strengths of members have been determined from an analysis that considers all the above effects, the members can be designed using the provisions for design of individual members (provided in Chapters D, E, F, G, H, and I).

The specification states explicitly that any method of analysis and design that considers all the specified effects is permissible, and then presents certain specific approaches that account for the last four of the listed effects (P-Δ effects, P-δ effects, geometric imperfections, and inelasticity).

Direct Analysis Method

The most generally applicable method of accounting for P-Δ and P-δ effects, geometric imperfections, and inelasticity is the Direct Analysis Method (presented in Appendix 7 of the AISC specification). It is applicable to all types of structural systems; the provisions of the Direct Analysis Method do not distinguish between braced frames, moment-resisting frames, shear wall systems, and combinations of these and other structure types. In the Direct Analysis Method:

- P-Δ and P-δ effects are accounted for through second-order analysis (either explicit second-order analysis or second-order analysis by amplified first-order analysis, for which a procedure is presented in the specification).
- Geometric imperfections are accounted for either by direct inclusion of imperfections in the analysis model or by the application of "notional loads" (which are a proportion of the gravity load, applied laterally).
- Stiffness reductions due to inelasticity are accounted for by reducing the flexural and axial stiffnesses of members by specified amounts or, at the designer's option, by a combination of reduced member stiffness and additional notional loads.

When the required strengths of members have been determined from an analysis conforming to the above requirements, individual members can be designed using an effective length factor of unity in calculating the nominal strengths of members subject to compression.

The specification provides enough direction to allow application of the Direct Analysis Method in "cook book" fashion. But it also lays out the logical basis for the provisions in a way that offers designers the option of tailoring the method to particular situations. For instance, it is spelled out that the specified 0.002 notional load coefficient to account for geometric imperfections is based on a maximum initial story out-of-plumbness ratio of 1/500; a different notional load can be used if the known or anticipated out-of-plumbness is different; the imperfections can even be modeled explicitly instead of applying notional loads.

In time, if not immediately, the Direct Analysis Method will almost certainly become the "standard" method of stability design of steel building structures.

Indirect Methods

For structures in which second-order effects are not very large (where the ratio of second-order drift to first-order drift is below a specified threshold), the specification offers two alternatives to the Direct Analysis Method.

Effective Length Method. In this method, the structure is analyzed using the nominal geometry and nominal elastic stiffness of all members; required member strengths are determined from a second-order analysis (either explicit second-order analysis or second-order analysis by amplified first-order analysis); all gravity-only load combinations include a minimum lateral load at each frame level of 0.002 of the gravity load applied at that level. Effective length factors (K) or buckling stresses for calculating the nominal strengths of compression members must be determined from a sidesway buckling analysis, except that K=1 may be used for braced frames or where the ratio of second-order drift to first-order drift is less than 1.1.

First-Order Analysis Method. This method is applicable only when the required compressive strength is less than half the yield strength in all members whose flexural stiffnesses are considered to contribute to the lateral stability of the structure. In this method, the structure is analyzed using the nominal geometry and nominal elastic stiffness of all members; required member strengths are determined from a first-order analysis; all load combinations include an additional lateral load at each frame level of a magnitude based on the gravity load applied at that level and the lateral stiffness of the structure. The nominal strengths of compression members may be determined assuming K=1; beam-column moments must be adjusted (using a formula that is provided) to account for non-sway amplification.

The alternative analysis methods and corresponding stability design requirements in the 2005 AISC specification are summarized in Table 1.

Methods of Second-Order Analysis

As noted in the discussion of alternative analysis-design approaches, the Direct Analysis Method and one of the two indirect methods require a second-order analysis of the structure. The second-order analysis can take the form of an explicit second-order analysis that includes both P-Δ and P-δ effects. Alternatively, the second-order analysis can consist of amplified first-order analysis, for which a detailed procedure is provided in the specification. (This is the "B1-B2" procedure familiar to designers from previous editions of the specification.)

Since stability is an inherently nonlinear phenomenon, it is essential that all second-order analyses be carried out at the LRFD load level. To obtain the proper level of reliability when ASD is used, the analysis must be conducted under 1.6 times the ASD load combinations and the results must then be divided by 1.6 to obtain the forces and moments for member design by ASD. (The 1.6 load multiplier must also be used, in ASD, when checking the ratio of second-order drift to first-order drift, as required under certain provisions.)

Additional Information

This outline of the analysis provisions in the 2005 AISC specification is intended primarily as an introduction to these provisions and to show the logical progression of the provisions from general requirements applicable to all structures to specific procedures that designers may choose to use for the design of typical structures. More information on the rational basis of the new specification provisions can be found in the Commentary to the specification and the references listed therein.

Further Developments

The most versatile and powerful of the three alternative methods of stability analysis and design in the 2005 AISC specification is the Direct Analysis Method. An appendix to this paper (available in the full version of this paper online at **www.aisc.org/epubs**) offers a model specification reformulated around the Direct Analysis Method alone, making it easier to understand and use. This represents the direction in which the AISC specification appears to be evolving; the stability section of the next edition is likely to resemble this model specification. A second appendix (also available with full version at **www.aisc.org/epubs**) explains the substantive differences between this model specification and the present AISC specification. MSC

Reference

AISC (2005), *Specification for Structural Steel Buildings*, ANSI/AISC 360-05, American Institute of Steel Construction, Inc., Chicago.

Bending in the Right Direction

BY GEOFF WEISENBERGER

Curved steel doesn't just happen. Precision instruments and expert benders are responsible for these increasingly popular architectural and structural elements.

CLEVELAND IN WINTER ISN'T MOST PEOPLE'S IDEA OF A GOOD TIME— especially when traveling there from Chicago, where it's just as cold, as Todd Alwood, an AISC regional engineer and Secretary of AISC's Bender-Roller Committee, and I did in early March. Places like Miami, San Diego, and Las Vegas sound much more appealing when you've got an opportunity to escape the Chicago area in winter.

Luckily, the warm hospitality from the folks at Kottler Metal Products, to whom we paid a visit, made up for the weather. In fact, when I told Kottler's president, Barry Feldman, that my toothpaste was confiscated at the airport (it wasn't in the requisite plastic bag), he went into his office and found a fresh tube for me! I've been on a lot of business trips, but no one has ever given me toothpaste before.

Perhaps the hospitality can be attributed to the fact that Kottler has been family-run since its origin almost a century ago in a three-car garage in Cleveland. Nowadays, the bending and rolling company operates out of a 60,000-sq.-ft. facility in suburban Willoughby, employing approximately 30 and bending steel for projects all over the U.S. and outside of the country as well.

And business is good. Kottler's orders are split roughly in half between structural steel and tube and pipe, and these two main areas can be broken down into multiple industries. Barry credits this ability to service different markets as one of the key contributors to his company's success. "Since we cater to a multitude of industries, when one is down, another is up, keeping our labor force in balance," he says. "We have never encountered a layoff due to lack of work."

The recent demand for architectural bent steel certainly doesn't hurt. Barry explains that arches have become more and more popular in the U.S. over the last two decades, noting that using bent steel in a project only adds an incremental cost. "We're used to having box-like buildings," he says. "Arches have brought back some sense of style."

Now, I have a pretty good idea of what "bending and rolling" is, but I ask Barry the difference between the two. "Bending is rolling, but rolling is bending also," he says.

How Steel is Bent

Have you ever seen a steel beam bent in real life? If not, we've got the next best thing. These pictures show the most common bending process, which is called roll bending or pyramid bending. The rolling machine has three adjustable rolls in a pyramid configuration; a tighter roll spacing produces a tighter radius. The beam shown is a W36x135 being rolled along its weak axis, the "easy way."

The beam is placed in the rolling machine and the operator adjusts the three rolls to the proper spacing before starting the bending process.

The operator slowly begins rolling, and he frequently checks the beam for distortion of the web and flanges in these early passes.

Several additional passes are carried out, with the operator measuring the overall radius after each pass to check the beam's progress.

Bending Towards an Industry Standard

Communication issues are a key target for AISC's bender-roller committee, composed of representatives from AISC Associate Member bender-rollers.

One of the committee's goals is to set standard terminology across the board—and educate the industry—so that architects and engineers specify the proper bending information to the fabricator and there's no confusion when transferring this information to the bender.

"An industry standard, in terms of nomenclature, proper information, and quality," says AISC Bender-Roller Committee Secretary, Todd Alwood, "will allow the design team to provide proper steel drawings from the onset that will move down the line through the fabricator, bender, and finally, erector, with no mistakes."

AISC's Bender-Roller Committee

Albina Pipe Bending Company, Inc.
Bowers Fabrication
Chicago Metal Rolled Products Company
COMEQ, Inc.
Greiner Industries, Inc.
Hodgson Custom Rolling, Inc.
Kottler Metal Products, Inc.
Kubes Steel, Inc.
Marks Metal Technology
Max Weiss Company
Oakley Steel Products Company
Paramount Roll & Forming, Inc.
WhiteFab, Inc.

"In the industry, one thinks of bending as a tighter radius bend and rolling as making a larger radius bend."

It used to be that heating steel was the only way to accurately bend it. However, the advent of more advanced equipment over the last 20-30 years has allowed steel to be bent and rolled with much more accuracy in a cold condition.

Of course, there are multiple techniques for bending and rolling, depending on the overall member size, wall thickness (web and flange thickness, HSS wall thickness, etc.), radius requirement, and end application of the material. The following methods, except of course for heat induction, are all performed with steel in the cold condition.

Rotary-draw bending involves rotating a piece of steel around a solid die and pulling the material around a specified radius while internally supporting the material with a mandrel (if it's hollow).

Incremental or camber bending is a process in which pressure is applied at the third point of the member via a hydraulic ram or press. This process is often used for curving steel to very large radii.

Another process is heat induction bending, where steel is heated and bent in increments and pulled to the designated radius. It's a slow and expensive process, Barry says.

And then there's rotoform bending, a specialized extrusion process in which the material is extruded from the straight condition into a bend. This bending technique is the most flexible in terms of radius parameters.

Finally, there's roll bending, which involves curving a piece of steel between three or more rolls. The member is rolled

The operator confirms the beam's final radius (14′-4$\frac{3}{16}$″ in this case), completing the bending process.

4

5 The curved beam is lifted out of the rolling machine and moved to another area of the shop where the member's geometry is checked one final time.

back and forth on multiple passes until the designated radius is achieved.

When it comes to structural steel, members can be bent two ways: the easy way involves bending a member along its weak axis, and the hard way means bending it along its strong axis.

Todd explains that it's difficult to find a bender that performs every single type of bending/rolling process. "Everyone can do several of them, but not all of them. Everyone has different strengths and weaknesses." For example, Kottler performs all of the aforementioned processes except for heat induction.

Standing Out

While Todd and Barry agree that many bending outfits have similar capabilities, they also note that each has its own proprietary techniques, and this is what differentiates companies from one another. For example, Barry says, pointing to a piece of bending equipment as we tour his facility, everyone has this particular machine, but each bender develops their own processes and manipulates their machines to do their own thing different and better than everyone else.

"Much of rolling and bending is an art and not a form—one company's ability to use a certain machine in a certain method," he says. Much in the same way that handing the same guitar to Jimi Hendrix and Eddie Van Halen would produce masterful—but completely different—guitar solos.

"No matter how good the machine is, you need a skilled operator in order to achieve a quality bend," Barry explains. "The bend is a byproduct of the machine and the material, as well as the operator. You can't just put it in, push a button and say there it goes, because on many of these jobs, especially for architectural applications, you may have 100 pieces, but they may have different radii and different degrees."

I ask Barry if the bending staff operates multiple machines. The answer is no; the same operator generally uses the same machine every day. This allows them to become experts on their machine; they know the machine, the materials it bends, and all its nuances. Benders start on smaller machines, and then move up to larger machines, which equals more responsibility and higher wages.

Of course, people like "big," and this provides another opportunity for benders to stand out from the competition. Kottler's facility can bend up to 40-in. channel beams and I-beams both the easy and hard way. "That gives us one of the largest structural capacities in the country," says Barry. The longest member the facility has bent was 87 ft., and they literally cut holes on both sides of the building to accommodate this job.

In the end, for Kottler at least, reputation ends up being the ultimate selling point. "We only have an internal sales force, so it's mainly word of mouth and referals from satisfied customers, which is our best mode of advertising," Barry says.

So what's the most difficult bending job? Barry is ready with the answer: Apply a hard-way bend to light material to a tight radius, "because then you have every variable working against you—the material, the thickness, and the radius."

Higher Standards

While Barry explains that bending and rolling equipment has been slow to change in recent years, one thing that has changed is that the industry has become much more demanding when it comes to the quality of a bend for architecturally exposed steel. "Even as recent as 10 years ago, you were able to bend a piece of tube or pipe or rectangular tube and have much distortion and concavity in it, and it would be acceptable in the industry," says Barry. "Today, with better equipment as well as better techniques, the industry has raised the baseline, insisting that we put out a better quality product. This is possible to do right now with new techniques that we've developed, as well as excellent equipment that's available in the marketplace."

All Kottler bending is performed to AESS standards outlined in AISC's *Code of Standard Practice* (**www.aisc.org/code**). Kottler inspects the segments to the AESS tolerance and desired degree bend to assure that the segments are correct prior to the end user receiving the goods. If an error is made, the segment is replaced with a new, quality piece so that the customer never has to see a faulty product. "Ultimately, when it leaves the shop, it's got to be right," says Barry.

When customers provide the material, it is critical that they work with the bender to determine the required length. Two factors affect the length required:

- The finished arc length is greater than the member span.
- Depending on the bending process used, varying amounts of extra material are required at one or both ends of the member to initiate the process.

If insufficient material length is originally supplied, the customer may have to add splices to comply with the bender's requirements.

Precision, not Primate

I left Kottler and Cleveland with a much greater understanding and appreciation of the steel bending process. The only disappointing part of our visit was that my theory of a giant King Kong-like gorilla chained to a wall—bending member after member with his bare hands, occasionally snapping one in half and pounding his chest and snarling in fury—turned out to be wrong. But that's probably a good thing. MSC

A list of structural steel bender-rollers appears on pp. 57-59 of this issue.

Structural Steel Bender/Rollers

The following firms offer structural steel bending and rolling services. The AISC logo next to a listing indicates that the firm is an AISC Associate Member bender/roller or an AISC Active Member fabricator providing bending and rolling services.

A-1 Roll Co.
586.786.6677
Mount Clemens, Mich.
www.a1roll.com

Advanced Bending Technologies, Inc.
604.856.6220 / 800.563.BEND
Langley, British Columbia, Canada
www.bending.net

Albina Pipe Bending Company, Inc.
503.692.6010 / 866.252.4628
Tualatin, Ore.
www.albinapipebending.com

Specializing in pipe, square and rectangular tube, structural steel, and spiral bending, forming, and fabrication since 1939. Ability to bend architecturally exposed material ranging from ⅛"to 26" OD. ½" up to 20" tubing (easy way, hard way, compound or off-axis). Angle, flat bar, square bar, wide-flange (I-beam), channel, plate, split tee, etc. (easy way, hard way or off-axis). Architectural exposure-quality spiraling of tube steel, channel, plate, and pipe to amazingly tight radii and steep pitches.

Bendco Bending and Coiling
713.473.1557
Pasadena, Texas
www.bendco.com

BendTec, Inc.
218.722.0205
Duluth, Minn.
www.bendtec.com

Induction bending of structural steel and pipe sizes ranging from 2" to 66" in diameter. BendTec is an AISC Certified fabricator for conventional and complex steel building structures, simple steel bridges, and major steel bridges with endorsements for sophisticated paint and fracture-critical. Also provides fabrication of structural steel and pipe services including welding, machining, heat-treating, quality control, painting and coating, and engineering services.

Bowers Fabrication
770.787.5331
Oxford, Ga.
www.bowersfab.com

Bowers Fabrication is a one-stop resource for custom heavy steel parts; large capacity plate rolling, bending, and cutting; large structural angle, beam, and tube rolling; professional fabrication (all types); and prompt, courteous service and delivery.

Chicago Metal Rolled Products Co.
800.798.4504
Chicago, Ill.
www.cmrp.com

Roll-curving structural steel and plate: Every size of angle, bar, channel, and tee as well as beam up to W44×285 the hard way on the world's largest beam roller. Plate rolling to 1¾"×11½' into cylinders and cones. HSS Bending: Tube and pipe up to 20" OD, from tight bends (2× the OD of the pipe) to large sweeps. Square tubing up to 16". Rectangular tubing up to 20"×12". Low-deformation, thin-wall bending to keep members light in weight-sensitive applications. Special Rolling: In addition to single-radius bending in one plane, rolling off-axis and multi-axis bends; multi-radius and reverse bends; true, helical coils; and plumb, circular, stair stringers. Roll-curving of formed shapes and extrusions: Strut and other formed channels, formed angles, hat sections, etc.; aluminum extrusions to create arches and bows on curtain wall and storefront systems. 2 to 3 day service. 96% on-time delivery for all products listed above. Hard way, easy way and every way in between! Plants in Chicago and Kansas City, Mo.

Clayton Industries, Inc.
205.715.2000
Birmingham, Ala.
www.claytonind.com

Greiner Industries, Inc.
717.653.8111
Mount Joy, Pa.
www.greinerindustries.com

Structural shape rolling and beam splitting: Roll I-beams up to 40" the easy way and 24" the hard way, tubing up to 26" by 16" or 20" square, and pipe up to 20" diameter. Precision-cut I-beams up to 36" into tees. Blasting and coatings: 500-ft-long state-of-the-art facility with 100-ton "four-point-pick-and-carry" crane system. AISC – Sophisticated Coatings Endorsement and SSPC-QP3 certification for the application of protective coatings. AISC structural steel fabrication: AISC certified for Major Steel Bridges and Complex Steel Buildings with Fracture-Critical and Sophisticated Coatings Endorsements. Specializing in the fabrication of large trusses, plate girders, and heavy structural steel building columns. Machining: Large CNC horizontal boring mill with 12-ft by 30-ft machining envelope. CNC gantry type machining center with 10-ft by 10-ft bed. Specializing in heavy base plates and large splice plates.

Hodgson Custom Rolling, Inc.
905.356.8132 / 800.263.2547
Niagara Falls, Ontario, Canada
www.hodgsoncustomrolling.com

Hodgson Custom Rolling, Inc. specializes in the rolling, bending, and forming of heavy plate from ¼" to 7" thickness, including cylinders, cones, structural sections, angle, wide-flange beam, I-beam, channel, pipe, tubing or rail, stringers for spiral staircases, etc. ASME certified, we service multiple industries including heavy manufacturing, oil, gas, hydroelectric, petrochemical, steel, mining, etc.

Kottler Metal Products, Inc.
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Willoughby, Ohio
www.kottlermetal.com

Structural steel bending capacity to form up to 40" channel/I-beam, both easy way and hard way; 20" tube and pipe, with minimal distortion, to the highest architectural standards. Pipe bending capacities include mandrel bending of pipe and tube up to 12" and roll bending of pipe and tube up to 20". Round, square, and rectangular with minimal distortion. Plate bending capacities with the ability to bend up to 1"-thick in cylinders and conicals. Rotoform capacity with the ability to bend up to 12" round pipe and tube as small as three times the diameter and with multiple radii.

Kubes Steel, Inc.
877.327.8357 / 905.643.1229
Stoney Creek, Ontario, Canada
www.kubesteel.com

Kubes Steel is proud of the service we offer to the steel construction and fabrication industry as Canada's premier provider of structural, section rolling, forming, and prefabrication services. We offer Canada's largest multi-section roll and specialized section bending capacity, including sections to a depth of 40" and pipe to 42" diameter. Kubes Steel's customer list embraces many of North America's preeminent fabricators. Call us to make your next project take shape.

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Mark IV Metal Products, Inc.
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Los Angeles, Calif.
www.markivmetal.com

Marks Metal Technology
800.526.1031
Clackamas, Ore.
www.marksmetal.com

Diamond curve technology: For hard way beams minimizes distortion and reduces the need for tails. Reverse curves without tangents are easily accomplished. Circular stairs, stringers, and components: The experience and geometrical skills to make your stairs right the first time. Components: stringers, handrails, tread, and landings. Complete stairs: tubular steel, structural channel, or plate. Plate rolling and custom profile shaping: Rolls and forms plate and custom profiles to exacting requirements of roundness and dimensional accuracy. Tees, beams, angle, pipe, bar, channel, cylinders, cones, cambering, and more. Structural fabrication: Skilled in stainless, aluminum, and mild steel fabrication to AWS, ASME, and AISC standards.

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Company	Products Offered	Product Description
Advanced Fabricating Machinery www.advancedfab.com 603.642.4906	**Stierli benders**	Bending machines up to 330 tons for bending, cambering, and straightening of beams, flats, and profiles. Available with NC/CNC controls and featuring a slot-free surface for reliability and safety.
	Comac section rolls	Section rolls with three-roll drive and double initial pinch, available with CNC and NC controls. Sizes up to 8 in. x 1 in. angle. Machines available for special applications.
	PlasmaCope 1200/2400	Cutting, coping, and holes in round tube up to 5 in. OD. Easy-to-program CNC control calculates angles and allows nesting of parts.
	Transfluid and Soco Bending machines	Tube and pipe bending for many different applications.
Bertsch, a Division of MegaFab www.bertschrolls.com 800.338.5471	**Plate Bending Rolls**	Rugged, reliable, heavy-duty plate rolls accurately form metals from gauge through 14 in. thick. Machine lengths from 3 ft to 40 ft. Complete lines of initial-pinch, double-pinch, and four-roll designs.
	Angle Rolls	Unique design offers double-pinch for minimal flats, ease of operator control, and uniform rolling. Vertical or horizontal working position; hydraulic drive; models to 50 horsepower; and 24-in. die diameter.
COMEQ, Inc. www.comeq.com 410.933.8500	**Angle Bending Rolls**	Double-pinch-type angle bending rolls. Seven models with two-directional hydraulic guide rolls with capacities to 5″ × 5″ × 5/8″, and 15 models with multi-directional hydraulic guide rolls with capacities to 10″ × 10″ × 1″.
	Plate Bending Rolls	Three-roll and four-roll double-pinch type plate bending rolls. Fully hydraulic with capacities from 16 gauge to 4″ thickness and lengths from 2′ to 30′. With or without CNC controls.
	Pipe, Tube, and Section Bending Rolls	Angle bending rolls with special rolls and equipment. For rolling angle leg-in and leg-out; stems leg-in, leg-out, and leg-down; flat bars; square bar; round bar; pipe; tube and channels.
	Beam Benders	Fully hydraulic models with section modulus capacity up to 1,000 cubic inches. Capacities to 44″ beam and channel, 14″ pipe, 16″ round bar, 15″ square bar, and 24″ flat bar.
E.G. Heller's Son, Inc. www.hellerson.com 800.233.0929	**Plate Bending Machines**	Three- and four-roll double-pinch systems, heavy-duty all-hydraulic plate-bending machines with various controls fitting every type of application.
	Section Bending Machines	Many models to fit customers' requirements exactly. All hydraulic drives with epicyclical sealed transmission boxes. Low maintenance. Horizontal or vertical operation. Various controls and tooling options available with fast deliveries.
	Plate Shears	Hydraulic swing beam shears come equipped with FOPBG with digital readout; shadow light; squaring arm; front sheet support; mar-free hold down pads; and ball transfers on the table for easy flow of material into the shear.
	Press Brakes	Hydraulic conventional down-acting double-cylinder ram with internal motorized depth stops; FOPBG with digital readout; front sheet supports; and choice of European- or American-style tooling as standard features. Die has multiple openings.
Faccin USA www.faccin.com 813.664.8884	**Plate Bending Rolls**	World leader in the production of heavy-duty bending rolls in three-roll initial-pinch, double-pinch, variable-axis, and four-roll configurations and full FMS systems.
	Wind Tower Rolling Systems	Coupling a plate bending roll with specialized options to optimize tower rolling efficiency and accuracy.
	Section (Angle) Bending Rolls	Heavy-duty hydraulic rolls for the processing of structural shapes, bars, pipe, and tubes. Starting from 4-in. angle capacity.
	Dished End Lines	Multiple machines to form and flange multiple sizes of dished ends for pressure vessels and tanks with a minimum of tooling required. Sizes from ¼ in. up to 2 in. in thickness.

project case study

Chicago Metal Rolled Products—University of Phoenix Stadium, Glendale, Arizona

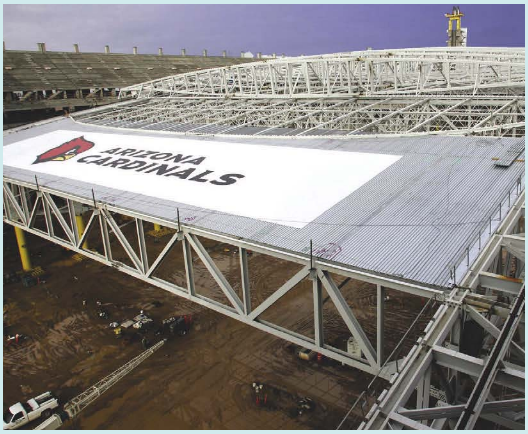
CHICAGO METAL ROLLED PRODUCTS CURVED 402 TONS OF TUBING for the roof trusses of the University of Phoenix Stadium in Glendale, Arizona, the new home of the NFL's Arizona Cardinals (a 2007 IDEAS² Award National Winner; see p. 33).

Spanning the width of the field are 256-ft-long lenticular trusses, so-called because both the top and bottom chords are curved, creating a profile that resembles a convex lens. The two retractable roof panels use sixteen such trusses. The company stored 213 pieces of tubing delivered from mills in Chicago, then curved and shipped parts over the course of five months, always meeting the fabricator's schedule.

Early involvement in the project allowed Chicago Metal Rolled Products to offer cost- and time-saving suggestions. For example, using its advanced technology, the company provided 52 ft of distortion-free arc from stock only 54 ft long. With traditional rolling methods, 6 to 10 ft of each tube would be lost to scrap.

According to the project manager and subcontract administration manager, this challenging fabrication fit-up took place with no quality issues in the plant or in the field—a tribute to the teamwork of the roller, fabricator, the erector.

—George F. Wendt, President, Chicago Metal Rolled Products, Chicago



Chicago Metal Rolled Products curved 402 tons of 12″ square tubing for the retractable roof of University of Phoenix Stadium in Glendale, Arizona.

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