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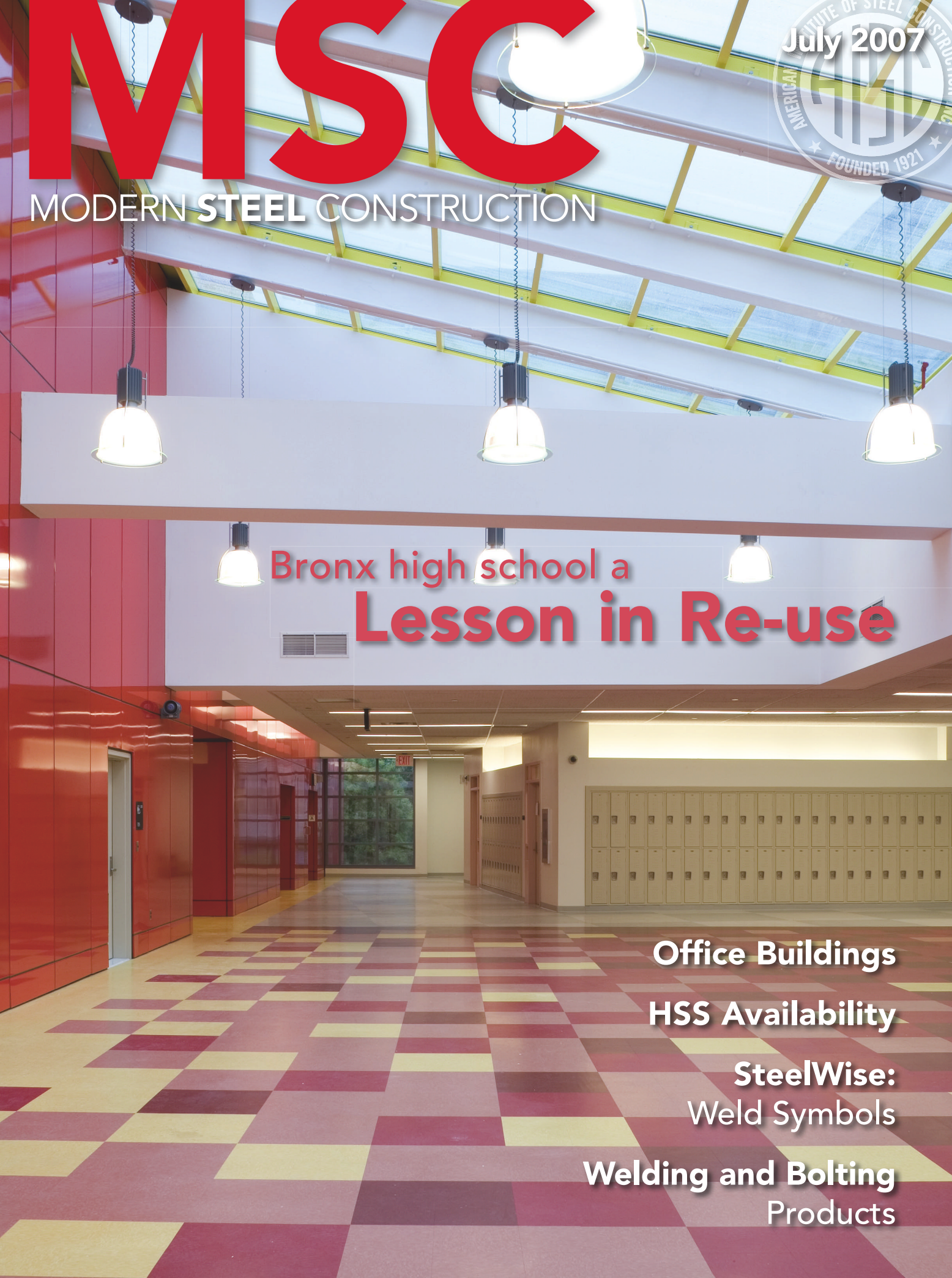

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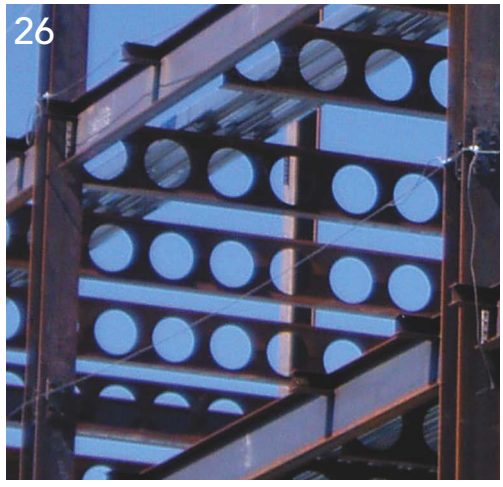

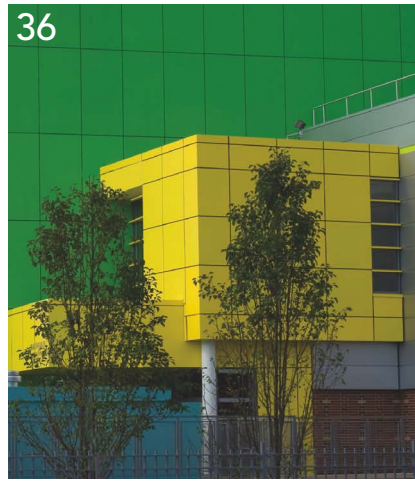

ON THE COVER: New high school at the Bathgate Educational Campus, Bronx, N.Y.

MODERN STEEL CONSTRUCTION (Volume 47, Number 7). ISSN 0026-8445. Published monthly by the American Institute of Steel Construction, Inc., (AISC), One E. Wacker Dr., Suite 700, Chicago, IL 60601. Subscriptions: Within the U.S.—single issues $3.50; 1 year, $44; 3 years $120. Outside the U.S.—single issues $5.50; 1 year $88; 3 years $216. Periodicals postage paid at Chicago, IL and at additional mailing offices. Postmaster: Please send address changes to MODERN STEEL CONSTRUCTION, One East Wacker Dr., Suite 700, Chicago, IL 60601.

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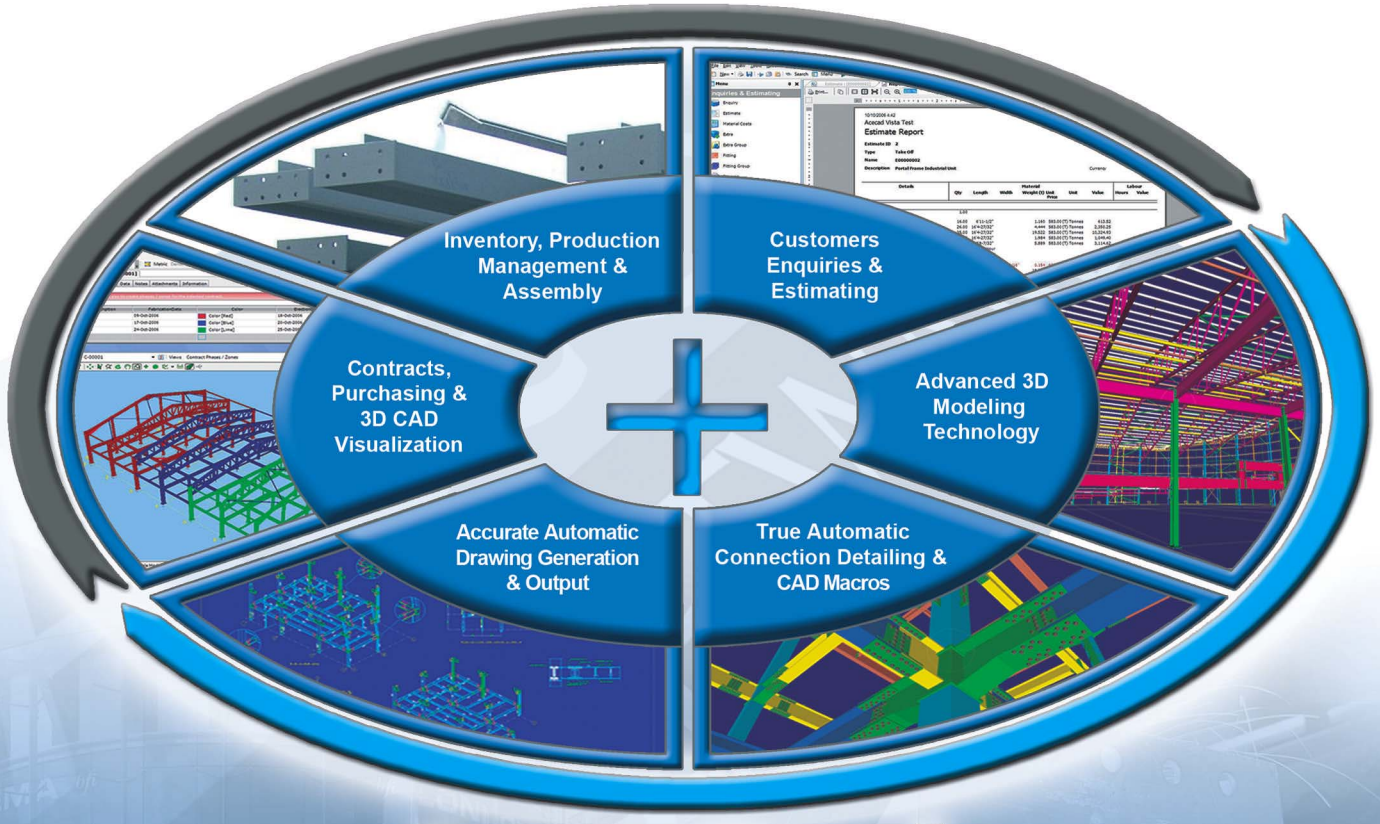

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editor's note

ONE OF THE GREAT ADVANTAGES OF HAVING YOUNG CHILDREN IS THAT YOU STILL KNOW ENOUGH TO HELP THEM WITH THEIR HOMEWORK. I've seen the work my older nieces and nephews did while they were in high school—and too much of it seems like what little I remember of my university work.

In a powerful address at this year's Structures Congress, ASCE President William F. Marcuson, III challenged civil engineers to reinvent the profession or risk going the way of telephone operators in the mid-1960s. Marcuson noted that before 1965, when you placed a call it went through an operator. But automated switching equipment did away with that entire profession. And he worries that civil engineering is becoming a commodity that relies either on outsourcing or automated design programs.

"Engineering is starting to be priced as a commodity rather than a profession," he stated, partially as a result of the "globalization of engineering." At the same time, he's concerned that we're not doing enough to prepare our children for a future in engineering. Among 21 developed countries, he stated, U.S. high school seniors ranked below average in both math and science. We're also seeing more tort suits and less research in the U.S. And only three U.S. companies ranked in the top 10 for the number of patents filed.

Even if every high school student in the U.S. took the type of highly competitive math and science classes I've seen my nieces and nephews take, we'd still be behind the eight ball. As Marcuson pointed out, China and India (with three billion people, combined) are producing more engineers than we ever could.

So what will allow the American civil engineer of the future to demand higher pay than their counterpart in India or China? Marcuson states that it is essential for all U.S. civil engineers to have advanced knowledge and attitude, and to be better prepared as a global technology leader.

His words ring particularly true when you consider the difficulty in hiring good project managers today—not to mention finding the right people to manage engineering firms. So what does he suggest? Education, training, specialization, and preparation alone are not enough. Today's civil engineers need continuing and continuous education on leadership. They need to be proactive, not reactive, to understand and participate in the civil policy process; they need to communicate—both with the technical and non-technical audience; and they need to teach, coach, and mentor other engineers.

SCOTT MELNICK
EDITOR

P.S. On a personal note, I'd like to offer my condolences on the passing of one of the industry's true giants, William J. LeMessurier. Some people will remember him best for his large body of significant projects. Many people will long remember him for the ethical dilemma he overcame in warning about and fixing the flawed design of the Citicorp Tower in New York City.

Others will remember him for his marvelous innovations, such as the development of the staggered truss framing system. I'll remember him for a long conversation in 1983, when as a new grad I was assigned the task of writing an article about a proposal for what would then be the world's tallest building.

Unfortunately, neither the developer nor the design team were willing to make any comments or release any details—rather hindering the writing of an article for any publication this side of the *National Enquirer*. Out of desperation, I called Bill—who I had never spoken to before and who had nothing to do with the project. But being the special person he was, he spent more than an hour on the phone discussing high-rise design and hypothesizing about potential systems.

Needless to say, it turned out to be a much more interesting article than anything I could have written about the actual proposal (which never was built). When AISC gave him the J. Lloyd Kimbrough Award (AISC's highest honor) in 1999, I reminded him of the conversation—and how I was one of the many people that he so naturally helped over the years.

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Base Anchorage in Seismic Zone

Should anchor rods be designed for base shear forces only, not amplified loads, using the Ω factor and not the vertical or horizontal component of the $R_yF_yA_g$ force of the brace?

We do a lot of one-story commercial buildings where the base shear forces are quite small, and we are being questioned by fabricators, contractors, architects, etc. over huge gusset plate connections that result from the $R_yF_yA_g$ of the tube braces. The footing, anchor rods, and even column sizes seem disproportionate to the brace connection. Where does the force go if you ignore it in the design of these members?

We are under the 1999 *Standard Building Code*, which does not differentiate between special and ordinary concentric braced frames (except through referring to ASCE 7). This code refers to the 1997 AISC *Seismic Provisions*, which would technically allow us to ignore the seismic provisions for one- and two-story structures. However, we have been trying to use the 2002 provisions to be more up-to-date. The 1997 provisions allowed for the brace connection for OCBF to be designed for load combinations 4-1 and 4-2, but we see that this was taken out in the 2002 provisions for OCBF, along with the one- and two-story exception. The SCBF still allows the connection to be designed for the maximum force that can be transferred by the system. If you design the foundations for the base shear and let that limit the system, then aren't you basically cancelling out the requirement for the connection to be designed for the $R_yF_yA_g$ force, which effectively puts you back at square one?

We asked Rafael Sabelli, a presenter of AISC's seminar on the seismic provisions and new seismic manual, to respond:

I believe that the stated assumptions are very good. Essentially, my view is that the engineer needs to understand how the structure will yield, and design accordingly. In the case of low structures (one- and two-story), the "yielding" may be rocking—in other words, uplift of the spread footings. It is theoretically unnecessary to design elements of the structure for more force than the rocking capacity, but I would suggest that the engineer bear a few things in mind:

1. Rocking leads to large displacements, and the "stiff" CBF quickly develops very high drifts. In my own judgment, I would not permit rocking at the design base shear for SCBF (R = 6), but I think it is OK at the base shear for OCBF (R = 3.25 in ASCE 7-05).
2. A true upper-bound rocking capacity is difficult to quantify. I would use a minimum safety factor of 1.5 on calculated footing and grade-beam weight to estimate the upper bound.
3. Taller structures (three stories and up) have been shown to yield even after rocking. Thus I would still design the steel structure to have the appropriate ductility (i.e., I would not waive the AISC 341 requirements).

So, in short, I would design the anchor rods for either the strength of the structure or the hold-down capacity of the footing (with the safety factors I feel comfortable with). For low buildings, I'd try to make sure there is enough bracing so that rocking does not occur at a very low force level.

Rafael Sabelli, S.E.
DASSE Design, San Francisco

Backing Bar Removal

We have a steel building frame where we are using ordinary moment frames (OMF) with a seismic force resisting system defined as "Structural steel systems not specifically detailed for seismic resistance," R = 3. Since this category does not require compliance with the AISC *Seismic Provisions for Structural Steel Buildings*, which requires removal of backing bars for OMFs, I would surmise that we do not need to remove the backing bars. Is this correct?

The acronym OMF is usually reserved for a seismic load resisting system with R > 3, as defined by the IBC model building code and/or ASCE 7. In your case, you really have a conventional moment frame designed to the requirements in the AISC *Specification for Structural Steel Buildings* with R = 3 and not an OMF. Hence the backing bar removal requirement found in the AISC *Seismic Provisions* does not apply.

Since you are not bound to the detailing requirements of the AISC *Seismic Provisions*, the AISC specification requirements would then be the referenced document. The AISC specification references AWS D1.1 *Structural Welding Code – Steel*, which states:

Steel backing for welds in statically loaded structures (tubular and non-tubular) need not be welded full-length and need not be removed unless specified by the Engineer.

There may be some instances where it is desirable (or necessary) to remove the backing bars to facilitate an inspection process. You may want to discuss this with the inspection agency early in the project if possible, in order to include the information in the bid documents.

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

Moment Strength of Bolt Group

On p. 7-19 of the 13th edition *Steel Construction Manual*, an equation is given for the pure moment capacity of a bolt group when the instantaneous center is at the center of the bolt group. Where does the 1.25 in the equation come from? What is the design capacity using LRFD?

To better fit test data, it was decided to increase the bolt strength by 1/0.8, or 1.25 when checking eccentricity. This is because the Chapter J bolt values include a 20% reduction in available strength to account for uneven load distribution in long bolted connections. In most flexural connections, you will not have an extremely long connection, and this reduction is removed so that the method better reflects the available strength.

The bolt group strength is used in the design procedure for extended single plate connections to determine a maximum plate thickness. This plate thickness limit ensures that plate yielding

will be more critical than bolt shear—that is, a ductile failure mode exists in the connection to accommodate the rotation required of a simple shear connection. It is used similarly in both ASD and LRFD.

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

Shear Stud Placement

For design of composite steel beams, is there a good reason to consider the use of a non-uniform spacing over the span? I have heard of placing more at the ends where the shear is higher. Would that be reasonable?

Section I3.2d(6) of the 2005 AISC specification allows the placement of shear connectors as uniformly spaced on each side of the point of maximum bending moment and the adjacent points of zero moment. This is a simplification that recognizes that the shear strength is present and there is adequate capacity to deform to develop it when the studs are not concentrated toward the zones of higher shear. The phrase "unless otherwise specified" is included in that section, however, and allows for non-uniform spacing, which may be desirable in some cases, such as when uniform placement is not possible due to deck flute locations. In such cases I have seen engineers specify that more studs be placed near the high shear point.

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

Additional Capacity Needed

I am designing a new stair that will be supported on an existing structural steel composite floor system. The beams are designed very close to their limits, so I must reinforce them. When I attempt to add steel (WT, C, L) to the bottom flange of the beam, the percentage composite drops below 25%, and I lose the ability to consider the beam composite, which means I would have to add a lot more steel. Has AISC done any research on adding studs to a composite beam to increase its composite action capability in order to accommodate additional loads?

Although the AISC specification and manual do not address it, additional shear studs can be installed to increase composite action. Refer to AISC FAQ 4.5.5 at **www.aisc.org/faq**, which discusses the coring of holes through the slab to allow placement of additional studs. Such a modification can be designed by the EOR, with consideration of such things as the strength of the existing concrete and the grout used to fill the holes around the added studs.

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

Bearing Length

I am trying to design an unstiffened seated connection using Table 10-6 in the 13th edition manual. What is the definition of the required bearing length N_{req} (in.) shown in the table? Is this referring to the actual beam bearing length on the angle, and if so, why do the allowable load values decrease as the bearing length increases?

The N_{req} listed in Table 10-6 is the required bearing length to satisfy the *Specification* limit states rather than the actual bearing length on the angle. Thus if the required bearing length increases, so will the eccentricity of the reaction on the seat angle, resulting in a lower strength.

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

Column Table Using r_x/r_y

I recently attended a seminar on the new manual, which included a study book outlining the seminar and including examples. I have been trying to familiarize myself with the axial compression section of this book (Chapter 2). An example uses a W14×120 column checking P_a using equation E3-2. This result is then checked against the capacity listed in Table 4-1. The results come out the same. I did a second problem using a W12×72 following the same approach and am coming up with significantly different values. I am not sure that I am using r_x/r_y correctly. Can you explain the use of the r_x/r_y factor in assessing the column capacity?

The ratio r_x/r_y is used as a convenience to permit the tables in the manual to be simplified. The tables assume that buckling about the *y*-axis controls, and the parameters must be adjusted when buckling about the *x*-axis is more critical.

Usually, the r_x/r_y ratio is used because the unbraced length is different about the *x* and *y*-axes. If you are using the specification equation, you would need to check which *KL/r* controls and determine the capacity accordingly. If you are using the Table and the KL/r_x controls, you will need to manipulate the unbraced length at which you enter the Table with the ratio r_x/r_y. This manipulation allows you to enter the Table, which is based on the *KL* with respect to the least (weak) radius of gyration r_y, and determine the correct axial strength with respect to the strong-axis radius of gyration r_x.

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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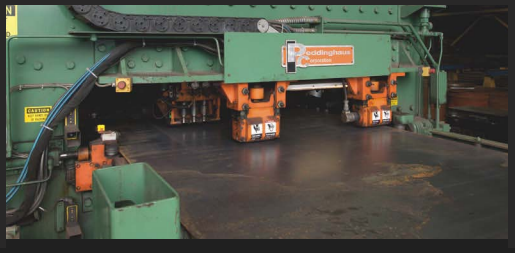

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steel quiz

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

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

1 **True/False:** In the AISC *Seismic Provisions*, all bolted joints found in seismic load resisting systems must be slip-critical.

2 In which plies of bearing-type connections are short-slotted holes permitted?

3 Which ASTM standard addresses the hot-dip galvanizing of fasteners and small parts?
- **a.** A780
- **b.** A123
- **c.** A767
- **d.** A153

4 **True or False:** Truss camber should be inspected immediately prior to erection.

5 Connection-element rupture strength at welds...
- **a.** is proportional to the minimum tensile strength of the element.
- **b.** is proportional to the minimum yield strength of the element.
- **c.** should be checked only when the connection element is designed for fatigue.
- **d.** is a serviceability issue.

6 How much of a bolt must project beyond the nut when properly installed?

7 What is the primary purpose of doing CVN (Charpy V-notch) tests on thick members and plates?

8 How does one approximate the torsional constant, *J*, for open cross-sections such as those found in wide-flanges, channels, and angles?

9 Does the 2% rule for beam lateral bracing account for bracing stiffness?

10 What does the term shear lag represent in the design of a tension member?

TURN PAGE FOR ANSWERS

steel quiz

ANSWERS

1 **False.** The 2005 *Seismic Provisions* (free download from www.aisc.org/2005seismic) do require that bolted joints in seismic load resisting systems must have faying surfaces prepared to at least a Class A slip resistance. High-strength bolts are mandatory and must be pretensioned during installation. However, when used in standard holes, the design shear strength of such bolted joints is permitted to be calculated as for bearing-type joints.

2 Short-slotted holes are permitted in any or all plies of a bearing-type connection, but the length of the slot must be normal to the direction of load. Refer to Section J3.2 of the 2005 AISC specification (www.aisc.org/2005spec).

3 **d.** ASTM A153 includes a special provision that allows the galvanizer to use a spinner or centrifuge to remove excess zinc from critical sections of small parts such as threads. This specification is similar to ASTM A123 (the more common specification covering hot-dip galvanizing of structural steel), as it requires minimum coating thicknesses based on the thickness and type (bolt, casting, forged part) of steel.

4 **False.** As stated in the 2005 AISC *Code of Standard Practice for Steel Buildings and Bridges*, Section 6.4.4: "For the purpose of inspection, camber shall be measured in the Fabricator's shop in the unstressed condition." This document is a free download from www.aisc.org/code.

5 **a.** That is, the connection-element rupture strength at welds is proportional to the minimum tensile strength of the element. Refer to Chapter J of the AISC specification for connection element and weld strength requirements. This subject is also addressed in Part 9 of the 13th edition *Steel Construction Manual*.

6 The 2004 RCSC specification, Section 2.3.2 states: "The bolt length used shall be such that the end of the bolt extends beyond or is at least flush with the outer face of the nut when properly installed." Download a free copy of this specification from www.boltcouncil.org.

7 When thick plates and heavy shapes are used in applications loaded in tension, the core area has to be sufficiently notch tough to ensure that brittle fracture will not occur. It should be noted that minimum notch toughness values exist for these applications in both the AISC specification and the AISC seismic provisions.

8 One can define several rectangular elements within an open cross-section (i.e., an angle contains two, whereas a W-shape contains three rectangular elements.) The torsional constant for each element can be approximated simply as $bt^3/3$, where b is the longer and t the shorter length of each element. Summing these quantities for each element comprising an open cross-section will result in a close approximation of the torsional constant for the entire cross-section. Please note that fillet radii have a small contribution and are ignored in this approximate approach. This procedure is not applicable to closed cross-sections.

9 No, it does not, as it only considers strength. This long-standing rule of thumb provides bracing for 2% of the compressive force in the flange or member being braced. Although it lacks an explicit consideration of the required bracing stiffness, this approximation is typically conservative when used with proper brace and connection details (i.e., details that have appropriate stiffness characteristics.) Note that the 2% rule applies only to compression members that are considered straight within ASTM tolerances. One can develop the judgment necessary to know when the details provide adequate stiffness, by using the more detailed and exact strength and stiffness criteria for beam bracing, which are included in Appendix 6 of the 2005 AISC specification.

10 Shear lag describes the behavior at an end connection of a tension member where some, but not all, of the cross-sectional elements are connected. The area that is effective in resisting tension may be less than the full calculated net area for the cross-section. An example is a single-angle tension member connected by only one leg. The adjacent leg at the connection does very little in the way of resisting tension at the connection, but becomes fully effective beyond the connection out in the length of the tension member.

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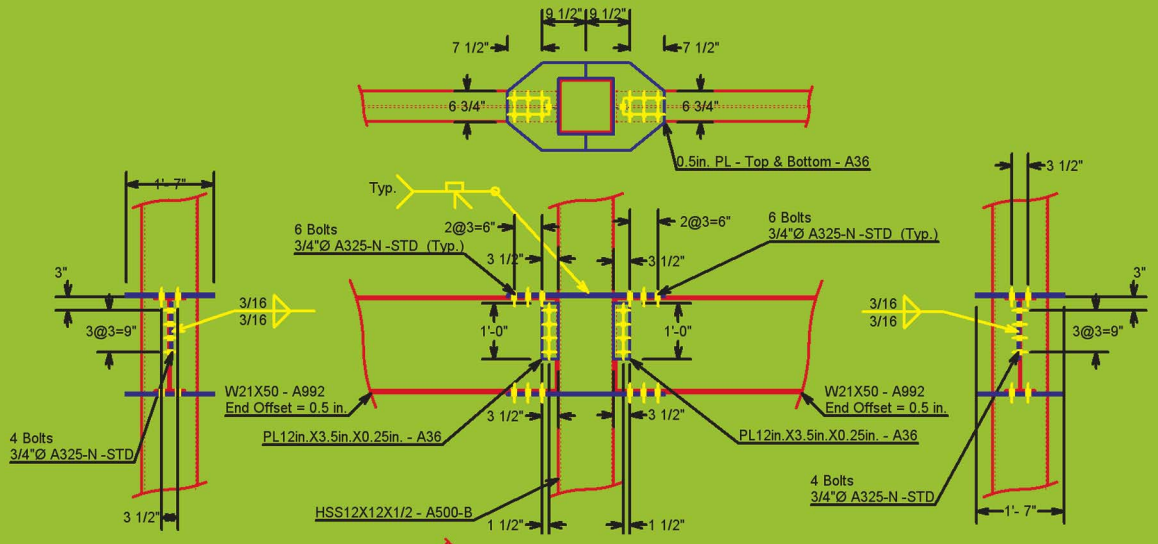

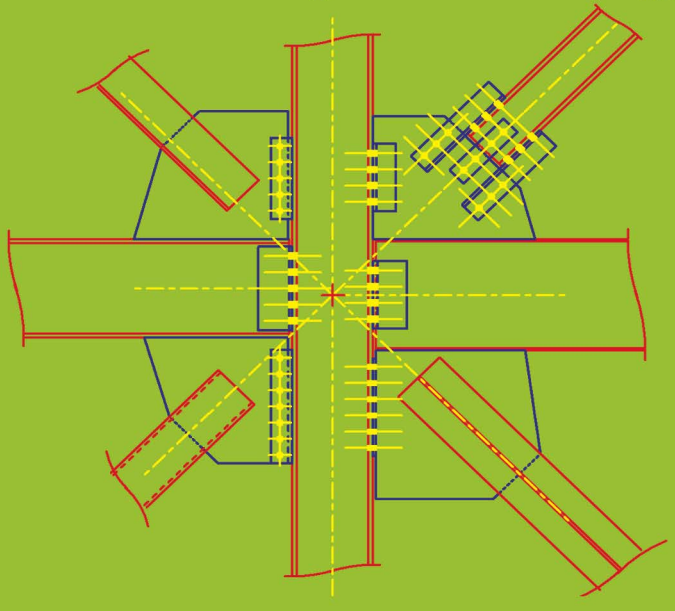

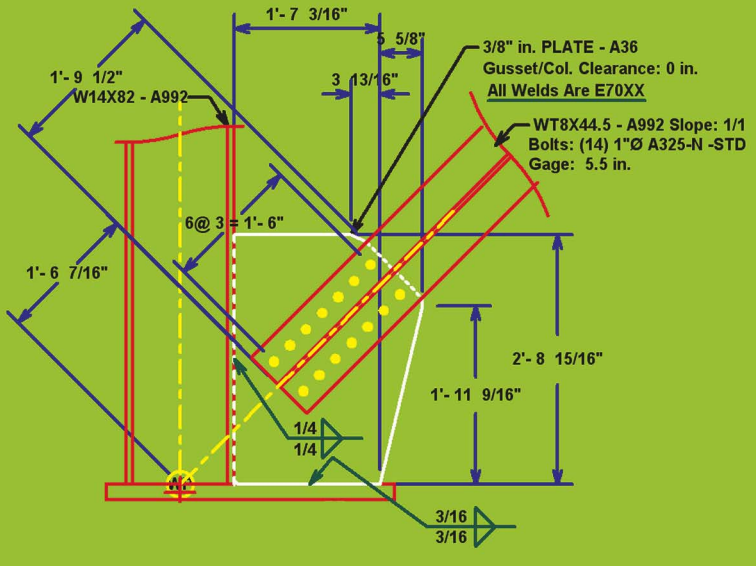

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news & events

INDUSTRY RESOURCES

A New HSS Resource

AISC has been actively working with the hollow structural section (HSS) industry to develop new resources and tools for the use and design of HSS structures. Through marketing efforts, educational ventures, and research, AISC has formed an HSS committee to tackle these issues and increase the use of HSS in construction projects.

As a new resource to engineers, AISC has struck an agreement with CIDECT (International Committee on the Design and Study of Tubular Structures) to provide AISC members with free access to CIDECT's nine HSS design guides. These design guides address various three-dimensional HSS designs, dynamically loaded applications, and connections.

In an effort to disseminate this information to our members, we have started a new area on our web site dedicated exclusively to HSS. With current marketing material, case studies, FAQs, published research, and now the CIDECT design guides, this area of the AISC web site should be your first stop for any project for which you're thinking about HSS. The link is **www.aisc.org/hss**.

DESIGN COMPETITION

2007 Blind Analysis Contest

E-Defense, the earthquake simulation facility of the (Japanese) National Research Institute for Earth Science and Disaster Prevention, is inviting U.S. engineers and investigators to participate in the 2007 Blind Analysis Contest. The competition has entrants predicting the collapse of a four-story frame on the world's largest three-dimensional shake table—an earthquake simulator capable of subjecting full-scale structures to the strongest earthquakes recorded in the world—located in Miki City, Hyogo Prefecture, Japan.

The building will be shaken and collapsed September 20-30, 2007 by applying an intense ground motion, a scaled version of the near-fault motion recorded during the 1995 Kobe earthquake. Each participant will predict the responses before and after the test, and the closest predictions to the test results will be awarded.

It is planned that the winners will be invited to and honored at a special session of the 14th World Conference on Earthquake Engineering (WCEE) next year in Beijing. Due dates for submitting results of pre-test analysis and post-test analysis are September 10 and November 30, 2007, respectively. Visit **www.bosai.go.jp/hyogo/ehyogo/index.html** for more information.

letters

Not in the Spec?

The article "Above-Grade, Below Estimate" (March, p. 55) describes a project in which hybrid girders have been used in a horizontally curved bridge. However, the AASHTO *Guide Specifications for Horizontally Curved Steel Girder Bridges* does not provide for hybrid girders, probably due to lack of related research.

Apparently, this hybrid bridge has been designed as a conventional bridge on a curved alignment. In your opinion, is this an appropriate design?

Andreas Paraschos, P.E.

The author responds:

Mr. Paraschos is correct; that specification does not cover the use of hybrid steel girders. This code is written in conjunction with the old AASHTO standard specifications. Both of these are being sunsetted by the AASHTO code-writing committees in favor of LRFD design.

The Gibson Road Viaduct was designed under the new AASHTO LRFD specifications. These specifications are written for both straight and curved hybrid girders.

Matt Johnson, P.E.
Senior Project Engineer
TranSystems

SPECIFICATIONS

Revised ASTM Spec Opens the Door for Hot-finished HSS

THERE'S A NEW TYPE OF HOLLOW STRUCTURAL SECTION COMING TO THE U.S. Thanks to revisions to ASTM A501, hot-finished HSS can now be specified domestically.

HSS manufactured in North America is typically cold-formed at ambient temperatures in accordance with ASTM A500. Corus, a steel manufacturer and hot-finished HSS producer headquartered in the U.K., has recently completed its efforts to revise ASTM A501 to allow North American specification of hot-finished products.

A "New" Spec

While ASTM A501 may be unfamiliar to most HSS specifiers and users, it is a well-established hot-finished HSS specification that covers smaller HSS manufactured with 36-ksi steel. The newly revised version, ASTM A501–07, now has a Grade B with a minimum yield strength of 50 ksi and a minimum tensile strength of 70 ksi. A Charpy V-notch impact test was added for the Grade B as well, with the minimum energy absorbed to be 20 ft-lb at 0 °F. These impact levels exceed the recommendation of 20 ft-lb at 70 °F given in the AISC *Seismic Provisions for Structural Steel Buildings*.

The key feature of the new version is the expanded size range available under the specification. Corus offers a range of large hot-finished HSS, referred to as Jumbo HSS, including square sizes from 14 in. through 32 in., with wall thicknesses up to 2.36 in.; and rectangular sizes from 20 in. by 14 in. through 30 in. by 20 in., with wall thicknesses up to 1.57 in.

Square and rectangular hot-finished HSS sizes—ranging from 8 in. to 16 in. squares, and from 8 in. by 6 in. to 20 in. by 12 in. rectangles—are also available, as is elliptical or oval HSS. All of these products can be specified as ASTM A501, Grade B.

Hot-Finishing

So what is hot-finish HSS? The process is similar to cold-formed HSS, except that the final shaping and sizing is completed after the steel has been heated to a full normalizing temperature, hence the name "hot-finished." HSS are manufactured from coils or plates of hot-rolled steel. For smaller sections, less than 22 in. square and 0.87 in. wall thickness, coils are cold-worked into round tubes and then welded by the electric resistance welding (ERW) process. For larger sections, plates are press-formed into tube sections and then welded by the submerged arc welding (SAW) process. Sections made with SAW welds are manufactured either from a single plate having one longitudinal weld or from two plates with two longitudinal welds, depending on the size and wall thickness.

The cold-worked sections are then "normalized" by heating them to Austenite temperatures (1,650–1,740 °F). While the sections are at this normalizing temperature, they are roll-formed or stretch-

reduced to their final size and finish in order to achieve the required fine-grained uniform ferrite structure, and then air-cooled. This process is performed on all sizes and shapes of HSS: square, rectangular, circular, and ovular.

Because of this manufacturing process, there are some inherent benefits of hot-finished HSS:

➜ The cold-working required to form the tube out of the steel coil or plate causes strain hardening and leaves varying amounts of internal residual stresses, especially at the corners. The normalizing of the steel virtually eliminates the residual stresses throughout the cross-section and gives a finer grain and homogeneous microstructure over the entire cross-section, including the weld line.

➜ Hot-finished HSS have a high level of dimensional stability. ASTM A501 specifies that the weight shall not be more than 3.5% under the theoretical weight.

➜ External corner radii of Jumbo HSS are typically limited to two times the nominal wall thickness. This tight corner profile gives higher geometric properties and provides for excellent fit-up for connecting same size sections.

➜ Since there is negligible residual stress, there are no restrictions on welding in the corner regions. The same welding procedures can be used in the flat sections and the corners.

➜ Hot-finishing provides high notch toughness over the entire section giving superior performance in cold temperatures or other conditions where there is increased risk of brittle fracture.

➜ Low yield strength to tensile strength ratios are maintained for hot-finished HSS. Typically, this ratio is between 0.70-0.80.

➜ Hot-finished HSS have good ductility and energy dissipation, giving superior performance in conditions of low-cycle fatigue.

High-profile and Hot-finished

While hot-finished HSS is new to North America, it has been specified in some major international projects. One of the more recent is the Dubai Mall in Dubai, U.A.E. Located in the development that also includes the Burj Dubai, the Dubai Mall is billed as the world's largest shopping space. Larger than 50 football fields, the mall boasts 1,000 shops and a three-story aquarium—and 15,980 tons of steel products (supplied by Corus), half of which are HSS; 7,165 tons of this are hot-finished HSS.

In addition, Guangzhou Baiyun International Airport, one of the largest air hubs in China, contains approximately 9,900 tons of hot-finished HSS, and jumbo HSS was used in the roof and cladding structures. Other major projects using hot-finished HSS include Wembley Stadium in London; Millennium Stadium in Cardiff, Wales; Tianjing (China) Olympic Stadium; and Hong Kong Stadium.

And thanks to the newly revised ASTM A501, in the coming years the U.S. just may accumulate an impressive hot-formed HSS portfolio of its own.

For additional information on hot-finished HSS, contact Brad Fletcher, Corus International Americas, at 847.592.3712 or brad.fletcher@corusgroup.com.

ENGINEERING JOURNAL

Second Quarter 2007 Article Abstracts

The following papers appear in the second quarter 2007 issue of AISC's *Engineering Journal*. *EJ* is also available online to AISC members and ePubs subscribers at **www.aisc.org/epubs**.

Development and Application of Large-size Shear Studs to Steel Girder Bridges

SAMEH S. BADIE, AMGAD GIRGIS, MAHER K. TADROS, AND NGHI NGUYEN

This paper presents the development and recent applications of 31.8-mm (1¼-in.) studs to steel girder bridges. The new studs have double the cross-sectional area of 22.2-mm (⅞-in.) studs, resulting in a reduction of the number of studs needed to achieve full composite action with the concrete deck by 50%. Use of the 31.8-mm (1¼-in.) studs has many advantages: (1) increase of fabrication and construction speed, (2) ease of deck construction, (3) ease of deck removal, and reduction of damage to studs and girder top flange during that removal, and (4) enhancement of the safety during construction because more space on the top flange is available for walking. Experimental investigation of the 31.8-mm stud showed that the stud fatigue and ultimate capacities can be conservatively determined using current AASHTO bridge specifications to achieve full-composite action.

Topics: Beams and Flexural Members, Bridges, Composite Construction

Seismic Performance of a 62-story Steel Frame Hotel Tower

ERIC M. HINES AND RICHARD A. HENIGE

This paper introduces the seismic design and performance of a 62-story hotel tower in Beijing, China, and discusses conceptual conflicts that arose during the design process between code provisions and expected seismic behavior. For instance, while the IBC 2000 requires such a tower to be designed as a special moment resisting frame, pushover analysis studies (not permitted by FEMA 350 for such a tall building, but allowed by the design review board for collapse analysis during this design process) suggested that inelastic rotation demands were on the order of the 2002 AISC requirements for intermediate moment resisting frames. Furthermore, while axial force demands in the columns, resulting from the pushover analyses, exceeded the demands calculated according to the AISC building overstrength factor of 3.0, these high axial load demands clearly resulted from the pushover analysis loading pattern derived from the tower's fundamental mode shape. Time-history analyses showed that both the extent of plastic hinging and the magnitude of overturning forces under actual earthquake demands were significantly lower than the levels produced from response spectrum and pushover analyses. Finally, in a capacity spectrum assessment under maximum considered earthquake (MCE) response spectrum loads, ductile capacity in the beams did very little to enhance the tower's performance. Several of these results were easily explained by the fact that the Chinese code response spectrum controlling the design was artificially high for longer periods. This code requirement implied that increased strength, not increased ductility, would improve the tower's ability to withstand MCE demands, according to a capacity spectrum assessment. The purpose of this paper is to identify these conflicts in the context of a real project where circumstances prevented the coordination of consistent seismic design criteria.

Topics: Seismic Design, Structural and Buildings Systems

Improving the Seismic Stability of Concentrically Braced Steel Frames

ROBERT TREMBLAY AND LAURE PONCET

An analytical study was performed to examine the seismic stability of multi-story concentrically braced steel frames. The building height was varied from four to 16 stories, and three braced frame systems were studied: conventional braced frames, buckling-restrained braced frames, and dual buckling-restrained braced frames. All structures were designed according to Canadian seismic provisions. Different force modification factors were used, and both the equivalent static load procedure and the modal response spectrum analysis were considered in design. P-delta effects were accounted for in the design of some of the buildings. The performance of the various structures is evaluated and compared by means of incremental dynamic analysis. The results show that the potential for instability for conventional braced frames is higher for taller structures or when the design loads are reduced. Tall buckling-restrained braced frames were also found to be prone to dynamic instability. Dual buckling-restrained braced frames exhibit a more robust response and represent a promising solution for tall braced steel frames.

Topics: Seismic Design, Research, Structural and Buildings Systems, Lateral Systems

The Analyses of Extended Shear Tab Steel Connections, Part I: The Unstiffened Connections

ADEEB RAHMAN, MUSTAFA MAHAMID, AKEF AMRO, AND AL GHORBANPOOR

The objective of this paper is to develop a viable, comprehensive 3-D finite element model capable of predicting the nonlinear behavior of unstiffened extended shear tab connections building on the experimental investigations of Sherman and Ghorbanpoor. The model allows the examination of a wide range of connection types, configurations, materials, and loadings. The paper presents important relevant parameters that are crucial in making the finite element (FE) analysis possible. The FE model is intended to validate the existing experimental results and to predict the behavior of deeper connections without the need for further expensive experiments. This model presents a viable modeling procedure to effectively account for contact behavior, bolt tensioning and nonlinearity. Analysis of surfaces in contact requires special numerical techniques due to the inherent nonlinearity. Parameters such as coefficient of friction, bolt pre-tensioning, and surface stiffness must be considered to achieve proper contact between the surfaces. In this paper two 3-D FE models, having three-bolt and five-bolt unstiffened extended shear tab connections, are constructed. The three-bolt connection failed primarily in column web mechanism failure mode with bolt shear and twist of the shear tab as secondary failure modes. However, the five-bolt connection failed primarily in twisting of the shear tab, while column web mechanism and bolt shear were the secondary failure modes. The web mechanism failure mode is due to the punching of the shear tab

into the web of the column, resulting in high plastic strains and permanent deformation in the web.
Topics: Connections-Simple Shear, Research, Analysis

The Analyses of Extended Shear Tab Steel Connections, Part II: Stiffened Connections

MUSTAFA MAHAMID, ADEEB RAHMAN, AND AL GHORBANPOOR

The objective of this paper is similar to the companion paper published in the same issue of *Engineering Journal*: to develop a viable, comprehensive 3-D finite element model capable of predicting the nonlinear behavior of shear tab connections. However, this paper addresses in detail the analyses and failure prediction of the stiffened shear tab connection versus the unstiffened connections discussed in Part I. Correlation between the results of the computational finite element method and the experimental investigation is established and verified. Past experimental investigations have shown that the unstiffened shear tab connections are prone to twisting failure and low load-carrying capacity. Therefore, the use of stiffened shear tab connections is a viable design approach to overcome these problems. This paper compares various predicted failure modes from a finite element analysis with those observed in a recent experimental study performed by Sherman and Ghorbanpoor. In this paper, three-, six-, and eight-bolt stiffened extended shear tab connections are analyzed and compared. In addition, five FE models of two-bolt and deep connections are analyzed in the plastic range to predict their failure modes. These models are two-bolt beam-to-column, ten-bolt beam-to-girder connection, ten-bolt beam-to-column connection, twelve-bolt beam-to-girder connection, and twelve-bolt beam-to-column connection.

The three- and the five-bolt connections failed primarily in shear yielding, bearing failure of the holes around bolts, and in bolt shear. Secondary failure was observed in the form of girder web mechanism and shear tab twist. The eight-bolt connection failed primarily in bolt shear and bearing of holes around bolts. The failure modes predicted by the FE analysis were in agreement with those from the experimental investigation. The locations of high plastic strain, bearing failure of holes, plate twisting mechanism, and the web deterioration were identical in the FE model and the experimental observations. The FE model generated in this analysis proved to be accurate in predicting the failure mechanism of the extended shear tab connections.
Topics: Connections-Simple Shear, Research, Analysis

Graphical Design Aid for Beam-Columns (LRFD)

VINOD HOSUR AND BINSON AUGUSTINE

A graphical design aid and design procedure is presented for beam-columns, beams, and columns considering importance of C_b factor, as the value of C_b varies from 1.0 to 2.3, which is quite significant as against conservative value of C_b—in other words, C_b = 1—used by William J. Kiel in preparing his graphical design aids. The design procedure and charts are developed, taking into consideration the equivalent uniform moment factor, C_b, unbraced length, L_b, for moment capacity, and effective length, KL, for axial load capacity. Although the design aids are developed for beam-columns, the same curves can be used for beams and columns independently.
Topics: Beams and Flexural Members, Columns and Compression Members, Combined Loading

Current Steel Structures Research

REIDAR BJORHOVDE

This regular feature of *Engineering Journal* provides information on new and ongoing research around the world. In the 10th installment, research projects are summarized on the following topics: behavior of steel connections under seismic conditions, welded connections, robustness of structures, and performance of bridge structures.
Topics: Research

Changing Attitudes

BY MIKE SCHWIEBERT

The Latitude One office high-rise in downtown Miami may just be the beginning of a structural steel revolution in South Florida.

FOR MANY YEARS THE DEFAULT CHOICE FOR BUILDING CONSTRUCTION IN SOUTH FLORIDA HAS BEEN CONCRETE. But with a strong construction growth market throughout the state, structural steel is making inroads, thanks to competitive pricing per square foot coupled with scheduling advantages.

Across the state the misconceptions of steel construction in the past have been proven to be just that: misconceptions. Most major metropolitan areas, such as New York, Chicago, Boston, Philadelphia, and many others, have been using steel for the vast majority of their larger projects for years. Florida has always had the old mind-set that "seeing is believing," and it has now been seen, thanks to an open-minded owner, a structural engineering firm well versed in steel structures, and a visionary architect. This team has shown the Florida construction industry that steel is a viable choice for larger commercial projects in this region, and they've helped create the largest structural steel office building in Miami: 455,000 sq. ft using 4,300 tons of structural steel. The 24-story Latitude One includes 13 floors of office suites, eight levels of parking, and a lobby that provides additional room for retail space.

The choice of steel was largely due to the construction manager's extensive experience with this type of project, having completed numerous successful steel projects in

Suffolk

Cives

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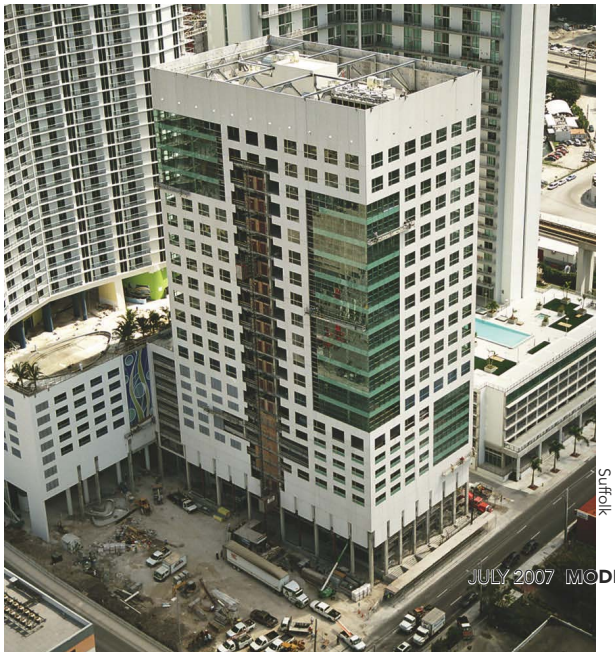
the Northeast. Schedule is always a concern in the construction industry and can either make or break a job, and Latitude One's Miami location made schedule that much more important; the need to beat the hurricane season and make sure the building was reasonably "dried in" was of utmost importance. Of course, the building also needed to be built to withstand hurricane-force winds.

As floor tiers were plumbed and final-bolted, floor decks were turned over for concrete placement at a rate of almost one level per week. Floors were then turned over for other trades. These workers were able to begin their work much more quickly, since they did not have to wait for



Suffolk

Opposite: The 24-story Latitude One office tower is part of a planned development along the Miami River and is adjacent to Miami's Metro.

Top: The 14-ton fabricated base anchors were set in place to exacting tolerances.

Middle: The base of the building contains eight levels of steel-framed parking.

Left: The completed tower features 13 floors of column-free office space.

the curing process and shoring removal to take place, as they would have with concrete. Once the steel erection was beyond the second tier, the construction team was able to turn over one floor every five days for follow-on trades. As with most downtown projects, lay-down area was minimal at best. However, structural steel allowed for small erectable sequences, delivered to the hook on a daily basis, to work within the lay-down space available throughout the erection phase.

The labor situation also swayed the job toward steel. With the condominium boom throughout Florida, there was also a shortage of skilled laborers in concrete, which drove labor prices to an all-time high. Another reason concrete was not a good choice for this project was that the market pricing for raw materials and labor was more volatile than that of steel at the time. The concrete prices would fluctuate day to day, and there was no way to predict where they would go.

Base Anchors

The most unique and critical part of the fabrication and erection was the base anchor assemblies. Each anchor assembly weighed nearly 14 tons and had to be fabricated and then erected to near-perfect tolerances; once these were set in place and the foundation was poured, it would have been impossible to adjust them. The erector's attention to this critical first phase of erection was paramount to the success of the main building erection.

A Sign of Things to Come?

Latitude One may bode well for the future of structural steel in this longtime concrete state. "All it took was one building to get the ball rolling," says Cives Project Manger Lyn Busby. "Since the erection of this building, we have seen multiple buildings being designed in steel, and many of them are much larger than this building."

"It is finally catching on in Florida that steel is faster and, in a lot of cases, more affordable," he continues. "I am looking forward to more steel projects in Miami, as it has been a long time coming."

As the construction market continues to grow in south Florida, so will the demand for structural steel. With the strong commercial and retail markets, owners will always be looking for the best value to make their projects economically viable. In the case of Latitude One, the benefits of steel outweighed those of concrete, making it a great material decision to help add to the Miami skyline. MSC

Mike Schwiebert is the Southern Regional Sales Manager for Cives Steel Company.

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McNamara & Salvia, Boston

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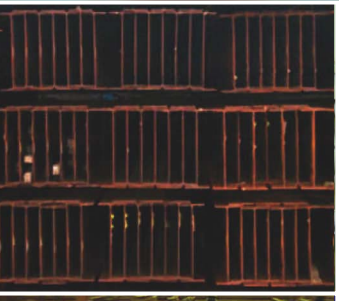

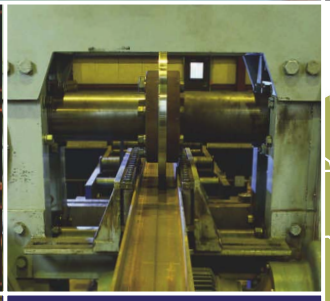

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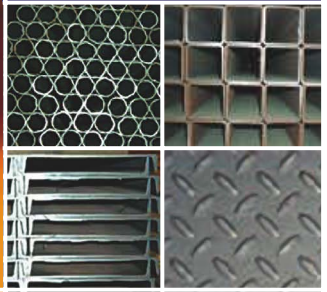

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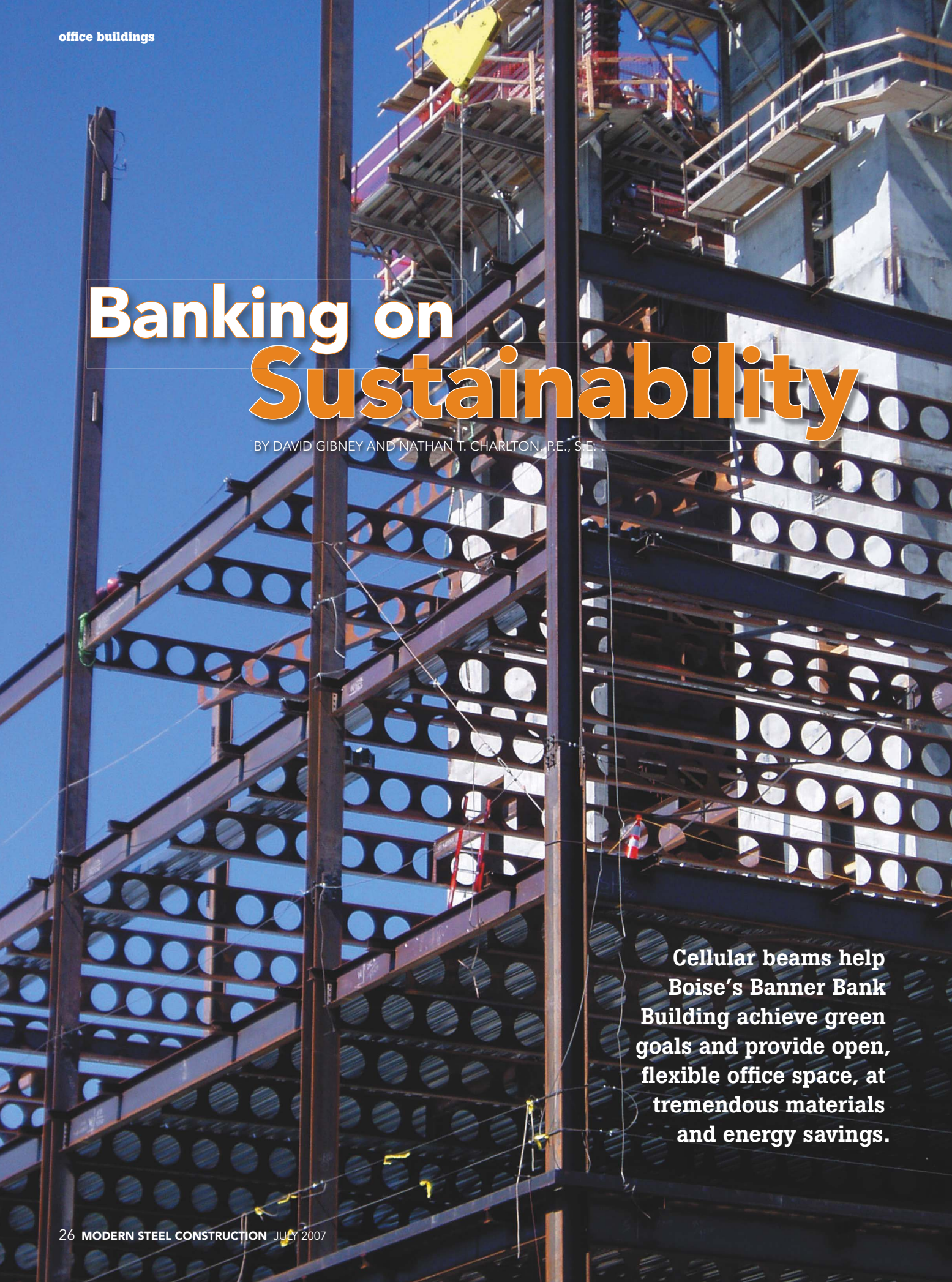
Customer Satisfaction Built With Steel

Banking on Sustainability

BY DAVID GIBNEY AND NATHAN T. CHARLTON, P.E., S.E.



Cellular beams help Boise's Banner Bank Building achieve green goals and provide open, flexible office space, at tremendous materials and energy savings.

EVERY CONSTRUCTION PROJECT HAS A WISH LIST FROM THE DEVELOPER, SOME MORE STRINGENT THAN OTHERS. In the case of the Banner Bank Building in Boise, the developer presented a unique list of three rules to his design team.

First, he wanted the building to achieve LEED Gold standards. Second, ultimate space-program flexibility was a mandate. Third, when it came to design rules… there were no design rules. The architect's Boise office assembled a team of local design professionals with a track record of collaborating to develop, test, and implement creative design solutions

The result is a state-of-the-art 180,000-sq.-ft, 11-story office building where structural framing decisions contributed in unique and unforeseen ways to ultimately help the building exceed the original LEED project goal and become a LEED Platinum project—the highest level of certification awarded by the U.S. Green Building Council (USGBC) .

Not-so-standard Procedure

Traditionally, when a building design team, principally the architect, begins to establish basic design elements such as space program requirements, building size and massing, building orientation, and fundamental building systems—including exterior cladding systems, shading elements, and wall fenestrations—the structural engineer is not consulted. Once a preliminary design is established the structural engineer is then typically asked to discuss the appropriateness and the pros and cons of various structural systems. In this "structure-after-design" scenario the structural engineer is asked to comment on the following:

- Based on a preliminary column grid, estimated floor-to-floor height, and myriad other metrics, which structural system makes the most sense?
- Should braced frames, shear walls, or moment-resisting frames be selected to resist lateral loads?
- What are the owner's project schedule expectations?
- Which construction contract delivery method has been discussed with the owner?
- What are the relative cost differences between various structural systems?

The Banner Bank Building design team asked these questions of its structural engineer, but with two key differences: the structural engineer participated in the design from the very beginning of the process; and Gary Christensen, owner and developer, posed no limitations in terms of building systems, materials, or construction methodologies. "There are no rules of thumb here," stated Christensen in an early team meeting. "In fact, cut off your thumbs!"

The design process kicked off with a two-day design charette, which involved discussing different approaches to structural design, mechanical and electrical systems, façade design, and the integration across all disciplines of sustainable design strategies and elements.

During the meeting, the structural engineer asked some unusual questions to test the team's and owner's commitment to cost-effective, efficient design. While structural design itself contributes very few possible points to a project's LEED "point total," it can result in increased points for other disciplines. Some of the questions were:

- How does the selection of a particular structural system affect a construction schedule or accelerate construction?
- How little structure is required to complete the structure?
- Which structural system augments the mechanical design—floor/wall mass for thermal benefit, structure depth as it relates to mechanical duct routing, acoustic damping, vibration mitigation, and so on?
- Which structural system will require the least amount of raw building materials?
- Which structural system will provide required strength with the least weight? (Note: Less structure mass results in lower foundation demand, lower seismic mass, smaller columns, lighter crane picks, lower cost, faster time to market, and thus less interest paid in the interim.)
- Can the choice of a particular structural system make repeated tenant improvements easier, faster, and less costly?

From these discussions the developer coined the phase "Use fewer pieces of larger sizes that bolt together faster." This has become Christensen's mantra for all of his projects. With the Banner Bank Building, he also directed the design team to allow the structural design to establish the underlying basis for the overall design, realizing that efficiency in structure can create cost-effectiveness without compromising the building's architectural look or spatial program requirements.

Building the Bank

The project site is a typical Boise quarter-block: 122 ft by 150 ft. The actual building footprint is 121 ft by 139.5 ft. The architect's concept was an open office plan with a typical central core containing two stairs, three elevators, an elevator lobby, and restrooms. The need for a highly flexible office floor plate did not fit well with the traditional 30-ft by 30-ft structural grid. The design called for a column-free floor plan with beams spanning just over 45 ft on the north and south sides of the core and 28-ft span members in the middle of the building defining the core area.

The 11-story Banner Bank Building features 45-ft clear spans for office layout flexibility.

Photos: HDR Architecture, Inc.

The cellular-beam appearance is mimicked in structural steel details for the exterior entrance canopy.

A floor plan free of interior columns answered the challenge of creating an ultimately flexible floor plan for future tenant improvement. A steel gravity-framed structure was selected after a thorough investigation of numerous structural systems. Two interior central concrete shear elements at the outboard side of the stair enclosure resist lateral loads. However, spanning 45 ft with conventional wide flange beam framing would result in framing 2 psf to 3 psf heavier than necessary, including heavier beams, girders, and columns.

The structural engineer recommended cellular beams for the project, provided by CMC Steel Products. Also called castellated beams, they feature round or hexagonal holes created in the web through a unique fabrication process. Cutting through the web following a particular pattern about the beam center line, and offsetting each half of the beam results in a beam 50% deeper than the root beam. For example, a W18×35 root beam results in a CB 27×35 (cellular beam), a beam with an increased span capacity and lighter than a required conventional shape, all things being equal. The holes demonstrate the fact that the strength of a beam is not necessarily dependent on how much material makes up the member, but in fact, how the material is proportioned throughout. To further economize a floor framing design, asymmetric CB beams used in composite construction take advantage of smaller top flanges required in the transformed section and a larger bottom flange resisting tension stresses. First patented in 1937, cellular beams offer significant advantages:

- They are, pound for pound, stiffer than traditional wide flange beams.
- They result in a lighter structure.
- When CB beams are used in longer spans, less columns are required, resulting in fewer footings and less material handled overall. This design scenario can result in a stiffer floor.

A Good Investment

Beyond providing structural benefits, using cellular beams can have other positive effects on a building as well:

Construction schedule. By removing columns from the floor plate, the field erection time is significantly reduced due to fewer, larger parts that bolt together faster ,and less foundation elements to support the loads of the building above. The results are reduced labor cost and a reduction in overall schedule, which when offset by the premium paid per pound for the cellular beams (due to increased fabrication effort), can make cellular beams very cost-effective. This was the case with the Banner Bank project.

Mechanical and electrical benefits. A "hidden" benefit that was not realized until well into the design of Banner Bank: Web penetrations create a continuous plenum space from the ceiling to the underside of the structural floor above, resulting in a reduced number of smoke detectors required in the plenum. In fact, at Banner Bank, there are no smoke detectors in the ceiling plenum at all. The beam web holes allow air to freely flow throughout the plenum, thus allowing smoke detection to be accomplished right at the return air intake of the air handler on each floor. The result: only one smoke detector required per floor. This single benefit of cellular beam framing saved the owner close to $100,000 in up-front costs.

Cellular beam web penetrations were aligned from beam to adjacent beam, allowing services to be easily run in the ceiling cavity.

By aligning CB web penetrations from beam to adjacent beam, the openings can be used for routing ducts, fire sprinkler piping, conduits, and cabling. Pre-planning amounts to orienting columns in the same direction so that one beam does not frame into a girder web and another into a column flange. If columns are oriented with their strong axis parallel to the girder span, then the column web and girder web are only offset by the thickness of the girder's shear plate connection. This will result in good alignment of all beam web penetrations.

Cellular beams weigh 35% to 50% less than wide-flange beams capable of carrying the same loads with the same span.

In addition, the CB beams are deeper than they would have been as conventional shapes, resulting in a stiffer floor structure and reducing footfall vibration perceptibility.

Tenant space planning flexibility. Banner Bank has 16,880 (gross) sq. ft of column-free floor plates. Composite floor beams are spaced up to 12 ft, 3 in. on center. The floor framing supports a 14-in.-high raised access floor. Mechanical supply air distribution is accomplished in the underfloor space, as are power and data lines. The developer selected a modular wall system for tenant space build-out. Walls can be easily deconstructed and moved to suit a new tenant. This virtually eliminated the need for gypsum partitions within the rentable floor area.

Structural Synergy

While reducing materials also reduces negative impacts on the environment, there are other sustainable benefits to the owner and to the building occupants as well; the sustainable advantage of cellular beams doesn't stop with the structure itself. As noted above, the cellular web allows air ducts, fire sprinkler piping, and telecommunications to penetrate through the beam rather than beneath it, thus saving vertical space. This in turn provides several sustainable benefits:

Increased daylight harvesting. By no longer having to run ductwork beneath a beam, the acoustic ceiling can be raised. Raising the acoustic ceiling allows exterior windows to be taller, which in turn provides more daylight further into the floor plate.

Reduced building materials. Using cellular beams can significantly reduce the total amount of building materials required in a multi-story building envelope, or allow for more floor area within the same envelope, than when using conventional wide flange beam framing. If the ceiling-to-floor space saved is 8 in. to 9 in. per floor, a building with a 14 ft floor-to-floor height will result in one additional floor of rentable space for every 18 to 21 floors. In the case of Banner Bank Building, the total floor-to-floor vertical height reduction, even with the use of a 14-in. raised floor system, was 8 in. per floor, compared to conventional framing and overhead HVAC distribution; this saved over seven vertical feet of building envelope materials and cost.

Energy conservation. Cellular beams weigh, on average, 35% to 50% less than wide-flange beams capable of carrying the same loads with the same span and tributary area. Since the cellular beams reduced the building envelope by over seven vertical feet, there was a reduction of 59.4 cubic yards of precast concrete exterior skin. According to a Portland Cement Association study published in *Building Green*, 1.7 million BTUs of energy are consumed to produce one ton of concrete by the time it is delivered to a job site.

Less steel. Banner Bank Building's structural frame required 12% less steel than using traditional wide-flange beams. This number might not sound too significant until you realize that 117 tons of steel was conserved, and 1.2 billion BTUs of energy was conserved by reducing the amount of steel required for fabrication

Continuous Sustainability

The structural system of Banner Bank Building is a model of efficiency. Its light, resource-efficient design supports the functionality of the building beyond what a wide flange system would be capable of, while reducing the amount of material needed to produce the structure and envelope. It conserved energy during construction and it will continue to enhance the building's energy performance for the life of the building. The many win-win sustainable solutions that resulted from the early inclusion of the structural engineer, and their decision to investigate cellular beams, are both dramatic and promising. MSC

David Gibney is a sustainable design project manager with HDR in Boise. Nathan Charlton is a principal with KPFF Consulting Engineers in Portland, Ore.

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Photos: KCE Structural Engineers, PC

Capital View

BY ALLYN KILSHEIMER, P.E.

An expansion project within a stone's throw of the U.S. Capitol adds a little more steel to a notoriously concrete town.

EXPANDING A LARGE BUILDING IN A DENSE URBAN AREA IS NEVER EASY, ESPECIALLY FROM A STRUCTURAL STANDPOINT. It becomes even more difficult when the existing building needs to remain operational throughout the project.

Such was the case with Capital Gallery in Washington, D.C. Luckily, project owner Boston Properties was able to envision the possibilities and tasked KCE Structural Engineers, PC with adding seven floors to the three-story portion of an existing office building and parking structure—also designed by KCE in the 1970s—that was not originally designed for this expansion. The existing parking structure and office space, including an adjacent existing eight-story portion, were required to remain occupied during construction, and the existing roof of the three-story portion would need to be converted to floor use. In addition, the complex's central courtyard was to remain open as well for commercial catering and a restaurant tenant.

The building's location in a busy part of D.C. also added to the challenge, especially in terms of its proximity to stations for two different train systems. An Amtrak station and rail lines are located next to the site, as is a Metro (subway) station entrance. Utility issues also needed to be addressed. An underground steam line serving the United States Capitol and other government buildings, and an underground secure communication link tunnel between the Executive and Legislative branches of the U.S. government both ran through and under the building structure and had to remain operational.

Existing Conditions

In situ as-built conditions varied widely from what was shown on the 1970s design documents, changing continuously across the site. This variability required KCE to reevaluate and adjust the documents for the new gravity framing and lateral support system as new discoveries were made. Subsurface investigative techniques were limited by the need to keep the three-story office portion of the structure occupied "until the last minute," as well as the need to keep the parking garage functional, safe, watertight, dust-free, and relatively noise-free.

The existing roof slab's live load carrying capacity was 30 psf. However, the new design required an 80-psf live load (exceeding the code-required minimum of 50 psf for offices), plus a 20 psf allowance for partitions. Carbon fiber strengthening was not yet recognized by the local building jurisdiction, and in any case the capacity increase would have been in excess of ACI maximum limits. KCE designed a bonded concrete overlay system with shear connectors to increase the load-carrying capacity and level the sloped roof surface to make it useful as an occupied floor.

Structural steel shear collars were added under the slab around the columns to increase shear capcity. These consisted of rolled angle shapes, made up to suit existing concrete column dimensions, as three-sided "U's" with mitered corners.

Steel angles with shear studs were attached to some existing concrete columns for reinforcement. A new concrete shell will encase these assemblies.

Seven floors of steel-framed offices were added atop this three-story concrete structure from the 1970s.

They were set in place with high-strength Hilti epoxy anchors with the closure piece field-welded and epoxy-bolted. Epoxy was injected into any existing gaps between the back of the angle and the front face of the column. The angles were placed about 1 in. below the underside of the slab, and a non-shrink grout was dry-packed into the void.

Steel jacketing, concrete enlargement, and complete column replacement were methods used to increase the capacity of existing concrete columns. The steel jacketing methods used epoxy anchors and epoxy injection systems to bond either steel plate and/or steel angles to the existing columns, with head and base angle "seats" to transfer the additional accumulated load through to the newly modified columns and foundations.

Long Span

Washington D.C. has been and remains a "concrete town." However, the owner wanted a long-span, column-free space—with a panoramic historic view of the nearby U.S. Capitol building and Capitol Hill—while keeping the space on the lower three floors occupied as long a possible. A long-span composite steel framing system of girders and purlins with 3-in. metal deck offered the necessary spans for tenant flexibility, as well as architectural ceiling coffers, at the lowest cost.

The structure used long-span composite steel and concrete, reducing the number of columns requiring strengthening by one half, while at the same time doubling the required load-carrying capabilities of strengthened columns and footings.

When it came to the expansion, the design team made adjustments due to in situ slab reinforcing over columns and the

column reinforcing itself that allowed for drilled-in high-strength epoxy anchors as column anchor bolts. Column removals, required due to the loading dock expansion and the addition of a central mechanical plant, were accomplished over occupied space with shoring systems designed by KCE, using special load transfer built-up girders and piggyback plate girders.

Prior to any other construction activity, KCE met accelerated schedule constraints by designing a method to install strengthened foundations while all garage levels, the commercial floor, and three office floors remained occupied.

These systems included micropile installations through various footings with shear transfer collars, four-section underpinning with lateral load transfer connections, above-lowest lift column shoring at the underside of the first framed deck with footing removal and replacement, and a saddle footing option that consisted of pouring a new footing over the existing footing and down around the sides, with lateral load connecting devices to the existing footing while temporarily hanging the column.

These foundation-strengthening systems were scheduled through the garage to limit the number of temporarily lost parking spaces to four at a time and to provide for 24-hour, continuous two-way driving aisle access.

The new elevator bank's pit walls function as girders carrying new structural steel columns and lateral bracing.

The new below-grade central mechanical plant required the removal of large portions of structural slabs and walls below grade that had been providing structural lateral restraint to columns, as well as foundation walls.

New built-up plate girders and rolled sections provided the new permanent sup-

port. KCE designed temporary structural steel bracing systems to allow for this work, as well as a supplemental system to keep the surrounding public spaces safe and the adjacent Amtrak and Metro stations functioning around the clock.

Lateral force resisting systems continued down from the steel frame and added superstructure through the existing concrete structure via built-up and rolled steel section members that were tied to and work with the existing concrete frame, transferring the loads to the newly strengthened foundations.

The new elevator bank pit system required the pit wall extensions to be girders carrying new structural steel columns, and the steel K and X wind bracing to be placed from above through the existing three story building. These girders were supported by new hand-dug caissons and tied to existing caissons, which, as excavation commenced, were found not to be of the size, location, or geometry called for by the original documents.

Lateral force resisting systems continued down from the steel and added superstructure through the existing concrete structure via built-up and rolled steel section members that were tied to and work with the existing concrete frame, transferring the loads to the newly strengthened foundations.

Dealing with Trains

Another facet of the expansion project was the fact that it subjected the immediately adjacent Metro structure to additional lateral loads. In addition, thanks to the ongoing construction of a glass-clad steel pipe truss canopy over the Metro station's entrance portal, the Capital Gallery expansion was required to use special protective steel shoring with horizontal bar joists and metal decking as a protective cover.

The adjacent Amtrak line and station, in addition to the Metro station entrance, limited crane access and required the support of a tower crane on the existing structure in addition to the use of truck crawler cranes supported by temporary shoring under the preexisting framed landscaped plaza area over the parking.

Raising the Profile

The owner and KCE, as well as the rest of the design and construction team, were able to overcome the obstacles of expanding an existing building in a busy area of the nation's capital and working above a continually occupied building—with no impact on adjacent transportation structures. And on top of that, they were able to raise the profile of steel with a prominent building in a high-profile location—and in a concrete town, no less. MSC

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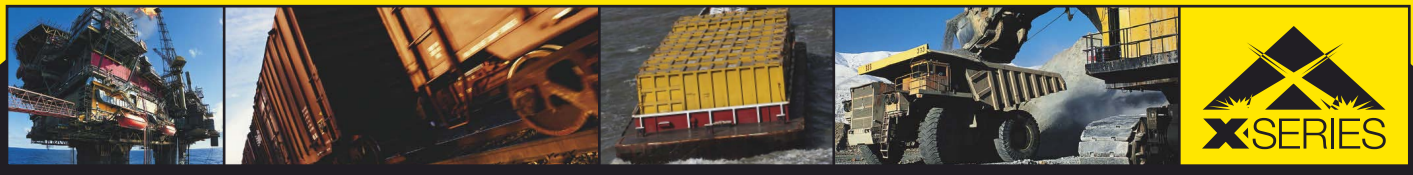
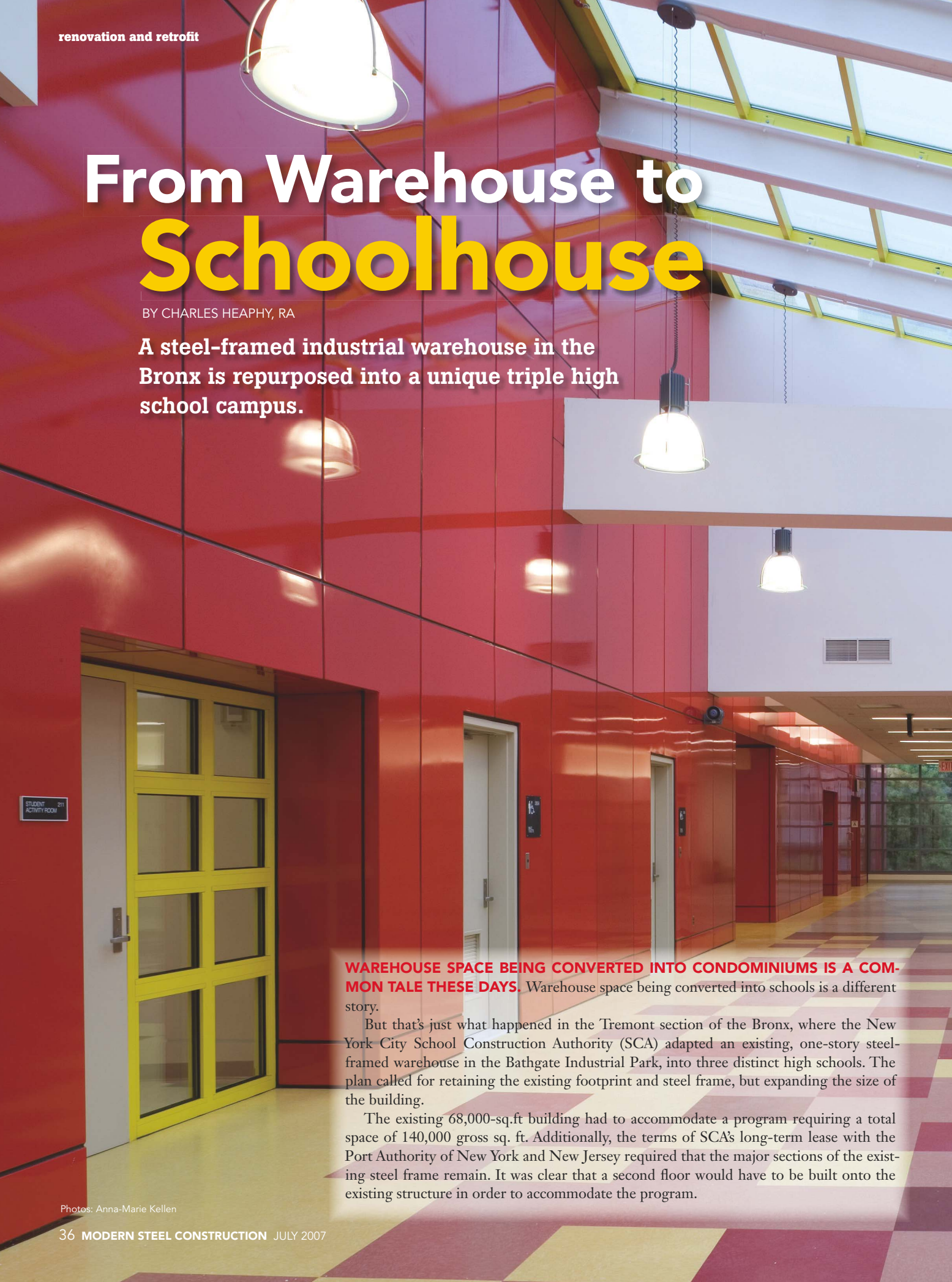


From Warehouse to Schoolhouse

BY CHARLES HEAPHY, RA

A steel-framed industrial warehouse in the Bronx is repurposed into a unique triple high school campus.



Photos: Anna-Marie Kellen

WAREHOUSE SPACE BEING CONVERTED INTO CONDOMINIUMS IS A COMMON TALE THESE DAYS. Warehouse space being converted into schools is a different story.

But that's just what happened in the Tremont section of the Bronx, where the New York City School Construction Authority (SCA) adapted an existing, one-story steel-framed warehouse in the Bathgate Industrial Park, into three distinct high schools. The plan called for retaining the existing footprint and steel frame, but expanding the size of the building.

The existing 68,000-sq.ft building had to accommodate a program requiring a total space of 140,000 gross sq. ft. Additionally, the terms of SCA's long-term lease with the Port Authority of New York and New Jersey required that the major sections of the existing steel frame remain. It was clear that a second floor would have to be built onto the existing structure in order to accommodate the program.

The resulting two-story building was designed with all common spaces on the first floor, including the cafeteria, library, music rooms, art studios and recreation room. The three high schools are on the second floor, where each has its own separate areas of classrooms, science labs, administrative offices, lockers, and central atria under enormous skylights.

Foundation

The interior concrete footings of the building were removed and replaced with new 40-ton drilled steel piles at each interior column location, sections of which were reused from the existing structure. The new steel piles were drilled to the depth of suitable soil-bearing capacity. They were required because the existing column footings were designed for 750 psf, which was insufficient to support the additional load of the new second floor. The existing steel columns were modified for connection directly to the steel piles by using steel plates of various thicknesses. This unusual steel-column-to-steel-pile connection replaced the need for traditional concrete pile caps.

The exterior concrete foundation and footings at the perimeter remained without any major modifications, since their existing capacity could support the additional loads of the new second-floor structure.

Steel Structure

The original steel structure consisted of steel columns and

The entrances to each of the three schools are distinguished by 50-ft-high aluminum-clad feature walls supported by steel trusses, each flanked by a glass-enclosed staircase.

sloped steel roof girders (both W shapes), which created the existing open, double-height industrial space. The existing column bays were approximately 19'-4" wide by 18'-4" deep. The columns (unbraced) were approximately 27'-0" high to the bottom of the sloping roof girders.

The existing steel columns and roof girders were removed from the site by the steel contractor and shipped to their shop for modifications. These included splicing 5'-4"-high W-shape extensions to raise the roof girders. This increased the total column height from 27 ft to 32 ft, which provided sufficient height for the addition of the second floor. This floor also served to provide lateral bracing to reduce the buckling reaction of the increased column height.

The new second-floor assembly consists of a 5½-in. lightweight concrete slab and metal deck and steel wide-flange floor framing. New roof framing, consisting of steel wide-flange sections and metal deck, was installed between the existing roof girders. New connections were provided as required to the existing steel columns and roof girders.

The modified steel structure, combined with the new steel structure, successfully accommodated the 15-ft floor-to-floor heights required by the standards of the NYC School Construction Authority.

Exterior

The architects realized that the existing exterior masonry wall assembly would need to be removed in order to reduce the total load on the existing perimeter foundation. They chose to replace the masonry wall with a new lightweight metal panel exterior wall system, which reduced the loads considerably, allowing the second-floor loads to be imposed without modifying the existing exterior footings.

The other advantage of replacing the masonry wall assembly was that it allowed the design to develop new elevations with expansive windows, which would be more appropriate for the schools' functions.

Grand Entrances

The entrance to each of the three schools is distinguished by a 50-ft-high aluminum-plate feature wall, which also provides a dramatic housing for the glass and steel-framed stair tower. The three feature walls, brightly colored in red, blue, and green, continue to the interior atria of each high school, providing a clear circulation path for students—from the entry to the center of the school. The steel frame

To lighten loads on the existing perimeter footings, which support the new second floor, the original masonry exterior was removed and replaced with a metal panel and glass curtain wall system.

trusses that support the walls provide an efficient, economical way to create these dominant visual features.

The stairs feature central steel tree columns (12-in.-diam. pipes) from which tapered steel sections are connected to support the steel stair, roof, and glass curtain wall. The steel structure is exposed and coated with intumescent fireproofing to provide a dynamic vertical circulation space.

Interior

The major public spaces—the student dining, library, exercise, and multipurpose rooms—have an exposed steel ceiling structure (with intumescent fireproofing) and an exposed steel acoustic deck ceiling to provide additional height for open, spacious common rooms.

The two major exposed steel beams in the multipurpose room were increased in depth using W36×280 sections with 30-in.-diam. holes to allow for the spiral ductwork to pass through the steel beams. This exposed structure provides a high open ceiling, as well as reinforces the structural aesthetic of the public school spaces.

The three large skylights are framed using exposed sloping steel sections to create dramatic interior courtyards for each of the three schools on the second floor.

The Future of NYC Schools

At the Bathgate Educational Campus, the design team was able to work with an existing steel frame structure and modify it with new steelwork that allowed both numerous structural modifications and strong design elements. The unusual program—three high schools sharing a single building—was well served by the design, and the materials were a major part of this. The fact that the steel structure is exposed throughout the school, in the public and major circulation areas, reinforces the programmatic and architectural elements.

The Bathgate campus opened in the fall of 2006 to unanimous approval from the community, students, principals, SCA, and the city. MSC

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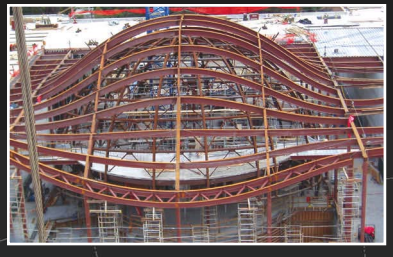

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BY TABITHA S. STINE, P.E.

Images: Pueblo

An innovative modular HSS construction system for the multi-story residential market touts time and money savings.

IN AN AGE WHERE LABOR ISSUES ARE ON THE RISE AND GENERAL CONDITIONS COSTS WEIGH HEAVILY ON PROJECTS, the speed of construction is as important as ever. The more that can be done off-site to reduce the total amount of on-site work, the more financially successful a project can become.

A modular system can help meet these goals of cost-effectiveness and construction speed—as well as that of design flexibility. Modular construction is on the rise, and the applicability of HSS in the multi-story residential market is a very practical and viable solution. With HSS being readily available in a short amount of time from both service centers and HSS producers, this option is now an easy win for fast-paced projects that would typically not be designed in structural steel. With small columns that can be buried within the walls of the structure, the architectural flexibility is also a huge bonus.

One such HSS modular system, geared toward the four-to-12-multi-story residential market, is the Pueblo Building System. Developed by two principals from Pueblo Building Technologies, San Francisco—Tom Graf and Jorge de Quesada—the Pueblo system uses prefabricated vertical trusses comprised of vertical and horizontal HSS members, light-gauge prefabricated floor panels, and poured-in-place concrete floors. The core component is the proprietary structural system; a Pueblo structure consists of shop-fabricated tubular steel frames of standard design. Once erected in the field, the frames are connected with secondary tubular beams, forming a 3D building skeleton. The tubular frame supports prefabricated floor panels using light-gauge cold-rolled steel joists with attached corrugated steel deck. The floor panels then receive a 2-in.-thick lightweight concrete topping reinforced with steel mesh. After the placement of the concrete topping, the structure is ready to receive the finishing trades.

Framing and Flooring

Ladder frames for the system are composed of vertical and horizontal welded HSS members, forming assemblies similar to a ladder and extending up to six stories in height. For buildings with more than six stories, the ladder frames can be stacked and field-welded; they are intended to support vertical loads only. The system's braced frames are of similar construction and maximum dimensions as those of the ladder frames, but with additional HSS diagonal members. Secondary connecting beams, also consisting of HSS sections, serve to connect the ladder and braced frames to complete a 3D structural cage.

For the flooring, prefabricated panels, comprised of lightweight "C" joists with an attached corrugated light gauge steel, form floor assemblies with a maximum width of 10 ft (to allow for normal road transportation) and lengths equal to the full span between supporting HSS members.

Starting off in San Francisco

At this time, the Pueblo system has only been designed for typical residential loading, with the possibility of reworking it for other types of structures in the future. The first building to incorporate a Pueblo-manufactured framing system was a four-story, 47,000-sq.-ft loft condominium building on Harrison Street in San Francisco, utilizing approximately 230 tons of HSS. The project consisted of four levels of condos over one story of concrete framed parking. Six-inch square HSS was used for the ladder and braced frames comprising the vertical assemblies. Shop assembly added to the cost savings of this project due to the fact that the modules were easily fabricated, stacked, and transported. In general, the Pueblo system readily lends itself to the jig systems used to form the ladder and braced frames in the shop. Because of their reduced weight,

This loft condominium project in San Francisco (also pictured under construction on the previous page) was the first structure to use the Peublo modular framing system.

the HSS assemblies are easy to handle and inexpensive to erect, since smaller-capacity cranes can be utilized on the job site.

A second project using Pueblo is currently under design, with construction starting later this year: a nine-story project on Washington Street in San Francisco consisting of two lower levels of standard concrete construction for parking, six upper condo levels using Pueblo framing, and an upper floor and mechanical penthouse using standard light gauge steel construction. The Pueblo system was chosen due to the huge cost and schedule savings over competing materials. Savings on the order of $12 per sq. ft are being anticipated, due in considerable part to the shortened construction period. When comparing this project to a concrete system, 16-18 weeks was estimated for the concrete alternate as compared to six weeks with Pueblo, for a schedule savings of two to three months.

The Washington Street project, designed by KPFF, is in seismic zone 4 with a R = 5.6 for the longitudinal direction and a R = 4.2 for the transverse direction, on account of the use of moment frames at the front and rear elevations and the large bay window openings at the end of the building. Steel for the project came in at around 7.21 psf for the HSS and 3.68 psf for the moment frames, which are comprised of wide flange sections. All columns are HSS 6×6 with wall thicknesses varying from ¼ in. to ⅝ in., depending on the loads. The beams use HSS 10×6, with thicknesses typically at ¼ in.

One Step Further

With the Pueblo system, Graf and de Quesada have taken the modular concept one step further, with the integration of

The Washington Street (San Francisco) project, scheduled for completion later this year, integrates the Pueblo system with conventional construction.

mechanical, electrical, plumbing, and air conditioning into the structural frame. They have also developed additional time- and cost-saving elements, such as stackable prefabricated bath and kitchen units, sectional stair units, and prefabricated wall panels, creating, in essence, a complete modular structural steel system for the multi-story residential market. Graf and de Quesada plan to promote the future growth of their patented technology by licensing it to fabricators and contractors.

Says de Quesada, "The new frontier in building construction resides in the increased use of standardized, factory-built components and building modules able to be incorporated into a wide diversity of designs." MSC

Tabitha Stine is AISC's Great Plains Regional Engineer and can be reached at stine@aisc.org. For more information on the Pueblo Building System, contact Tom Graf, P.E., at tegraf@hotmail.com or 415.290.5034. And to see a video of the Pueblo job on Harrison Street, go to ***www.aisc.org/hss*** *and click Marketing Case Studies.*

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Taking a Pass on Waivers

BY BRIAN RAFF, P.E., S.E.

AISC Certification's "No More Waivers!" program is setting out to live up to its name, and improved communication in the steel industry is the key.

MANAGING THE "NO MORE WAIVERS!" PROGRAM HAS BEEN AN INTERESTING AND CHALLENGING EXPERIENCE OVER THE LAST COUPLE OF YEARS. As an engineer myself, I enjoy gathering data and the challenge of correlating that data into something useful. What I find interesting is that waiver information is very different as it relates to different parts of the country with respect to success rates, number of waivers, types and sizes of projects, etc.

But if there is one universal trend within the steel construction industry, it is that communication is always a challenge. Out of all the waivers I've dealt with, I would estimate that more than half of all designers that require AISC Certification are never notified when their requirements are waived. That is a staggering number when you consider how many structural steel construction projects take place in a given year.

A major challenge that designers face today is being kept in the loop when it comes to the decisions made on their project after their drawings leave their office. You can have more influence on how your drawings become realized in the field by requiring the use of an AISC Certified fabricator or erector in project specifications, and communicating the value of this requirement to the owner and contractor. AISC Certification now provides new resources to help you communicate the value of AISC Certification and become proactive in maintaining support for your project quality requirements.

Communicating Value

Designers usually require an AISC Certified fabricator or erector for their projects, because they understand what a certified quality management system represents and believe that they will be able to demonstrate the added value to their client. But many designers are never given that chance. Often, the scope of a design firm's responsibilities does not include the construction administration phase of the project. Contractors looking for the lowest bids may attempt to exploit this communication gap and waive quality requirements mandated by the contract documents without any notification to the designer.

So what can you do to ensure that you are kept in the loop and that your requirements are met? Communicate the value of the quality requirements to the entire project team early on—particularly to the owner. Take every opportunity to inform your team about why you have made AISC Certification a requirement. Focus efforts on demonstrating value to the owner, a key project decision-maker by reason of the financial backbone he or she provides for a project. The communication effort by the designer is critical, because without it owners may rely too heavily on their general contractor or construction manager to make technical construction-related decisions when it comes to quality. There are documented cases where contractors have awarded contracts to the lowest bidder, regardless of whether they met the requirements set forth in the contract documents. Let the owner know that there may be additional information that his/her contractor may have left out. For example, did you know that by using an AISC Certified fabricator, you may not be required to meet the Special Inspection requirements set forth in section 1704 of the current International

Where Are We Now?

In the past, the "No More Waivers!" program played a predominantly reactive role when it came to saving quality-related project requirements. AISC Certification could only respond to those waivers that were brought to our attention. "No More Waivers!" relied mostly on specifiers and AISC Certified firms to identify potential waiver cases and to engage AISC as a partner to counter efforts to waive requirements. Together, through timely action focused on key project decision makers and appropriate information about the value of Certification, we were able to save jeopardized project Certification requirements 26% of the time in 2006.

The current goal of the "No More Waivers!" program is to eliminate quality requirement waivers altogether by making AISC Certification a prequalification to any bid list. As progress toward achieving this goal, Certified fabricators, erectors, and especially specifiers are increasingly assuming lead roles and taking the initiative in protecting Certification requirements—building cases for individual projects and working to educate members of the building industry in their local markets about the value of Certification without relying solely on AISC. In this sense, AISC Certification has transitioned into becoming a more proactive resource, enabling specifiers and Certified companies by providing more tools and information to make their cases.

The AISC Certification program is more widely accepted when compared to a year ago, and the awareness of the program among engineers and architects has increased dramatically. Since the beginning of 2007, AISC Certification has seen a total of only 13 waivers, a 59% decrease in the number of waivers received by this point last year! In addition to the lower number of waivers, 31% of those projects had a successful outcome, suggesting that the current overall proactive approach to waivers is more efficient, as well as more successful, than the reactive approach.

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**.

Building Code? This sort of knowledge can save your client money. And AISC has taken steps to make this knowledge more accessible.

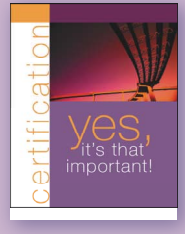
We've had Certification brochures for years, but they have never been available electronically—until now. The availability of these electronic files makes it much easier to share information about quality and the AISC Certification program with clients and colleagues. To download any of the AISC Certification brochures, please visit **www.aisc.org/certbrochure**. You are encouraged to email this URL to potential clients as well as your employees so that everyone has ready access to information supporting the value of your AISC Certification requirements—and knows where to look when faced with a potential waiver.

If you find yourself in a potential waiver situation and you need to inform the owner or contractor of your project about the value of quality and AISC Certification, writing a letter specific to your project is another good option. To help you get you started, AISC Certification provides a sample letter, available as an electronic resource

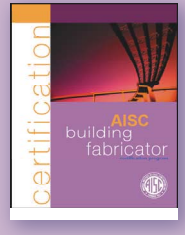
Reading Up on Certification

When faced with a situation where your Certification requirements are in jeopardy, know that help is available through the following AISC Certification tools and resources:

"Yes, It's That Important!" This brochure is geared toward engineers interested in not only finding out more about the AISC Certification program, but also how to educate their project team members on it. Find out what quality certification is, the differences between Certification and inspection, what to expect from a Certified company, key qualifications of Certified companies, and how to defend against pressure to waive your AISC Certification requirements.



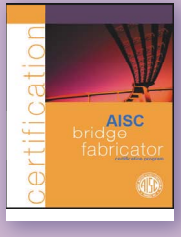
AISC Building Fabricator Certification Program This brochure provides information about the AISC Standard for Steel Building Structures [STD] Certification—the only current building fabrication Certification category. Included is some general information about the Standard, what fabricators can expect from an audit, and key required qualifications. This is also a great brochure for specifiers, contractors, and owners interested in finding out more details about the program.



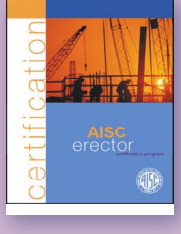
online at **www.aisc.org/nomorewaivers**. This sample letter can be used as a guideline, and the information included will be helpful in bringing your project owner up to speed on the value of your quality requirements. It also provides a summary of requirements covered by the AISC Certification program, a few key qualifications of a Certified fabricator or erector, and information about how complaints from project stakeholders are used to improve the program and Certified firms. Take the time to send your own version of this letter to the owner, contractor, and construction manager. With a follow-up phone call, you can ensure that members of your project team have received your message and understand the value of your quality requirements. The call will also allow you to answer questions.

If your letter and follow-up efforts fail to gain consideration in your waiver situation, you are invited to call or write AISC Certification for additional support. AISC can most effectively support your efforts when actions are based on the information you have collected. Use the "No More

AISC Bridge Fabricator Certification Program Included in this brochure is information about the AISC Simple [SBR] and Major Bridge [CBR] Certification categories. This document provides a brief overview about the different Certification levels, program endorsements, key items that are independently audited, and resources to get a prospective company started. This brochure is also a great resource for specifiers who design bridges for state DOT's and other state and federal agencies.



AISC Erector Certification Program This brochure provides information about the AISC Certified Steel Erector (CSE) or Advanced Certified Steel Erector (ACSE) Certification programs. It also provides a brief overview of the different Certification levels, what erectors can expect from an audit, key items that are independently audited, and resources to get a company started. Use this brochure to educate your project team members about the many areas that this program addresses.



Waivers!" form provided at **www.aisc.org/nomorewaivers** as a tool to communicate your waiver response history and identified decision-makers.

Lead by Example

The tools mentioned have been sent to our Certified fabricators and erectors as a waiver "survival pack," and the feedback has been positive and enthusiastic. In early May, Zane Keniston, one of Quality Management Company's auditors, e-mailed me to relate the following positive story from an AISC Certified company.

Representatives of Reynolds Iron Works, Inc., Williamsport, Pa., shared with Zane that they had been awarded a large public school contract that required an AISC Certified fabricator. The folks at Reynolds were excited, because the engineer on this project refused to waive the requirement for AISC Certification despite pressure from the contractor. When Zane asked Reynolds' owner if he could share details of the story with us at AISC Certification, the owner was delighted and sent copies of all his supporting documentation showing conversations that took place including a copy of the Division 5 specification and addenda pages of pre-bid RFIs seeking the waiver. It was clear that Reynolds Iron Works and the engineer had kept an open line of communication and that through the initiative of Reynolds representatives, the engineer was very well informed about the benefits and value of AISC Certification.

Increasing Awareness

As we move forward, our collective goal is to increase the industry's understanding of how quality provides value to projects. One way to do this is by advocating AISC Certification as a means for achieving quality in fabricated and erected steel. Using resources available to communicate with your project team early on allows you take an active role in protecting your specified quality requirements and AISC Certification. With those resources, you can also respond to attempts made to waive quality requirements through timely action focused on owners and contractors. Take on each project as if it were a building block of opportunity to improve the overall quality of the steel industry. MSC

Brian Raff is AISC's manager of certification business development.

There's a Flagpole Spec?

BY MATTHEW FADDEN AND JILL RAJEK

The story behind the design and construction of the world's tallest flagpoles.

JULY IN AMERICA MEANS WARM WEATHER, COOKOUTS, AND OF COURSE, INDEPENDENCE DAY. No matter where you are on the 4th, there is a good chance "Old Glory" will be flying nearby. And while the flag is a prominent and recognizable symbol of America, we often overlook an important part of its display: the flagpole.

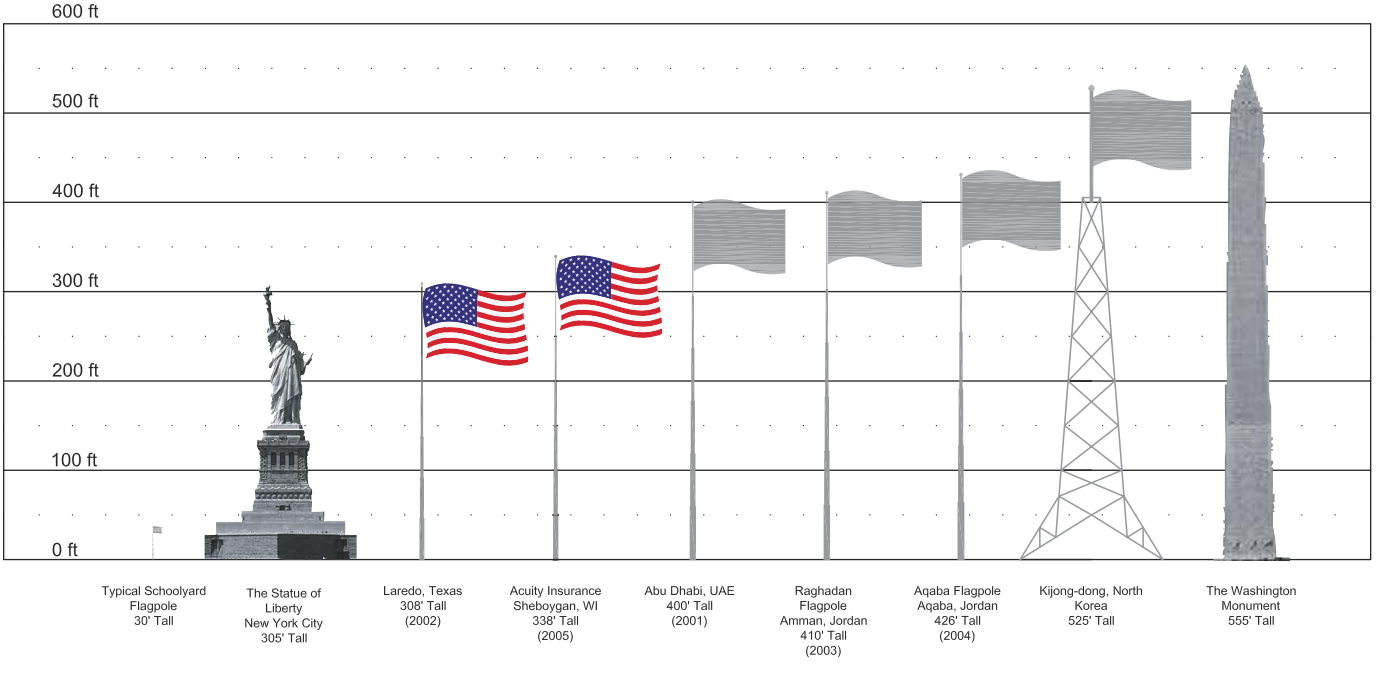
As might be expected, the design and fabrication of flagpoles is not arbitrary. The National Association of Architectural Metal Manufacturers (NAAMM) has published a guide specification that has been approved by the American National Standard Institute (ANSI), outlining the design requirements for metal flagpoles. In honor of the 4th of July, we thought it would be interesting to take a look at some of the world's tallest flagpoles and investigate flagpole design using ANSI/NAAMM FP1001-97, *Guide Specifications for Design of Metal Flagpoles*.

Lots of Flag, Lots of Steel

The United States has several tall flagpoles of its own. For example, the *Dallas Morning News* reported that on Memorial Day of 2002, a 308-ft flagpole was dedicated in Laredo, Texas at Laredo National Bank. This is 3 ft taller than another symbol of America, the Statue of Liberty. People on either side of the U.S.-Mexico border can see the 100-ft by 50-ft American flag flying from the Laredo pole. However, the desire to go taller did not stop there.

Sheboygan, Wis., a town of approximately 50,000, is best known as the home of Johnsonville Bratwurst and for its scenic lake views. Most people would consider Sheboygan to be little more than your typical American town. What they don't realize is that Sheboygan claims the distinction of having the tallest freestanding flagpole in the U.S. The flagpole was raised by Acuity Insurance in time for Independence Day in 2005, according to the *Sheboygan Free Press*. The 338-ft pole is made of tubular steel sections 6 ft in diameter at the base that decrease in diameter as the height increases. Overall, the pole contains 65 tons of steel and supports a 120-ft by 60-ft flag weighing 300 lb.

But even at this massive size, worldwide there are even taller flagpoles. The record for the tallest unsupported flagpole is held by the Aqaba Flagpole in Aqaba, Jordan. Although there is a flagpole in North Korea that is taller, it's supported by a truss structure. The figure below shows several of the world's tallest flagpoles, all



A height comparison of some of the world's tallest flagpoles, including several well-known structures.

made of steel. Materials such as aluminum can be used for smaller flagpoles, but steel is the material of choice for the world's tallest.

The Flagpole Spec

The design process presented by ANSI/NAAMM FP1001-97 consists of selecting a flagpole size, determining the flag size to be flown, calculating the loadings on the flagpole, and performing a stress analysis to ensure the design meets the specification.

There are two loading types that must be considered when designing a flagpole: flagpole loadings and flag loadings. Flagpole loadings consist of dead loads and wind loads. The dead loads include the weight of the flagpole, the weight of the flag, and the weight of any hardware and accessories that will be attached. The flagpole wind loads consist of the pressure on the flagpole due to the wind and the wind drag on the flag. The flagpole specification uses ASCE 7 to compute the wind loads on the flagpole.

According to the guide specification, flag loading is a result of the wind acting on the flag, which in turn results in loading on the pole. The formulas used in the flagpole specification for flag loadings are empirical and are based on actual data taken from flight testing of different-sized flags and different materials. Testing consisted of connecting the test flag to a tow line, which was then connected through a load cell to an airplane. This allowed for continuous readings of the drag force on the test flag. Wind load data was recorded at different air speeds. The empirical formulas in the specification provide results that reasonably match the data recorded during testing.

The flagpole loadings and the flag loadings are used to calculate shear, bending moment, and axial compressive forces on the flagpole. The wind loadings are used to determine the shear force and the bending moment, and the dead load is used to calculate the axial compressive force. These forces are then used to determine the actual stresses on the flagpole. A stress analysis is performed to ensure the actual stresses do not exceed the allowable stresses as specified in ANSI/NAAMM FP1001-97. Foundation design must be performed to meet applicable building codes, and designers should exercise good engineering judgment when designing flagpole foundations.

After the design work is completed, fabrication can begin. Flagpole fabrication consists of rolling, forming, and welding different steel sections. Because each flagpole is unique, the fabrication process is not limited to these tasks. A finishing coat is applied to the steel for maintenance and aesthetics. After fabrication is complete, the flagpole is shipped to its final destination and erected.

So the next time you see the flag flying, you can be proud to know that steel is, quite literally, supporting a symbol of America. MSC

Matthew Fadden and Jill Rajek are both interns with AISC. Matt recently received his B.S. in Civil Engineering from the University of Illinois at Urbana-Champaign and will begin his graduate studies this fall at the University of Michigan in Ann Arbor. Jill is pursuing her B.S. in Civil Engineering from the University of Wisconsin-Platteville and plans to graduate next May.

Saying What You Mean

BY TOM SCHLAFLY AND JASON ERICKSEN, S.E.

Common sense and clear thinking will help you create weld symbols that get you the results you want.

EVERYTHING YOU NEED TO KNOW ABOUT STANDARD SYMBOLS FOR WELDS can be found in the American Welding Society publication *Standard Symbols for Welding, Brazing and Nondestructive Examination* (ANSI/AWS A2.4-98). This standard includes some very detailed weld symbols, because it has to accomodate welding for a wide variety of materials, not just structural steel.

The common symbols used for structural steel and the basic elements of a weld symbol are shown in Table 8-2 of the AISC *Steel Construction Manual*. This table contains most of what you need to properly specify weld symbols for structural steel. However, the table can look like a bowl of alphabet soup and is often misunderstood. But with a working knowledge of the most common types of welds for structural steel, as well as some recommendations from AISC, the floating letters can be rearranged to take on some meaning. (In many cases, an alternative to specifying information in the weld symbol is to specify the required strength of the joint. The issue of when to use a weld symbol and when to use an alternate method will be covered in a future SteelWise article.)

Taking Sides

Weld information below the reference line applies to the side of the joint that the arrow points to (arrow side), while weld information above the reference line applies to the other side of the joint. The "other side" refers to the opposite side of the joint, or a piece in the joint—*not* the other side of the connection. As defined in the AISC *Specification for Structural Steel Buildings*:

Connection: Combination of structural elements and joints used to transmit forces between two or more members.

Joint: Area where two or more ends, surfaces, or edges are attached. Categorized by type of fastener or weld used and method of force transfer.

Figure 1 indicates the arrow side and the other side for several types of joints and includes common misconceptions as well. The joints in each illustration are indicated in red.

TYPically Confusing

The use of the word "typical" or the abbreviation "TYP" is common to save space on drawings. Its use can be very effective—unless it is confusing. This abbreviation can sometimes yield some interesting and unintended results. When using the note, make it clear what the indicated weld is typical for. Write things like "TYP both ends" or "TYP all web stiffeners" to elaborate on what is intended. A few extra words can save many extra dollars. Figure 2 indicates examples of good use of "typical" notes.

Symbology 101

Figure 3 shows the suggested information the structural engineer should include on their drawings, an example of what the shop drawings would indicate, and a sketch of the weld itself for many common types of welds. For help in selecting which type of weld to specify, see AISC *Design Guide 21, Welded Connections—A Primer for Engineers*. Remember, where a symbol is not clear, AWS

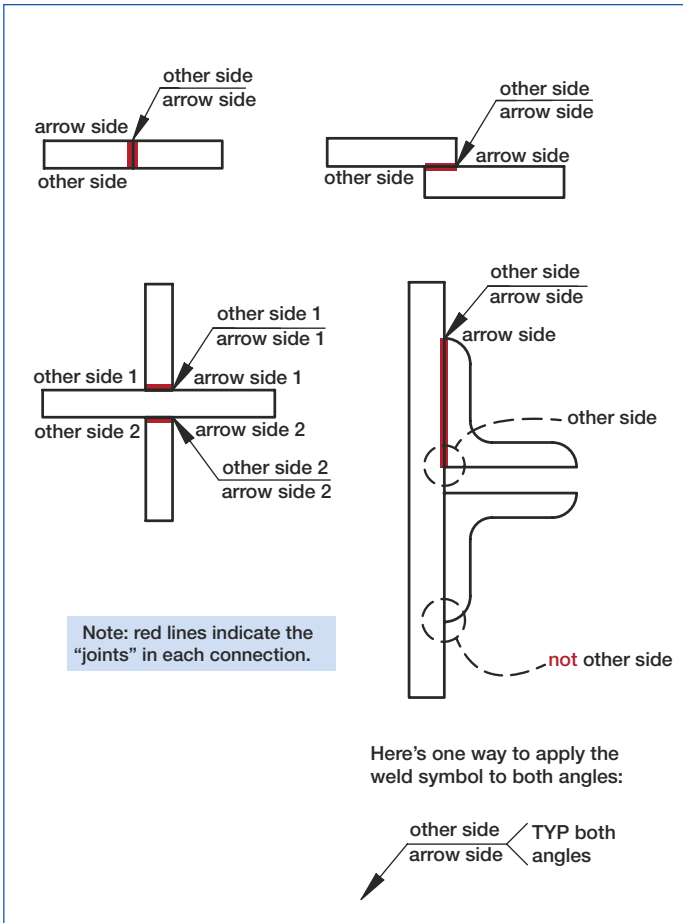


Figure 1. Indicating "sides" in welded joints.

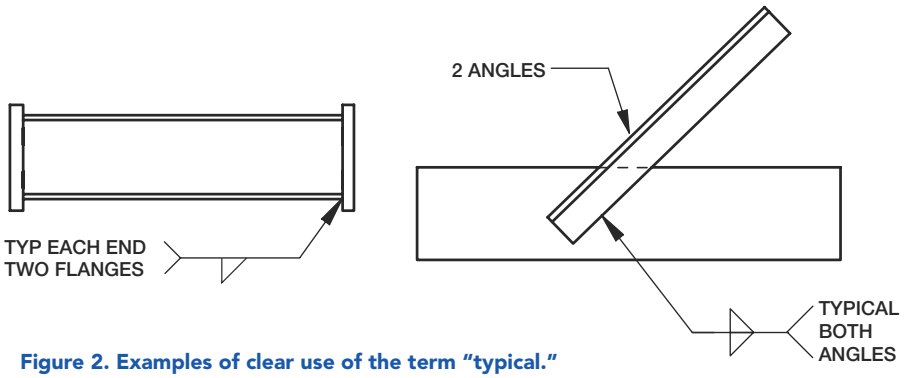


Figure 2. Examples of clear use of the term "typical."

says a sketch of the required weld should be shown. Common weld types include:

Complete joint penetration groove weld (CJP). The engineer need only specify "CJP" in the tail of the weld symbol when such a weld is required, as shown in Figure 3. The contractor can choose whether the weld should be a single- or double-sided weld, as well as whether a V, bevel, U, or another option is appropriate. The detail shown in Figure 3 is just one example of the joint preparation that is allowed for a CJP.

Partial joint penetration groove weld (PJP). The engineer must specify the effective throat E and the filler metal strength. Based on the welding process that will be used and other factors, the contractor can determine the required depth of joint preparation S that will achieve the required E dimension. The contractor can also determine whether the PJP will consist of bevel grooves, V groves, or other preparations. The engineer may want to specify whether the joint should be single- or double-sided. See the *Design Guide 21* for a discussion on single sided PJP welds.

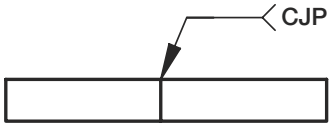
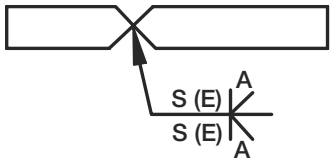
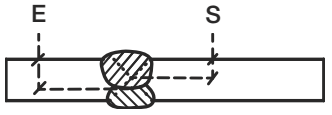
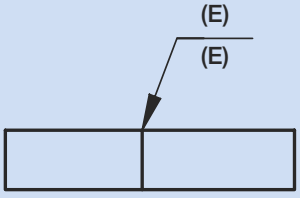
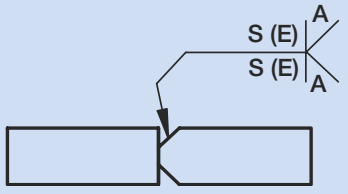
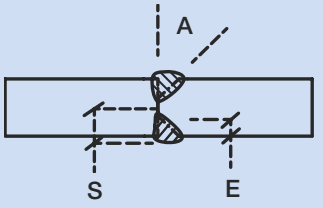
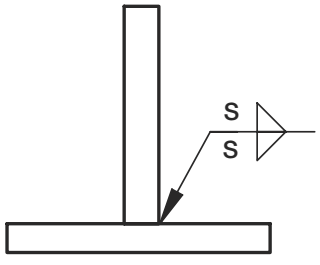
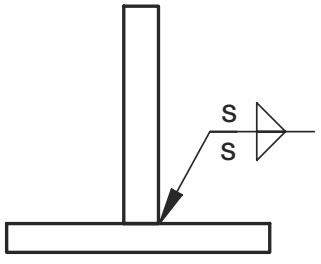
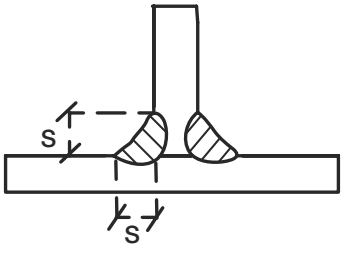
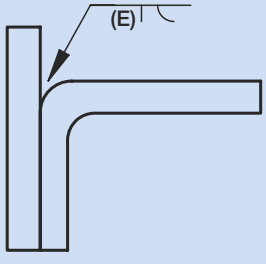
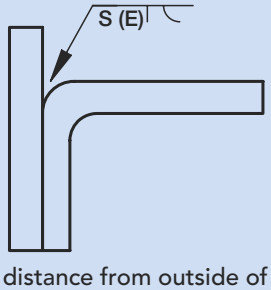
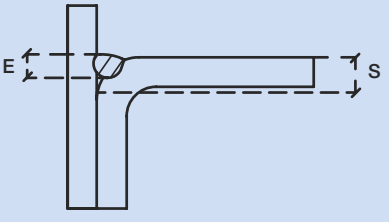
Fillet weld. The engineer can specify the length and size of a fillet weld, and may want to specify if the joint should be single- or double-sided. See the *Design Guide 21* for a discussion on single-sided fillet welds. Note that all fillet welds are assumed to be continuous unless noted otherwise.

Flare bevel groove weld or flare V groove weld. This connection is typically found in cases where rectangular HSS sections are used, but can also apply to round bars. The engineer can specify the effective throat and filler metal strength. Geometry can get complicated in these welds, so there is extra incentive to specify the required strength in this case. The dimensions S extend to the tangent point of the radius to the other connected part. S would be the radius of a round bar of the outside radius of the wall in an HSS section. (See the illustration in Figure 3.) Therefore, S is determined by the geometry of the connected parts and is beyond the control of the engineer and contractor.

Location, Location, Location

There are several ways to indicate the length, pitch (spacing), and location of welds. The length and pitch can easily be indicated to the right of the basic weld symbol as shown in Figure 4a, where L = length and P = pitch. This method does not indicate the location of the weld. If the weld needs to be in a certain location, this

Figure 3. Common Weld Symbols

Weld Type	Structural Drawings Show:	Shop Drawings Show:	Weld Produced:
CJP*	 Geometry is left to the contractor.	 S = preparation depth E = effective throat A = preparation angle	
PJP	 Geometry is left to the contractor.	 S = preparation depth E = effective throat A = preparation angle The break in the weld symbol means the arrow points to the piece to be prepared.	
Fillet**		 S = weld leg	
Flare-Bevel**		 S = distance from outside of HSS to tangent at plate E = effective throat	

* If joint or connection has a required strength defined by the SER, sizes are not necessary on structural drawings.
** See Figure 4 for specifying weld length and location.

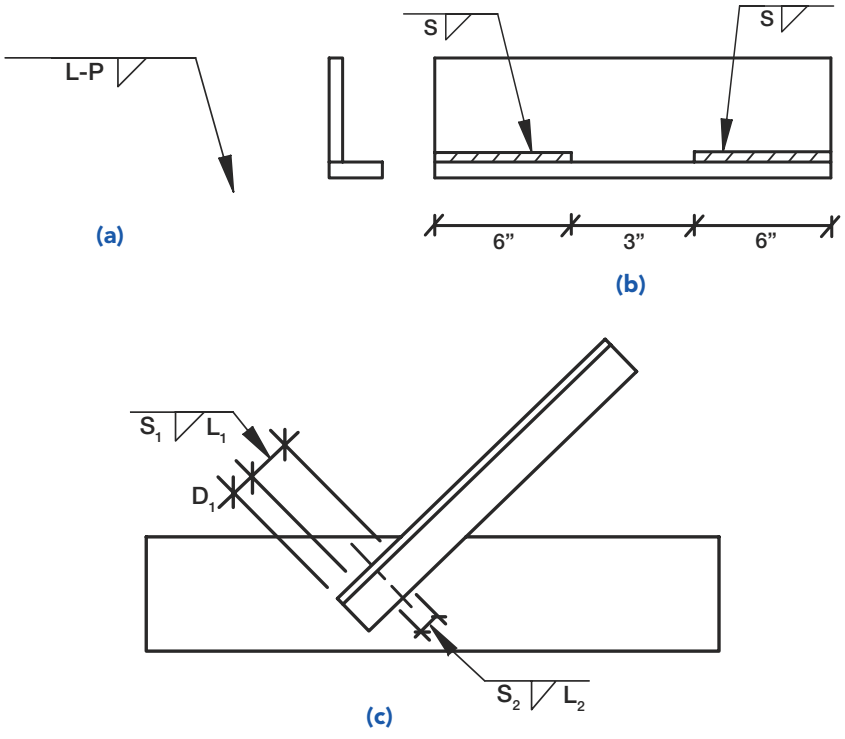


Figure 4. Locating and dimensioning welds.

location can be indicated on a detail as in Figures 4b and 4c. Figure 4b uses hatching and dimensions to indicate where the weld should be located. Figure 4c indicates that the weld should start a distance of D_1 from the end of the angle, but indicates the length in the weld symbol.

Mixed Message

A common notation on design drawings is “E70XX.” While most people would accept that note as requiring the use of electrodes classified to a 70 ksi tensile strength, we’ve heard from a few folks that interpreted it as restricting the process to SMAW because of the format of the electrode designation. Also, there are occasions where the use of 60 or 80 ksi filler metal is desirable, and the E70 notation prevents the use of these electrodes.

AISC Table J2.5 and AWS Table 2.3 tell the user what strength level to use relative to the base metal, and AWS Table 3.1 tells the user what filler metals meet those requirements. An engineer only needs to tell a user what electrode strength to use where the engineer has determined the size of a weld. Otherwise, AISC and AWS direct the contractor to weld with filler

metals complying with AWS A5 specifications, as they provide enough guidance to select appropriate fillers for each joint.

Skewed perspective

AWS D1.1 states that T joints under 80 degrees or over 100 degrees are considered skewed T Joints. The details on the bottom of page 8-36 of the AISC *Manual* (or Fig 3.11 of AWS D1.1) are considered prequalified for T joints. If the engineer sizes the weld, AWS D1.1 Section 2.2.4 says the leg size is shown for fillet welds for joints between 80 and 100 degrees. For welds in skewed T joints under 80 degrees or over 100 degrees, the effective throat is shown. AWS D1.1 section 2.4 states, "When the angle between the fusion faces is such that the identification of the weld type and, hence, proper weld symbol is in question, the detail of the desired joint and weld configuration shall be shown on the drawing with all necessary dimensions." Confusion occurs because at some point (angle) the weld for the skewed joint would change from a fillet to groove weld—and what is that angle? Instead of running the risk of being unclear, draw and dimension the joint. See Figure 5 for the suggested method of communicating the requirements. In the figure, D_1, D_2 and D_3 represent leg dimensions.

Technically Perfect

You've looked at all the references and devised the perfect weld symbol to put on your drawings. Now, stop and think about this: Someone has to be able to interpret that symbol in order to create the weld you have in mind.

Chances are that if you had to scratch your head to come up with the "perfect" symbol, someone down the line will be scratching their head trying to figure out what all that "perfect" symbolism means. And maybe that someone will make an assumption rather than asking for clarification. So, take away this last piece of advice: when in doubt, make a sketch of your intent in the tail of the weld symbol arrow. Pictures are harder to misinterpret. MSC

Tom Schlafly is AISC's director of research and a member of the AWS D1.1 committee. Jason Ericksen is the director of AISC's Steel Solutions Center.

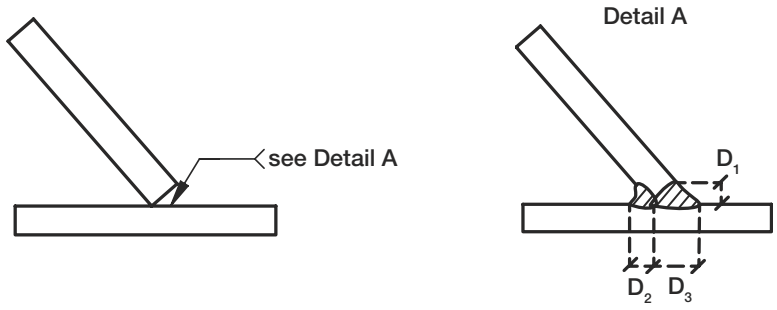


Figure 5. How to clarify a weld for a skewed T joint.

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Rectangular .75"x1.5" to 20"x12"
Round 1.050" to 20"
Wall Thickness .083" to .625"

Specifications:
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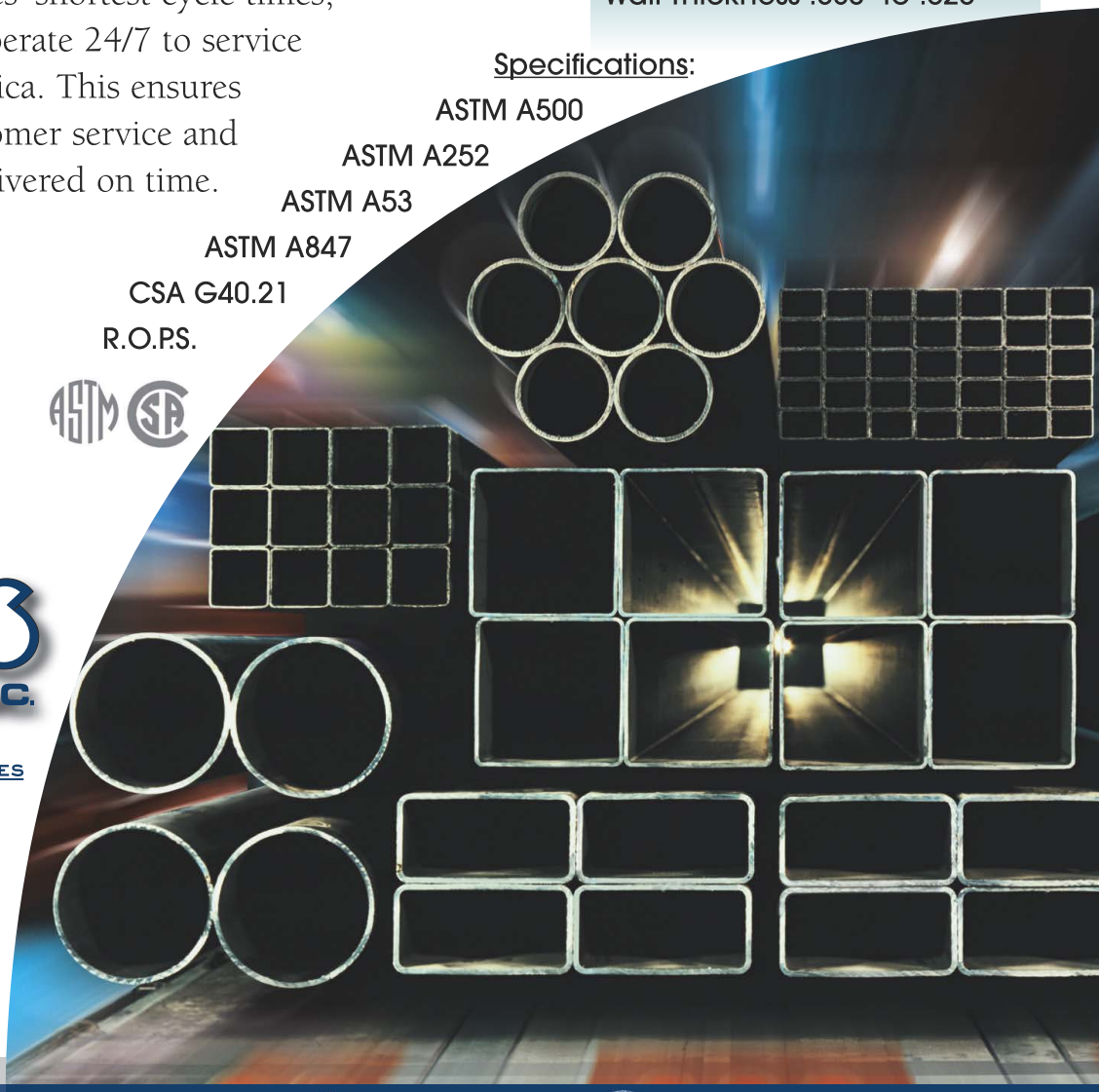
ASTM A252
ASTM A53
ASTM A847
CSA G40.21
R.O.P.S.



Atlas TUBE INC.

Manufacturing Facilities

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HSS Availability

THE FOLLOWING PAGES CONTAIN A LISTING OF AVAILABLE STEEL HOLLOW STRUCTURAL SECTIONS AS REPORTED BY MAJOR HSS PRODUCERS. The sizes listed in the table conform to the 13th Edition *Manual of Steel Construction*, which is based on ASTM A500.

An "X" in the table indicates the shape is available in ASTM A500 Grade B. A "Y" in the table indicates the shape is produced in ASTM A501 Grade B. Read more about ASTM A501 in the news article on p. 19. In addition, a summary of "Jumbo HSS" produced in ASTM A501 Grade B appears a the end of the list.

This listing is a snapshot of HSS availability at the time this issue went to press. HSS producers maintain the list through a password-protected area of the AISC web site. The most current version of the list can be found at **www.aisc.org/steelavailability.**

The listing is useful in the design process as a reference to determine the general availability of specific HSS. Generally, if many producers are listed for a given size, it is an indication that the size is commonly available. When only one or two producers are listed, it is prudent to contact a steel fabricator or local steel service center to determine availability. The less common sizes may require a minimum lot size of 25 to 100 tons to be produced.

Atlas Tube, Inc.
Phone: 519.738.5000
www.atlastube.com

Bull Moose Tube Company
Phone: 800.325.4467
www.bullmoosetube.com

Columbia Structural Tubing
Phone: 800.468.8913
www.oregonsteel.com/CST.html

Corus
Phone: 800.542.6244
www.corusgroup.com

Eugene Welding Co.
Phone: 800.336.3926
www.ewco.net

EXLTUBE
Phone: 816.474.5210
www.exltube.com

Hanna Steel Corp.
Phone: 800.633.3491
www.hannasteel.com

Hannibal Industries, Inc.
Phone: 323.588.4261
www.e-hii.com

Independence Tube Corp.
Phone: 800.376.6000
www.independencetube.com

IPSCO, Inc.
Phone: 563.242.0000
www.ipsco.com

Leavitt Tube Company, LLC
Phone: 800.532.8488
www.leavitt-tube.com

Longhorn Tube LP
Phone: 800.390.5029
www.longhorntube.com

Maruichi American Corp.
Phone: 562.903.8600
www.macsfs.com

Northwest Pipe Co.
Phone: 713.863.4300
www.nwpipe.com

Novamerican Steel, Inc.
Phone: 514.335.6682
www.novamerican.com

Procarsa Tube & Pipe Co.
Phone: 956.546.3122

Prolamsa, Inc.
Phone: 281.494.0900
www.prolamsausa.com

Southland Tube, Inc.
Phone: 205.251.1884
www.southlandtube.com

Valmont Industries Structural Tubing
Phone: 800.825.6668
www.valmont.com

Vest, Inc.
Phone: 323.581.8823
www.vestinc.com

Welded Tube Of Canada
Phone: 800.565.8823
www.weldedtube.com

	Atlas Tube Inc.	Bull Moose Tube Co.	Columbia Structural Tubing	Corus	Eugene Welding Co.	EXLTUBE	Hanna Steel Corp.	Hannibal Industries Inc.	Independence Tube Corp.	IPSCO Inc.	Leavitt Tube Company LLC.	Longhorn Tube LP	Maruichi American Corp.	Northwest Pipe Co.	Novamerican Steel Inc.	Procarsa Tube & Pipe Co.	Prolamsa Inc.	Southland Tube Inc.	Valmont Industries	Vest Inc.	Welded Tube of Canada
ROUND HSS																					
HSS 1.66 x 0.109	X	X				X					X			X				X			X
HSS 1.66 x 0.14	X	X				X	X				X			X	X			X			X
HSS 1.66 x 0.143	X	X									X			X				X			X
HSS 1.9 x 0.109	X	X									X			X				X			X
HSS 1.9 x 0.12	X	X									X			X	X			X			X
HSS 1.9 x 0.125	X	X									X			X				X			X
HSS 1.9 x 0.134	X	X									X			X				X			X
HSS 1.9 x 0.14	X	X									X			X				X			X
HSS 1.9 x 0.145	X	X				X	X				X			X	X			X			X
HSS 1.9 x 0.154	X	X									X			X				X			X
HSS 1.9 x 0.188	X																	X			X
HSS 2 x 0.188																					X
HSS 2.25 x 0.25		X																			X
HSS 2.25 x 0.188	X	X																			X
HSS 2.25 x 0.125	X	X																			X
HSS 2.375 x 0.109	X	X				X		X			X			X				X			X
HSS 2.375 x 0.125	X	X				X	X	X			X			X	X			X			X
HSS 2.375 x 0.148	X	X									X			X				X			X
HSS 2.375 x 0.154	X	X				X	X	X		X	X			X	X			X			X
HSS 2.375 x 0.188	X	X				X	X	X		X	X			X	X		X	X			X

	Atlas Tube Inc.	Bull Moose Tube Co.	Columbia Structural Tubing	Corus	Eugene Welding Co.	EXLTUBE	Hanna Steel Corp.	Hannibal Industries Inc.	Independence Tube Corp.	IPSCO Inc.	Leavitt Tube Company LLC.	Longhorn Tube LP	Maruichi American Corp.	Northwest Pipe Co.	Novamerican Steel Inc.	Procarsa Tube & Pipe Co.	Prolamsa Inc.	Southland Tube Inc.	Valmont Industries	Vest Inc.	Welded Tube of Canada
ROUND HSS																					
HSS 2.375 x 0.218						X	X	X		X				X	X		X	X			X
HSS 2.375 x 0.25						X	X	X		X					X		X	X			X
HSS 2.5 x 0.12	X	X						X						X				X			X
HSS 2.5 x 0.125	X	X						X			X			X				X			X
HSS 2.5 x 0.188	X	X						X			X							X			X
HSS 2.5 x 0.25	X										X							X			X
HSS 2.875 x 0.12	X	X				X					X						X	X			X
HSS 2.875 x 0.125	X	X				X					X			X	X		X	X			X
HSS 2.875 x 0.188	X					X					X			X	X		X	X			X
HSS 2.875 x 0.203	X					X	X			X	X			X	X		X	X			X
HSS 2.875 x 0.25	X					X					X			X	X			X			X
HSS 2.875 x 0.276										X				X							X
HSS 3 x 0.12	X	X				X		X			X			X							X
HSS 3 x 0.125	X	X									X						X				X
HSS 3 x 0.134	X	X				X		X			X						X				X
HSS 3 x 0.152	X	X				X	X	X			X						X				X
HSS 3 x 0.154	X	X									X										X
HSS 3 x 0.188	X						X	X			X						X				X
HSS 3 x 0.203	X						X	X			X						X				X
HSS 3 x 0.216	X							X			X						X				X
HSS 3 x 0.25	X						X	X			X						X				X
HSS 3 x 0.3																					X
HSS 3.5 x 0.12	X	X				X					X			X			X	X			X
HSS 3.5 x 0.125	X	X				X	X				X			X	X		X	X			X
HSS 3.5 x 0.188	X					X	X				X			X	X		X	X			X
HSS 3.5 x 0.203	X					X	X			X	X			X	X		X	X			X
HSS 3.5 x 0.216	X					X	X				X			X	X		X	X			X
HSS 3.5 x 0.226	X										X			X			X	X			X
HSS 3.5 x 0.237	X										X			X				X			X
HSS 3.5 x 0.25	X					X	X				X			X	X			X			X
HSS 3.5 x 0.3						X	X				X			X				X			X
HSS 3.5 x 0.313											X										X
HSS 4 x 0.12		X				X		X			X			X				X			X
HSS 4 x 0.125		X				X	X	X			X			X			X	X			X
HSS 4 x 0.188		X				X	X	X			X			X			X	X			X
HSS 4 x 0.22											X			X			X	X			X
HSS 4 x 0.226						X		X			X			X			X	X			X
HSS 4 x 0.237						X	X	X			X						X	X			X
HSS 4 x 0.25						X	X	X			X						X	X			X
HSS 4 x 0.313																					X
HSS 4 x 0.318																					X
HSS 4 x 0.337							X														X
HSS 4 x 0.375																					X
HSS 4.5 x 0.12	X	X									X			X			X	X			X
HSS 4.5 x 0.125	X	X				X	X				X			X	X		X	X			X
HSS 4.5 x 0.188	X					X	X			X	X			X	X		X	X			X
HSS 4.5 x 0.237	X					X	X			X	X			X	X		X	X			X
HSS 4.5 x 0.337	X									X											X
HSS 4.5 x 0.375	X																				X
HSS 5 x 0.109														X				X			X
HSS 5 x 0.12	X										X			X				X			X
HSS 5 x 0.125	X					X	X	X			X			X				X	X		X
HSS 5 x 0.188	X					X	X	X			X			X				X	X		X
HSS 5 x 0.247	X																	X			X
HSS 5 x 0.25	X					X	X	X			X							X	X		X
HSS 5 x 0.258	X					X												X			X
HSS 5 x 0.312	X																				X
HSS 5 x 0.375	X																				X
HSS 5 x 0.5	X																				X
HSS 5.5 x 0.258											X										X
HSS 5.5 x 0.375											X										X
HSS 5.5 x 0.5											X										X
HSS 5.563 x 0.134	X					X								X	X			X			X
HSS 5.563 x 0.188	X					X					X			X	X			X			X
HSS 5.563 x 0.25	X					X					X			X				X			X
HSS 5.563 x 0.258	X									X	X			X	X			X			X
HSS 5.563 x 0.375	X									X	X							X			X
HSS 5.563 x 0.5	X										X							X			X
HSS 6 x 0.12														X				X			
HSS 6 x 0.125							X							X				X	X		X
HSS 6 x 0.188							X							X			X	X	X		X
HSS 6 x 0.25							X										X	X			X
HSS 6 x 0.28							X										X	X			X
HSS 6 x 0.312							X														X
HSS 6 x 0.375	X						X														X

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ROUND HSS																					
HSS 6 x 0.5																					X
HSS 6.625 x 0.125	X					X				X				X			X	X	X		X
HSS 6.625 x 0.156	X													X			X	X			X
HSS 6.625 x 0.188	X					X	X			X	X			X	X		X	X	X		X
HSS 6.625 x 0.25	X					X	X			X	X			X	X		X	X	X		X
HSS 6.625 x 0.28	X					X	X			X	X			X	X		X	X			X
HSS 6.625 x 0.312	X						X			X	X				X			X			X
HSS 6.625 x 0.375	X						X			X	X				X			X			X
HSS 6.625 x 0.432	X									X	X							X			X
HSS 6.625 x 0.5	X										X							X			X
HSS 7 x 0.125						X								X					X		
HSS 7 x 0.134														X							
HSS 7 x 0.188	X					X	X				X			X					X		X
HSS 7 x 0.25	X					X	X				X			X							X
HSS 7 x 0.312	X						X				X										X
HSS 7 x 0.375	X						X				X										X
HSS 7 x 0.5	X										X										X
HSS 7.5 x 0.188						X															X
HSS 7.5 x 0.25						X															X
HSS 7.5 x 0.312																					X
HSS 7.5 x 0.375																					X
HSS 7.5 x 0.5																					X
HSS 7.625 x 0.328																					X
HSS 7.625 x 0.375																					X
HSS 8.625 x 0.125	X													X				X	X		
HSS 8.625 x 0.188	X									X	X			X				X	X		X
HSS 8.625 x 0.25	X									X	X			X				X	X		X
HSS 8.625 x 0.322	X									X	X							X			X
HSS 8.625 x 0.375	X									X	X							X			X
HSS 8.625 x 0.5	X									X	X							X			X
HSS 8.625 x 0.625	X																	X			
HSS 8.75 x 0.188																					X
HSS 8.75 x 0.25																					X
HSS 8.75 x 0.312																					X
HSS 8.75 x 0.375																					X
HSS 8.75 x 0.5																					X
HSS 9.625 x 0.188	X																				X
HSS 9.625 x 0.25	X																				X
HSS 9.625 x 0.312	X																				X
HSS 9.625 x 0.375	X																				X
HSS 9.625 x 0.5	X																				X
HSS 9.625 x 0.625	X																				
HSS 10 x 0.125														X					X	X	
HSS 10 x 0.188														X					X		
HSS 10 x 0.25														X					X		X
HSS 10 x 0.312																					X
HSS 10 x 0.375																					X
HSS 10 x 0.5																					X
HSS 10.75 x 0.188	X													X				X			X
HSS 10.75 x 0.25	X													X				X			X
HSS 10.75 x 0.365	X																	X			X
HSS 10.75 x 0.5	X																	X			X
HSS 10.75 x 0.625	X																				
HSS 11.75 x 0.25	X																				
HSS 11.75 x 0.375	X																				
HSS 11.75 x 0.5	X																				
HSS 11.75 x 0.625	X																				
HSS 12.75 x 0.125														X				X	X		
HSS 12.75 x 0.188														X				X	X		
HSS 12.75 x 0.25	X													X				X	X		
HSS 12.75 x 0.375	X																	X			
HSS 12.75 x 0.406	X																	X			
HSS 12.75 x 0.5	X																	X			
HSS 12.75 x 0.625	X																				
HSS 13.375 x 0.25	X																				
HSS 13.375 x 0.375	X																				
HSS 13.375 x 0.5	X																				
HSS 13.375 x 0.625	X																				
HSS 14 x 0.188														X					X		
HSS 14 x 0.25	X													X					X		
HSS 14 x 0.375	X																				
HSS 14 x 0.438	X																				
HSS 14 x 0.5	X																				
HSS 14 x 0.625	X																				
HSS 16 x 0.188														X					X		

	Atlas Tube Inc.	Bull Moose Tube Co.	Columbia Structural Tubing	Corus	Eugene Welding Co.	EXLTUBE	Hanna Steel Corp.	Hannibal Industries Inc.	Independence Tube Corp.	IPSCO Inc.	Leavitt Tube Company LLC.	Longhorn Tube LP	Maruichi American Corp.	Northwest Pipe Co.	Novamerican Steel Inc.	Procarsa Tube & Pipe Co.	Prolamsa Inc.	Southland Tube Inc.	Valmont Industries	Vest Inc.	Welded Tube of Canada
ROUND HSS																					
HSS 16 x 0.25	X													X					X		
HSS 16 x 0.375	X																				
HSS 16 x 0.5	X																				
HSS 16 x 0.625	X																				
HSS 18 x 0.375	X																				
HSS 18 x 0.5	X																				
HSS 20 x 0.375	X																				
HSS 20 x 0.5	X																				
RECTANGULAR HSS																					
HSS 2 x 1 x 1/8	X	X			X						X	X		X						X	X
HSS 2 x 1 x 3/16	X	X			X																X
HSS 2 x 1 1/2 x 1/8	X	X			X						X									X	X
HSS 2 x 1 1/2 x 3/16	X	X			X																X
HSS 2 1/4 x 2 x 1/8		X			X				X			X									X
HSS 2 1/4 x 2 x 3/16		X			X				X			X									X
HSS 2 1/2 x 1 1/2 x 1/8	X	X			X	X			X		X		X		X					X	X
HSS 2 1/2 x 1 1/2 x 3/16	X	X			X		X		X		X				X					X	X
HSS 2 1/2 x 1 1/2 x 1/4	X	X							X		X									X	
HSS 2 1/2 x 2 x 1/8	X	X			X				X			X									X
HSS 2 1/2 x 2 x 3/16	X	X			X				X			X									X
HSS 2 1/2 x 2 x 1/4		X			X				X												
HSS 3 x 1 x 1/8	X	X			X			X			X	X		X						X	X
HSS 3 x 1 x 3/16	X	X			X			X													X
HSS 3 x 1 1/2 x 1/8	X	X			X	X		X	X		X	X	X		X					X	X
HSS 3 x 1 1/2 x 3/16	X	X			X			X	X		X		X		X						X
HSS 3 x 1 1/2 x 1/4	X	X							X		X										
HSS 3 x 2 x 1/8	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 3 x 2 x 3/16	X	X	X		X	X		X	X	X	X	X	X		X		X			X	X
HSS 3 x 2 x 1/4	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 3 x 2 x 5/16	X	X							X												X
HSS 3 x 2 1/2 x 1/8		X			X						X	X									X
HSS 3 x 2 1/2 x 3/16		X			X						X										X
HSS 3 x 2 1/2 x 1/4		X			X						X										X
HSS 3 x 2 1/2 x 5/16		X																			X
HSS 3 1/2 x 1 1/2 x 1/8	X	X			X				X		X				X						X
HSS 3 1/2 x 1 1/2 x 3/16	X	X			X				X		X				X						X
HSS 3 1/2 x 1 1/2 x 1/4		X			X				X		X										
HSS 3 1/2 x 2 x 1/8		X			X					X											X
HSS 3 1/2 x 2 x 3/16		X			X					X		X									X
HSS 3 1/2 x 2 x 1/4		X			X							X									X
HSS 3 1/2 x 2 x 3/8		X																			
HSS 3 1/2 x 2 1/2 x 1/8	X	X	X		X			X			X				X					X	X
HSS 3 1/2 x 2 1/2 x 3/16	X	X	X		X			X	X		X	X			X					X	X
HSS 3 1/2 x 2 1/2 x 1/4	X	X	X		X			X	X		X	X			X					X	X
HSS 3 1/2 x 2 1/2 x 5/16		X							X												X
HSS 3 1/2 x 2 1/2 x 3/8		X																			X
HSS 4 x 2 x 1/8	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X			X	X
HSS 4 x 2 x 3/16	X	X	X		X	X		X	X	X	X	X	X		X		X			X	X
HSS 4 x 2 x 1/4	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 4 x 2 x 5/16	X	X	X				X		X						X					X	X
HSS 4 x 2 x 3/8	X	X					X		X												X
HSS 4 x 2 1/2 x 1/8	X	X			X																X
HSS 4 x 2 1/2 x 3/16	X	X			X							X									X
HSS 4 x 2 1/2 x 1/4	X	X			X							X									X
HSS 4 x 2 1/2 x 5/16		X																			X
HSS 4 x 2 1/2 x 3/8		X																			X
HSS 4 x 3 x 1/8	X	X	X		X	X	X	X	X	X	X	X	X	X	X		X			X	X
HSS 4 x 3 x 3/16	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 4 x 3 x 1/4	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 4 x 3 x 5/16	X	X	X						X			X			X					X	X
HSS 4 x 3 x 3/8	X	X	X						X			X								X	X
HSS 5 x 2 x 1/8	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 5 x 2 x 3/16	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 5 x 2 x 1/4	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 5 x 2 x 5/16	X	X	X						X											X	X
HSS 5 x 2 x 3/8	X	X	X						X												X
HSS 5 x 2 1/2 x 1/8	X	X													X						X
HSS 5 x 2 1/2 x 3/16	X	X										X			X						X
HSS 5 x 2 1/2 x 1/4	X	X										X			X						X
HSS 5 x 3 x 1/8	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 5 x 3 x 3/16	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 5 x 3 x 1/4	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 5 x 3 x 5/16	X	X	X				X		X	X	X	X	X		X					X	X
HSS 5 x 3 x 3/8	X	X	X				X		X	X	X	X	X							X	X
HSS 5 x 3 x 1/2	X	X							X		X		X								X

	Atlas Tube Inc.	Bull Moose Tube Co.	Columbia Structural Tubing	Corus	Eugene Welding Co.	EXLTUBE	Hanna Steel Corp.	Hannibal Industries Inc.	Independence Tube Corp.	IPSCO Inc.	Leavitt Tube Company LLC.	Longhorn Tube LP	Maruichi American Corp.	Northwest Pipe Co.	Novamerican Steel Inc.	Procarsa Tube & Pipe Co.	Prolamsa Inc.	Southland Tube Inc.	Valmont Industries	Vest Inc.	Welded Tube of Canada
RECTANGULAR HSS																					
HSS 5 x 4 x 1/8	X	X	X						X			X	X							X	X
HSS 5 x 4 x 3/16	X	X	X						X		X	X	X							X	X
HSS 5 x 4 x 1/4	X	X	X						X		X	X	X							X	X
HSS 5 x 4 x 5/16	X	X	X						X		X		X							X	X
HSS 5 x 4 x 3/8	X	X	X						X		X		X							X	X
HSS 5 x 4 x 1/2	X	X	X								X										X
HSS 6 x 2 x 1/8	X	X	X		X	X	X	X	X	X	X	X	X				X			X	X
HSS 6 x 2 x 3/16	X	X	X		X	X	X	X	X	X	X	X	X				X			X	X
HSS 6 x 2 x 1/4	X	X	X		X	X	X	X	X	X	X	X	X				X			X	X
HSS 6 x 2 x 5/16	X	X	X				X		X				X							X	X
HSS 6 x 2 x 3/8	X	X	X				X		X				X								X
HSS 6 x 3 x 1/8	X	X	X			X	X		X	X		X	X				X			X	X
HSS 6 x 3 x 3/16	X	X	X			X	X		X	X	X	X	X				X			X	X
HSS 6 x 3 x 1/4	X	X	X			X	X		X	X	X	X	X				X			X	X
HSS 6 x 3 x 5/16	X	X	X				X		X	X	X	X	X							X	X
HSS 6 x 3 x 3/8	X	X	X				X		X	X	X	X	X							X	X
HSS 6 x 3 x 1/2	X	X									X										X
HSS 6 x 4 x 1/8	X	X	X			X			X	X			X				X			X	X
HSS 6 x 4 x 3/16	X	X	X			X			X	X	X	X	X				X			X	X
HSS 6 x 4 x 1/4	X	X	X			X			X	X	X	X	X				X			X	X
HSS 6 x 4 x 5/16	X	X	X			X			X	X	X		X							X	X
HSS 6 x 4 x 3/8	X	X	X			X			X	X	X		X							X	X
HSS 6 x 4 x 1/2	X	X	X						X		X		X							X	X
HSS 6 x 5 x 1/8	X	X							X												
HSS 6 x 5 x 3/16	X	X	X						X												X
HSS 6 x 5 x 1/4	X	X	X						X												X
HSS 6 x 5 x 5/16	X	X	X						X												X
HSS 6 x 5 x 3/8	X	X	X						X												X
HSS 6 x 5 x 1/2	X	X							X												X
HSS 7 x 2 x 1/8		X																			X
HSS 7 x 2 x 3/16		X																			X
HSS 7 x 2 x 1/4		X																			X
HSS 7 x 3 x 1/8	X	X				X			X												X
HSS 7 x 3 x 3/16	X	X	X			X			X												X
HSS 7 x 3 x 1/4	X	X	X			X			X												X
HSS 7 x 3 x 5/16	X	X	X						X												X
HSS 7 x 3 x 3/8	X	X	X						X												X
HSS 7 x 3 x 1/2	X	X							X												
HSS 7 x 4 x 1/8	X	X							X			X									
HSS 7 x 4 x 3/16	X	X	X				X		X		X	X									X
HSS 7 x 4 x 1/4	X	X	X				X		X		X	X									X
HSS 7 x 4 x 5/16	X	X	X				X		X		X										X
HSS 7 x 4 x 3/8	X	X	X				X		X		X										X
HSS 7 x 4 x 1/2	X	X	X								X										X
HSS 7 x 5 x 1/8	X	X				X			X	X		X	X							X	
HSS 7 x 5 x 3/16	X	X	X			X	X		X	X	X	X	X		X					X	X
HSS 7 x 5 x 1/4	X	X	X			X	X		X	X	X	X	X		X					X	X
HSS 7 x 5 x 5/16	X	X	X				X		X		X	X	X		X					X	X
HSS 7 x 5 x 3/8	X	X	X				X		X		X	X	X		X					X	X
HSS 7 x 5 x 1/2	X	X	X						X		X		X							X	X
HSS 8 x 2 x 1/8	X	X							X	X		X	X							X	X
HSS 8 x 2 x 3/16	X	X	X				X		X	X	X	X	X							X	X
HSS 8 x 2 x 1/4	X	X	X				X		X	X	X	X	X							X	X
HSS 8 x 2 x 5/16	X	X					X		X		X		X							X	X
HSS 8 x 2 x 3/8	X	X					X		X		X										X
HSS 8 x 3 x 1/8	X	X							X			X								X	
HSS 8 x 3 x 3/16	X	X	X				X		X		X	X								X	X
HSS 8 x 3 x 1/4	X	X	X				X		X		X	X								X	X
HSS 8 x 3 x 5/16	X	X	X				X		X		X									X	X
HSS 8 x 3 x 3/8	X	X	X				X		X		X									X	X
HSS 8 x 3 x 1/2	X	X									X										
HSS 8 x 4 x 1/8	X	X				X			X	X		X								X	
HSS 8 x 4 x 3/16	X	X	X			X	X		X	X	X	X	X		X					X	X
HSS 8 x 4 x 1/4	X	X	X			X	X		X	X	X	X	X		X					X	X
HSS 8 x 4 x 5/16	X	X	X				X		X	X	X		X		X					X	X
HSS 8 x 4 x 3/8	X	X	X				X		X	X	X		X		X					X	X
HSS 8 x 4 x 1/2	X	X	X				X		X	X	X		X							X	X
HSS 8 x 4 x 5/8		X							X												
HSS 8 x 6 x 3/16	X	X	X	X			X		X	X	X	X	X							X	X
HSS 8 x 6 x 1/4	X	X	X	X			X		X	X	X	X	X							X	X
HSS 8 x 6 x 5/16	X	X	X	X			X		X	X	X		X							X	X
HSS 8 x 6 x 3/8	X	X	X	X,Y			X		X	X	X		X							X	X
HSS 8 x 6 x 1/2	X	X	X	Y			X		X	X	X									X	X
HSS 8 x 6 x 5/8	X	X							X												
HSS 9 x 3 x 3/16		X							X												X

	Atlas Tube Inc.	Bull Moose Tube Co.	Columbia Structural Tubing	Corus	Eugene Welding Co.	EXLTUBE	Hanna Steel Corp.	Hannibal Industries Inc.	Independence Tube Corp.	IPSCO Inc.	Leavitt Tube Company LLC.	Longhorn Tube LP	Maruichi American Corp.	Northwest Pipe Co.	Novamerican Steel Inc.	Procarsa Tube & Pipe Co.	Prolamsa Inc.	Southland Tube Inc.	Valmont Industries	Vest Inc.	Welded Tube of Canada
RECTANGULAR HSS																					
HSS 9 x 3 x 1/4		X							X												X
HSS 9 x 3 x 5/16		X							X												X
HSS 9 x 3 x 3/8		X							X												X
HSS 9 x 3 x 1/2		X							X												
HSS 9 x 5 x 3/16	X	X	X						X												X
HSS 9 x 5 x 1/4	X	X	X						X												X
HSS 9 x 5 x 5/16	X	X	X						X												X
HSS 9 x 5 x 3/8	X	X	X						X												X
HSS 9 x 5 x 1/2	X	X	X						X												X
HSS 9 x 5 x 5/8		X							X												
HSS 9 x 7 x 3/16	X	X							X												X
HSS 9 x 7 x 1/4	X	X	X						X												X
HSS 9 x 7 x 5/16	X	X	X						X												X
HSS 9 x 7 x 3/8	X	X	X						X												X
HSS 9 x 7 x 1/2	X	X	X						X												X
HSS 9 x 7 x 5/8	X	X							X												
HSS 10 x 2 x 1/8	X	X							X											X	
HSS 10 x 2 x 3/16	X	X	X						X		X	X	X							X	X
HSS 10 x 2 x 1/4	X	X	X						X		X	X	X							X	X
HSS 10 x 2 x 5/16	X	X							X		X									X	X
HSS 10 x 2 x 3/8	X	X									X										X
HSS 10 x 3 x 1/8	X	X																			
HSS 10 x 3 x 3/16	X	X										X									X
HSS 10 x 3 x 1/4	X	X										X									X
HSS 10 x 3 x 5/16	X	X																			
HSS 10 x 3 x 3/8	X	X																			
HSS 10 x 3 1/2 x 1/8	X	X																			
HSS 10 x 3 1/2 x 3/16	X	X																			X
HSS 10 x 3 1/2 x 1/4	X	X																			X
HSS 10 x 3 1/2 x 5/16	X	X																			
HSS 10 x 3 1/2 x 3/8	X	X																			
HSS 10 x 3 1/2 x 1/2		X																			
HSS 10 x 4 x 3/16	X	X	X						X	X	X	X	X							X	X
HSS 10 x 4 x 1/4	X	X	X						X	X	X	X	X							X	X
HSS 10 x 4 x 5/16	X	X	X						X	X	X		X							X	X
HSS 10 x 4 x 3/8	X	X	X						X		X		X							X	X
HSS 10 x 4 x 1/2	X	X	X	Y					X		X		X							X	X
HSS 10 x 4 x 5/8		X		Y																	
HSS 10 x 5 x 3/16		X										X									
HSS 10 x 5 x 1/4		X										X									
HSS 10 x 5 x 5/16		X																			
HSS 10 x 5 x 3/8		X																			
HSS 10 x 6 x 3/16	X	X	X				X		X	X	X	X	X							X	X
HSS 10 x 6 x 1/4	X	X	X				X		X	X	X	X	X							X	X
HSS 10 x 6 x 5/16	X	X	X	X			X		X	X	X		X							X	X
HSS 10 x 6 x 3/8	X	X	X	X,Y			X		X	X	X		X							X	X
HSS 10 x 6 x 1/2	X	X	X	X,Y			X		X		X		X							X	X
HSS 10 x 6 x 5/8	X	X		Y					X												
HSS 10 x 8 x 3/16	X	X	X				X		X		X		X								
HSS 10 x 8 x 1/4	X	X	X				X		X		X		X								
HSS 10 x 8 x 5/16	X	X	X				X		X		X		X								
HSS 10 x 8 x 3/8	X	X	X				X		X		X		X								
HSS 10 x 8 x 1/2	X	X	X				X		X		X		X								
HSS 10 x 8 x 5/8	X	X							X												
HSS 12 x 2 x 3/16		X							X		X										X
HSS 12 x 2 x 1/4		X							X		X										X
HSS 12 x 3 x 3/16		X																			X
HSS 12 x 3 x 1/4		X																			X
HSS 12 x 3 x 5/16		X																			X
HSS 12 x 3 1/2 x 5/16		X																			X
HSS 12 x 3 1/2 x 3/8		X																			X
HSS 12 x 4 x 3/16	X	X	X				X		X		X		X							X	X
HSS 12 x 4 x 1/4	X	X	X				X		X		X		X							X	X
HSS 12 x 4 x 5/16	X	X	X				X		X		X		X							X	X
HSS 12 x 4 x 3/8	X	X	X				X		X		X		X							X	X
HSS 12 x 4 x 1/2	X	X	X	Y			X		X		X		X							X	X
HSS 12 x 4 x 5/8		X		Y																	
HSS 12 x 6 x 3/16	X	X	X				X		X				X								
HSS 12 x 6 x 1/4	X	X	X				X		X		X		X								
HSS 12 x 6 x 5/16	X	X	X				X		X		X		X								
HSS 12 x 6 x 3/8	X	X	X				X		X		X		X								
HSS 12 x 6 x 1/2	X	X	X				X		X		X		X								
HSS 12 x 6 x 5/8	X	X							X												
HSS 12 x 8 x 3/16	X	X	X				X		X				X							X	
HSS 12 x 8 x 1/4	X	X	X				X		X		X		X							X	

	Atlas Tube Inc.	Bull Moose Tube Co.	Columbia Structural Tubing	Corus	Eugene Welding Co.	EXLTUBE	Hanna Steel Corp.	Hannibal Industries Inc.	Independence Tube Corp.	IPSCO Inc.	Leavitt Tube Company LLC.	Longhorn Tube LP	Maruichi American Corp.	Northwest Pipe Co.	Novamerican Steel Inc.	Procarsa Tube & Pipe Co.	Prolamsa Inc.	Southland Tube Inc.	Valmont Industries	Vest Inc.	Welded Tube of Canada
RECTANGULAR HSS																					
HSS 12 x 8 x 5/16	X	X	X				X		X		X		X						X	X	
HSS 12 x 8 x 3/8	X	X	X	X			X		X		X		X						X	X	
HSS 12 x 8 x 1/2	X	X	X	X,Y			X		X		X		X						X	X	
HSS 12 x 8 x 5/8	X	X		Y					X										X		
HSS 12 x 10 x 1/4		X																	X		
HSS 12 x 10 x 3/8		X																	X		
HSS 12 x 10 x 1/2		X																	X		
HSS 14 x 4 x 3/16	X	X																			
HSS 14 x 4 x 1/4	X	X																			
HSS 14 x 4 x 5/16	X	X																			
HSS 14 x 4 x 3/8	X	X																			
HSS 14 x 4 x 1/2	X	X																			
HSS 14 x 4 x 5/8		X																			
HSS 14 x 6 x 3/16	X	X																			
HSS 14 x 6 x 1/4	X	X																		X	
HSS 14 x 6 x 5/16	X	X																		X	
HSS 14 x 6 x 3/8	X	X																		X	
HSS 14 x 6 x 1/2	X	X																		X	
HSS 14 x 6 x 5/8	X	X																			
HSS 14 x 10 x 1/4	X	X																	X		
HSS 14 x 10 x 5/16	X	X																	X		
HSS 14 x 10 x 3/8	X	X																	X		
HSS 14 x 10 x 1/2	X	X		X															X		
HSS 14 x 10 x 5/8	X	X																	X		
HSS 14 x 12 x 3/8																			X		
HSS 14 x 12 x 1/2																			X		
HSS 14 x 12 x 5/8																			X		
HSS 16 x 4 x 3/16	X	X																			
HSS 16 x 4 x 1/4	X	X																			
HSS 16 x 4 x 5/16	X	X																			
HSS 16 x 4 x 3/8	X	X																			
HSS 16 x 4 x 1/2	X	X																			
HSS 16 x 4 x 5/8		X																			
HSS 16 x 8 x 1/4	X	X																	X		
HSS 16 x 8 x 5/16	X	X																	X		
HSS 16 x 8 x 3/8	X	X																	X		
HSS 16 x 8 x 1/2	X	X		X,Y															X		
HSS 16 x 8 x 5/8	X	X		Y															X		
HSS 16 x 12 x 5/16	X																		X		
HSS 16 x 12 x 3/8	X																		X		
HSS 16 x 12 x 1/2	X																		X		
HSS 16 x 12 x 5/8	X																		X		
HSS 18 x 6 x 1/4	X	X																			
HSS 18 x 6 x 5/16	X	X																			
HSS 18 x 6 x 3/8	X	X																			
HSS 18 x 6 x 1/2	X	X																			
HSS 18 x 6 x 5/8	X	X																			
HSS 18 x 10 x 5/16	X																		X		
HSS 18 x 10 x 3/8	X																		X		
HSS 18 x 10 x 1/2	X			X,Y															X		
HSS 18 x 10 x 5/8				Y																	
HSS 18 x 12 x 3/8																			X		
HSS 18 x 12 x 1/2																			X		
HSS 18 x 12 x 5/8																			X		
HSS 18 x 14 x 5/16																			X		
HSS 18 x 14 x 3/8																			X		
HSS 18 x 14 x 1/2																			X		
HSS 18 x 16 x 1/4																			X		
HSS 18 x 16 x 5/16																			X		
HSS 18 x 16 x 3/8																			X		
HSS 18 x 16 x 1/2																			X		
HSS 18 x 16 x 5/8																			X		
HSS 20 x 4 x 1/4	X																				
HSS 20 x 4 x 5/16	X																				
HSS 20 x 4 x 3/8	X																				
HSS 20 x 4 x 1/2	X																				
HSS 20 x 8 x 5/16	X																		X		
HSS 20 x 8 x 3/8	X																		X		
HSS 20 x 8 x 1/2	X																		X		
HSS 20 x 8 x 5/8	X																				
HSS 20 x 12 x 5/16	X			X															X		
HSS 20 x 12 x 3/8	X			X															X		
HSS 20 x 12 x 1/2	X			Y															X		
HSS 20 x 12 x 5/8	X			Y															X		
HSS 20 x 16 x 3/8																			X		

	Atlas Tube Inc.	Bull Moose Tube Co.	Columbia Structural Tubing	Corus	Eugene Welding Co.	EXLTUBE	Hanna Steel Corp.	Hannibal Industries Inc.	Independence Tube Corp.	IPSCO Inc.	Leavitt Tube Company LLC.	Longhorn Tube LP	Maruichi American Corp.	Northwest Pipe Co.	Novamerican Steel Inc.	Procarsa Tube & Pipe Co.	Prolamsa Inc.	Southland Tube Inc.	Valmont Industries	Vest Inc.	Welded Tube of Canada
RECTANGULAR HSS																					
HSS 20 x 16 x 1/2																			X		
HSS 20 x 16 x 5/8																			X		
HSS 20 x 18 x 3/8																			X		
HSS 20 x 18 x 1/2																			X		
HSS 20 x 18 x 5/8																			X		
HSS 22 x 20 x 3/8																			X		
HSS 22 x 20 x 1/2																			X		
HSS 22 x 20 x 5/8																			X		
HSS 24 x 22 x 3/8																			X		
HSS 24 x 22 x 1/2																			X		
HSS 24 x 22 x 5/8																			X		
HSS 26 x 24 x 3/8																			X		
HSS 26 x 24 x 1/2																			X		
HSS 26 x 24 x 5/8																			X		
HSS 28 x 24 x 3/8																			X		
HSS 28 x 24 x 1/2																			X		
HSS 28 x 24 x 5/8																			X		
HSS 30 x 24 x 3/8																			X		
HSS 30 x 24 x 1/2																			X		
HSS 30 x 24 x 5/8																			X		
HSS 32 x 24 x 3/8																			X		
HSS 32 x 24 x 1/2																			X		
HSS 32 x 24 x 5/8																			X		
SQUARE HSS																					
HSS 1 1/2 x 1 1/2 x 1/8	X	X			X		X	X			X	X	X		X		X			X	X
HSS 1 1/2 x 1 1/2 x 3/16	X	X			X		X	X			X		X		X					X	X
HSS 1 1/2 x 1 1/2 x 1/4	X						X						X						X		
HSS 1 5/8 x 1 5/8 x 1/8					X												X				
HSS 1 3/4 x 1 3/4 x 3/16	X				X		X														X
HSS 1 3/4 x 1 3/4 x 1/4							X														
HSS 2 x 2 x 1/8	X	X			X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
HSS 2 x 2 x 3/16	X	X			X	X	X	X	X	X	X	X	X		X	X	X			X	X
HSS 2 x 2 x 1/4	X	X				X	X	X	X	X	X	X	X		X	X	X			X	X
HSS 2 x 2 x 5/16									X												
HSS 2 1/8 x 2 1/8 x 1/8	X	X			X						X	X									X
HSS 2 1/8 x 2 1/8 x 3/16	X				X							X									X
HSS 2 1/4 x 2 1/4 x 1/8		X			X				X		X	X					X				X
HSS 2 1/4 x 2 1/4 x 3/16					X				X			X					X				X
HSS 2 1/4 x 2 1/4 x 1/4					X												X				
HSS 2 1/2 x 2 1/2 x 1/8	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
HSS 2 1/2 x 2 1/2 x 3/16	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X			X	X
HSS 2 1/2 x 2 1/2 x 1/4	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X			X	X
HSS 2 1/2 x 2 1/2 x 5/16	X								X												X
HSS 3 x 3 x 1/8	X	X	X		X	X	X	X	X	X	X	X	X	X	X	X	X			X	X
HSS 3 x 3 x 3/16	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X			X	X
HSS 3 x 3 x 1/4	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X			X	X
HSS 3 x 3 x 5/16	X		X				X		X	X					X					X	X
HSS 3 x 3 x 3/8	X						X		X	X										X	
HSS 3 1/2 x 3 1/2 x 1/8	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X			X	X
HSS 3 1/2 x 3 1/2 x 3/16	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X			X	X
HSS 3 1/2 x 3 1/2 x 1/4	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 3 1/2 x 3 1/2 x 5/16	X	X	X						X	X					X					X	X
HSS 3 1/2 x 3 1/2 x 3/8	X		X						X	X										X	
HSS 4 x 4 x 1/8	X	X	X		X	X	X	X	X	X	X	X	X		X		X			X	X
HSS 4 x 4 x 3/16	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X			X	X
HSS 4 x 4 x 1/4	X	X	X		X	X	X	X	X	X	X	X	X		X	X	X			X	X
HSS 4 x 4 x 5/16	X	X	X				X		X	X	X		X		X	X				X	X
HSS 4 x 4 x 3/8	X	X	X				X		X	X	X		X		X	X				X	X
HSS 4 x 4 x 1/2	X	X							X		X		X							X	X
HSS 4 1/2 x 4 1/2 x 1/8	X	X					X		X			X				X	X				X
HSS 4 1/2 x 4 1/2 x 3/16	X	X					X		X			X				X	X				X
HSS 4 1/2 x 4 1/2 x 1/4	X	X					X		X			X				X	X				X
HSS 4 1/2 x 4 1/2 x 5/16	X	X					X		X							X					X
HSS 4 1/2 x 4 1/2 x 3/8	X						X		X												X
HSS 4 1/2 x 4 1/2 x 1/2	X																				X
HSS 5 x 5 x 1/8	X	X	X			X	X		X	X		X	X		X	X	X			X	X
HSS 5 x 5 x 3/16	X	X	X			X	X		X	X	X	X	X		X	X	X			X	X
HSS 5 x 5 x 1/4	X	X	X			X	X		X	X	X	X	X		X	X	X			X	X
HSS 5 x 5 x 5/16	X	X	X				X		X	X	X		X		X	X				X	X
HSS 5 x 5 x 3/8	X		X				X		X	X	X		X		X	X				X	X
HSS 5 x 5 x 1/2	X		X						X		X		X							X	X
HSS 5 1/2 x 5 1/2 x 1/8		X					X		X			X				X					X
HSS 5 1/2 x 5 1/2 x 3/16	X	X					X		X			X				X					X
HSS 5 1/2 x 5 1/2 x 1/4	X	X					X		X			X				X					X
HSS 5 1/2 x 5 1/2 x 5/16	X	X					X		X							X					X

	Atlas Tube Inc.	Bull Moose Tube Co.	Columbia Structural Tubing	Corus	Eugene Welding Co.	EXLTUBE	Hanna Steel Corp.	Hannibal Industries Inc.	Independence Tube Corp.	IPSCO Inc.	Leavitt Tube Company LLC.	Longhorn Tube LP	Maruichi American Corp.	Northwest Pipe Co.	Novamerican Steel Inc.	Procarsa Tube & Pipe Co.	Prolamsa Inc.	Southland Tube Inc.	Valmont Industries	Vest Inc.	Welded Tube of Canada
SQUARE HSS																					
HSS 5 1/2 x 5 1/2 x 3/8	X						X		X												X
HSS 6 x 6 x 1/8	X	X				X	X		X			X	X			X				X	X
HSS 6 x 6 x 3/16	X	X	X			X	X		X	X	X	X	X			X				X	X
HSS 6 x 6 x 1/4	X	X	X			X	X		X	X	X	X	X			X				X	X
HSS 6 x 6 x 5/16	X	X	X				X		X	X	X		X							X	X
HSS 6 x 6 x 3/8	X	X	X				X		X	X	X		X			X				X	X
HSS 6 x 6 x 1/2	X	X	X				X		X	X	X		X			X				X	X
HSS 6 x 6 x 5/8	X	X							X												
HSS 7 x 7 x 1/8		X							X							X					
HSS 7 x 7 x 3/16	X	X	X	X			X		X	X	X	X	X			X				X	X
HSS 7 x 7 x 1/4	X	X	X	X			X		X	X	X	X	X			X				X	X
HSS 7 x 7 x 5/16	X	X	X	X			X		X	X	X		X			X				X	X
HSS 7 x 7 x 3/8	X	X	X	X			X		X	X	X		X			X				X	X
HSS 7 x 7 x 1/2	X	X	X				X		X	X	X		X			X				X	X
HSS 7 x 7 x 5/8	X	X							X												
HSS 8 x 8 x 1/8		X							X							X					
HSS 8 x 8 x 3/16	X	X	X				X		X	X	X	X	X			X				X	X
HSS 8 x 8 x 1/4	X	X	X	X			X		X	X	X	X	X			X				X	X
HSS 8 x 8 x 5/16	X	X	X	X			X		X	X	X		X			X				X	X
HSS 8 x 8 x 3/8	X	X	X	X,Y			X		X	X	X		X			X				X	X
HSS 8 x 8 x 1/2	X	X	X	X,Y			X		X	X	X		X			X				X	X
HSS 8 x 8 x 5/8	X	X		Y					X												
HSS 9 x 9 x 3/16	X	X							X												
HSS 9 x 9 x 1/4	X	X	X						X												
HSS 9 x 9 x 5/16	X	X	X						X										X		
HSS 9 x 9 x 3/8	X	X	X						X										X		
HSS 9 x 9 x 1/2	X	X	X						X										X		
HSS 9 x 9 x 5/8	X	X																	X		
HSS 10 x 10 x 3/16	X	X	X				X		X	X			X			X				X	
HSS 10 x 10 x 1/4	X	X	X				X		X	X	X		X			X				X	
HSS 10 x 10 x 5/16	X	X	X				X		X	X	X		X			X				X	
HSS 10 x 10 x 3/8	X	X	X	X,Y			X		X	X	X		X			X				X	
HSS 10 x 10 x 1/2	X	X	X	X,Y			X		X	X	X		X			X				X	
HSS 10 x 10 x 5/8	X	X		Y					X										X		
HSS 12 x 12 x 1/4	X	X														X					
HSS 12 x 12 x 5/16	X	X														X			X		
HSS 12 x 12 x 3/8	X	X														X			X		
HSS 12 x 12 x 1/2	X	X		X,Y												X			X		
HSS 12 x 12 x 5/8	X	X		Y															X		
HSS 14 x 14 x 5/16	X															X			X		
HSS 14 x 14 x 3/8	X															X			X		
HSS 14 x 14 x 1/2	X			X,Y												X			X		
HSS 14 x 14 x 5/8	X			Y															X		
HSS 16 x 16 x 5/16	X			X												X			X		
HSS 16 x 16 x 3/8	X			X												X			X		
HSS 16 x 16 x 1/2	X			Y												X			X		
HSS 16 x 16 x 5/8	X			Y															X		
HSS 18 x 18 x 3/8																			X		
HSS 18 x 18 x 1/2				Y															X		
HSS 18 x 18 x 5/8				Y															X		
HSS 22 x 22 x 3/8																			X		
HSS 22 x 22 x 1/2																			X		
HSS 22 x 22 x 5/8				Y															X		
HSS 24 x 24 x 3/8																			X		
HSS 24 x 24 x 1/2																			X		
HSS 24 x 24 x 5/8				Y															X		
HSS 26 x 26 x 3/8																			X		
HSS 26 x 26 x 1/2																			X		
HSS 26 x 26 x 5/8				Y															X		
HSS 28 x 28 x 3/8																			X		
HSS 28 x 28 x 1/2																			X		
HSS 28 x 28 x 5/8				Y															X		
HSS 30 x 30 x 3/8																			X		
HSS 30 x 30 x 1/2																			X		
HSS 30 x 30 x 5/8				Y															X		
HSS 32 x 32 x 3/8																			X		
HSS 32 x 32 x 1/2																			X		
HSS 32 x 32 x 5/8				Y															X		
HSS 36 x 36 x 3/8																			X		
HSS 36 x 36 x 1/2																			X		
HSS 36 x 36 x 5/8																			X		
HSS 40 x 40 x 3/8																			X		
HSS 40 x 40 x 1/2																			X		
HSS 40 x 40 x 5/8																			X		
HSS 44 x 44 x 1/2																			X		

	Atlas Tube Inc.	Bull Moose Tube Co.	Columbia Structural Tubing	Corus	Eugene Welding Co.	EXLTUBE	Hanna Steel Corp.	Hannibal Industries Inc.	Independence Tube Corp.	IPSCO Inc.	Leavitt Tube Company LLC.	Longhorn Tube LP	Maruichi American Corp.	Northwest Pipe Co.	Novamerican Steel Inc.	Procarsa Tube & Pipe Co.	Prolamsa Inc.	Southland Tube Inc.	Valmont Industries	Vest Inc.	Welded Tube of Canada
SQUARE HSS																					
HSS 44 x 44 x 5/8																			X		
HSS 48 x 48 x 1/2																			X		
HSS 48 x 48 x 5/8																			X		

Jumbo and Oval HSS

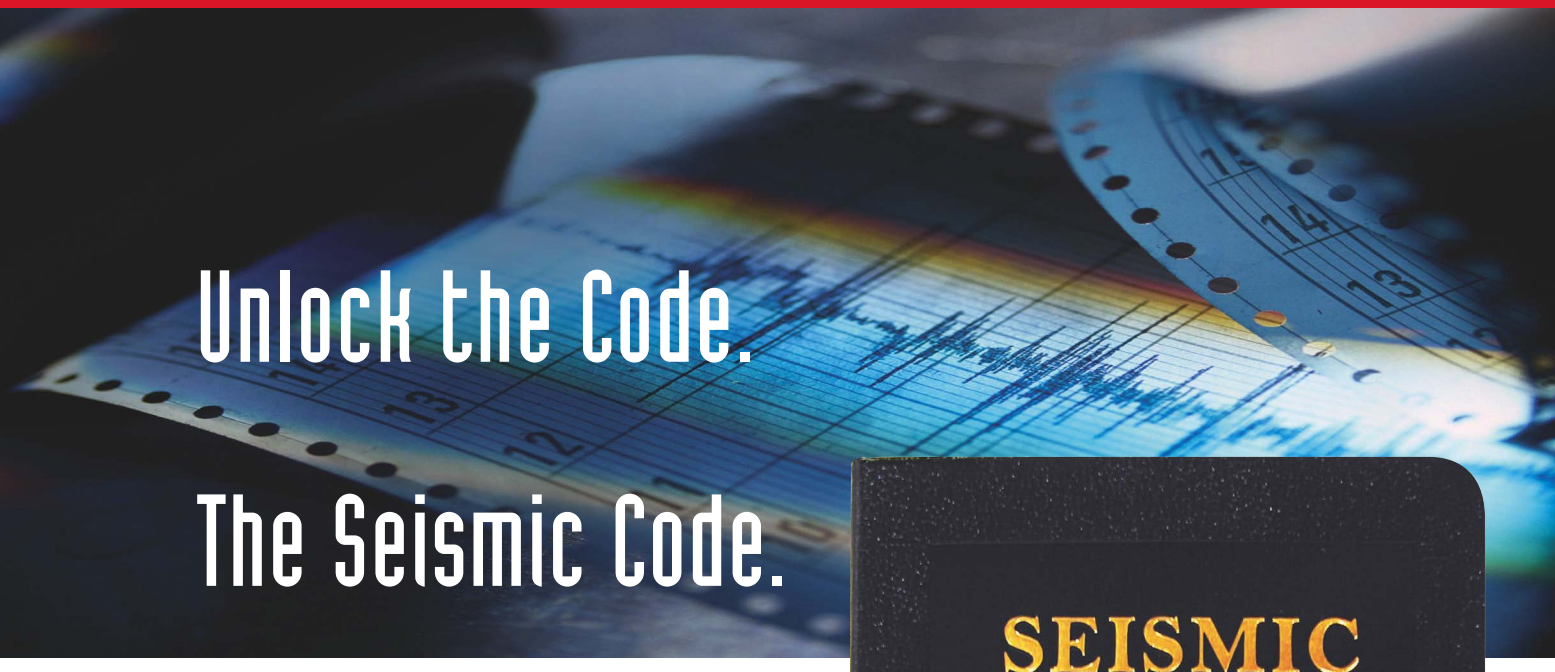
The following hot-finished shapes are produced by Corus under the newly-revised ASTM A501 Grade B specification. Please contact Corus for availability.

Jumbo Rectangular HSS
HSS 22 x 14 x 0.5
HSS 22 x 14 x 0.63
HSS 22 x 14 x 0.75
HSS 22 x 14 x 0.87
HSS 22 x 14 x 1
HSS 22 x 14 x 1.1
HSS 24 x 16 x 0.5
HSS 24 x 16 x 0.63
HSS 24 x 16 x 0.75
HSS 24 x 16 x 0.87
HSS 24 x 16 x 1
HSS 24 x 16 x 1.1
HSS 24 x 16 x 1.25
HSS 26 x 18 x 0.63
HSS 26 x 18 x 0.75
HSS 26 x 18 x 0.87
HSS 26 x 18 x 1
HSS 26 x 18 x 1.1
HSS 26 x 18 x 1.25
HSS 26 x 18 x 1.4
HSS 30 x 20 x 0.63
HSS 30 x 20 x 0.75
HSS 30 x 20 x 0.87
HSS 30 x 20 x 1
HSS 30 x 20 x 1.1
HSS 30 x 20 x 1.25
HSS 30 x 20 x 1.4
HSS 30 x 20 x 1.6

Jumbo Square HSS
HSS 14 x 14 x 0.75
HSS 14 x 14 x 0.87
HSS 14 x 14 x 1
HSS 16 x 16 x 0.87
HSS 16 x 16 x 1
HSS 16 x 16 x 1.1
HSS 18 x 18 x 0.5
HSS 18 x 18 x 0.63
HSS 18 x 18 x 0.75
HSS 18 x 18 x 0.87
HSS 18 x 18 x 1
HSS 18 x 18 x 1.1
HSS 18 x 18 x 1.25
HSS 20 x 20 x 0.5
HSS 20 x 20 x 0.63
HSS 20 x 20 x 0.75
HSS 20 x 20 x 0.87
HSS 20 x 20 x 1
HSS 20 x 20 x 1.1
HSS 20 x 20 x 1.25
HSS 20 x 20 x 1.4
HSS 22 x 22 x 0.63
HSS 22 x 22 x 0.75
HSS 22 x 22 x 0.87
HSS 22 x 22 x 1
HSS 22 x 22 x 1.1
HSS 22 x 22 x 1.25
HSS 22 x 22 x 1.4
HSS 22 x 22 x 1.6
HSS 24 x 24 x 0.63
HSS 24 x 24 x 0.75
HSS 24 x 24 x 0.87
HSS 24 x 24 x 1
HSS 24 x 24 x 1.1
HSS 24 x 24 x 1.25
HSS 24 x 24 x 1.4
HSS 24 x 24 x 1.6
HSS 24 x 24 x 1.75
HSS 24 x 24 x 2
HSS 26 x 26 x 0.63
HSS 26 x 26 x 0.75
HSS 26 x 26 x 0.87
HSS 26 x 26 x 1
HSS 26 x 26 x 1.1
HSS 26 x 26 x 1.25
HSS 26 x 26 x 1.4
HSS 26 x 26 x 1.6
HSS 26 x 26 x 1.75
HSS 26 x 26 x 2
HSS 26 x 26 x 2.17
HSS 26 x 26 x 2.36
HSS 28 x 28 x 0.63
HSS 28 x 28 x 0.75
HSS 28 x 28 x 0.87
HSS 28 x 28 x 1
HSS 28 x 28 x 1.1
HSS 28 x 28 x 1.25
HSS 28 x 28 x 1.4
HSS 28 x 28 x 1.6
HSS 28 x 28 x 1.75
HSS 28 x 28 x 2
HSS 28 x 28 x 2.17
HSS 28 x 28 x 2.36
HSS 30 x 30 x 0.63
HSS 30 x 30 x 0.75
HSS 30 x 30 x 0.87
HSS 30 x 30 x 1
HSS 30 x 30 x 1.1
HSS 30 x 30 x 1.25
HSS 30 x 30 x 1.4
HSS 30 x 30 x 1.6
HSS 30 x 30 x 1.75
HSS 30 x 30 x 2
HSS 30 x 30 x 2.17
HSS 30 x 30 x 2.36
HSS 32 x 32 x 0.63
HSS 32 x 32 x 0.75
HSS 32 x 32 x 0.87
HSS 32 x 32 x 1
HSS 32 x 32 x 1.1
HSS 32 x 32 x 1.25
HSS 32 x 32 x 1.4
HSS 32 x 32 x 1.6
HSS 32 x 32 x 1.75
HSS 32 x 32 x 2
HSS 32 x 32 x 2.17
HSS 32 x 32 x 2.36

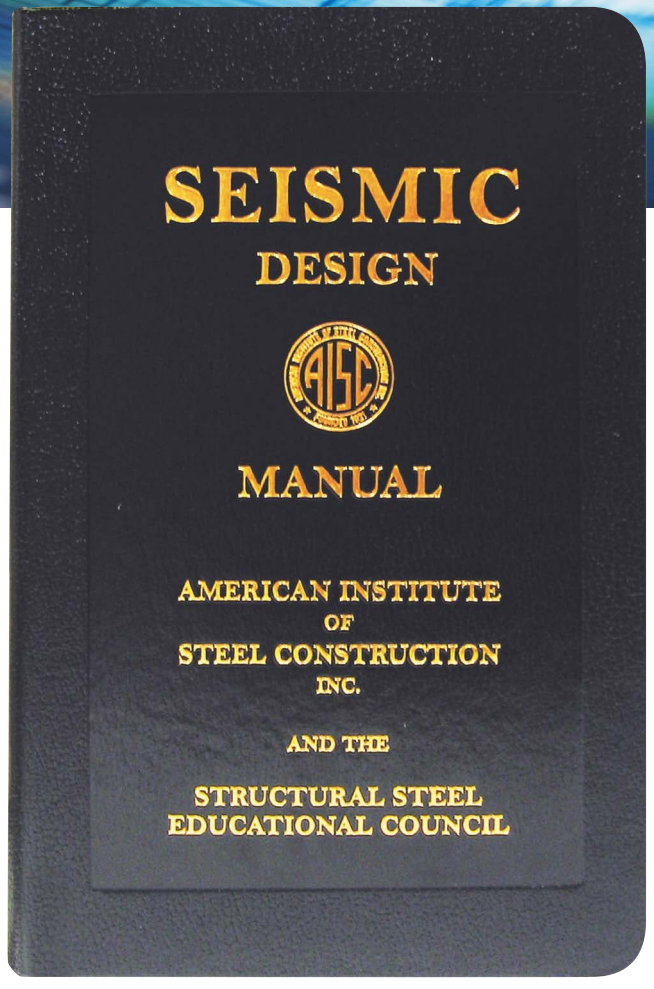
Oval HSS
Oval HSS 6 x 3 x 0.157
Oval HSS 6 x 3 x 0.197
Oval HSS 6 x 3 x 0.248
Oval HSS 8 x 4 x 0.248
Oval HSS 8 x 4 x 0.315
Oval HSS 8 x 4 x 0.394
Oval HSS 8 x 4 x 0.492
Oval HSS 10 x 5 x 0.248
Oval HSS 10 x 5 x 0.315
Oval HSS 10 x 5 x 0.394
Oval HSS 10 x 5 x 0.492
Oval HSS 12 x 6 x 0.315
Oval HSS 12 x 6 x 0.394
Oval HSS 12 x 6 x 0.492
Oval HSS 12 x 6 x 0.63
Oval HSS 16 x 8 x 0.315
Oval HSS 16 x 8 x 0.394
Oval HSS 16 x 8 x 0.492
Oval HSS 16 x 8 x 0.63
Oval HSS 20 x 10 x 0.394
Oval HSS 20 x 10 x 0.492
Oval HSS 20 x 10 x 0.63

Revised Printing Now Available



Unlock the Code.

The Seismic Code.



The International Building Code seismic design requirements are no longer exclusive to California — unlocking the door for the new national design criteria.

Knowing your technical requirements and seismic provisions can get puzzling. The AISC *Seismic Design Manual* gives you the key to unlocking the building code in a format that is already familiar to you.

With easy-to-understand illustrations rendering every detail for these systems, the *Seismic Design Manual* guides you through the specifics of when seismic load and design requirements are essential.

The Manual highlights the ANSI/AISC 341-05 *Seismic Provisions for Structural Steel Buildings* and ANSI/AISC 358-05 *Prequalified Connections for Special and Intermediate Steel Moment Frames for Seismic Applications*. The 2005 Seismic Provisions are the first to combine ASD and LRFD into a unified format. You will have all the tools you need in one source for the seismic design of structural steel.

The new *Seismic Design Manual* is available at $175.00 for AISC members and $350.00 for non-members. To order your copy — or to learn more about joining AISC — visit www.aisc.org/publications today!

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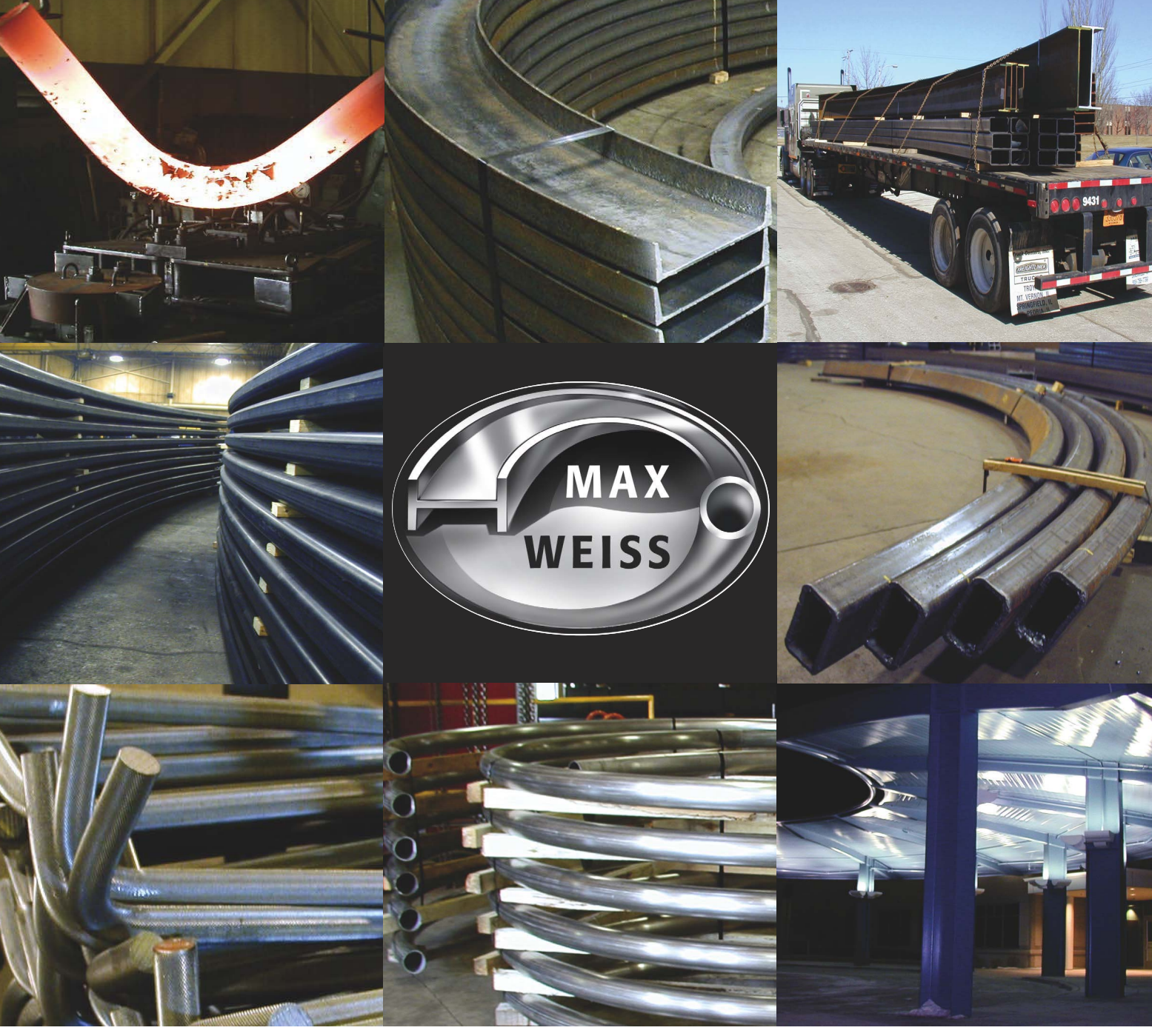

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Case Studies in Welding

Welding plays a crucial role in the success of these two well-known projects. Here's the inside story.

San Francisco-Oakland Bay Bridge

THE REPLACEMENT EAST SPAN OF THE SAN FRANCISCO-OAKLAND BAY BRIDGE NEEDED TO STAND UP TO AN 8.1-MAGNITUDE EARTHQUAKE. AISC-member Trans Bay Steel, Napa, Calif., was selected to fabricate one of the new seismic protection devices for the bridge: a 6.5-ft-diameter hinge system installed at the expansion joints of the bridge's concrete deck segments. Designed to accommodate expansion and contraction caused by temperature changes and motion, one end of the system is fixed, while the other end is clad with stainless steel to allow it to slide within the fixed portion.

Fabricating the A-709 HPS GR 70 steel plate—ranging from 65 to 100 mm thickness—into cylinders and cladding the sliding portion presented multiple challenges. The job specified very tight tolerances, and welding specifications had to meet AWS D1.5:1996 requirements for fracture-critical material.

"This was a completely new design, never built before," says Trans Bay President Bill Kavicky. "We were the first fabricator in the world to attempt forming and rolling this particular grade of material in these thicknesses."

The Fabrication Process

The plate was cut on an ESAB Avenger 2 cutting gantry with a rotating triple-torch oxyfuel bevel cutting head. The bevel head contours the cut to the exact shape needed for a good weld, eliminating some secondary operations and greatly reducing production time.

After the plate was cut, it was formed with Davi plate-forming rolls, specially purchased for this project, on what is believed to be the largest roll forming machine on the West Coast. Once the "can" was formed, the long seam was tack-welded and then moved to welding stations, also from ESAB, where automated subarc (SAW) welding completed the seam. The steel was pre-heated to 140 ºC, the internal long seam was welded, and the can was moved to an outside station where the seam was back-gouged and ground smooth to ensure a quality full-penetration weld for the outer seam. The SAW welding procedure included approximately 30 passes for the inside weld and another 30 for the outside weld.

After the cylinders were welded, they were re-rolled to meet the 1 mm to 3 mm tolerance in roundness. Diaphragm plates were welded inside the sliding side to provide extra support for the stainless steel overlay and stiffening where the beam mounts to the concrete structure of the bridge. The fillet welds on these plates were also performed with the subarc process. The final specifications required 80 ksi yield strength, 90 ksi tensile strength, and minimum Charpy impact value of 30 ft-lb at -30 ºC.

The cylinders required about 30 passes for the inside weld and about 30 passes for the outside weld.

The cylinders were then moved to a large Betts lathe to be squared off to ensure that they were perfectly perpendicular to the center axis. Each cylinder is 8 to 9 ft. long, and four to eight cylinders were welded together to form each side of the hinge system. The round seams were also welded with the subarc method.

Applying the Overlay

One of the bigger challenges of the project was the need to apply a stainless steel overlay to the sliding section in order to facilitate movement and prevent corrosion. Again, ESAB provided a solution by converting some of Trans Bay's subarc welding equipment for cladding. Instead of welding wire, the cladding head uses a strip electrode 1/16 in. thick and 1½ in wide. Trans Bay used an ESAB stainless steel strip band with a carbon component of 2%, and with 20% chromium and 23% nickel additives. This was partnered with an ESAB 10.05 flux designed to produce a self-releasing slag and optimum bead shape.

ESAB recommended adding a 309 stainless steel underlay that bonds directly to the underlying steel, and a layer of 316 stainless steel was then applied on top of this. The build-up of material is dependent on travel speed, and Trans Bay operated the system at 27 volts and 770-780 amps to create each layer at approximately 3.5 mm thickness. After the cladding, the cylinders were machined down to a total thickness of 5 mm of stainless steel and sanded to a final surface finish of 8 µm.

At the end of the fabrication process, all welds were examined by NDT methods, and were ultrasound- and X-ray-tested. The final weight of a complete hinge system ranged from 75 to 127 tons.

—Sue DiBianca, President, Windhaven Communications, West Falls, N.Y.

Grand Canyon Skywalk, Arizona


APCO Construction

4,000 FT ABOVE THE COLORADO RIVER, THE NEW GRAND CANYON SKYWALK EXTENDS 65 FT FROM THE CLIFF EDGE OF THE GRAND CANYON AT THE WESTERN RIM. The glass floor and sidewalls of the horseshoe-shaped walkway ensure heart palpitations to anyone vaguely troubled by heights. A 15-second freefall to the canyon floor would span twice the height of the world's tallest skyscraper. A typical day here can see vertical winds of more than 90 miles per hour.

To secure the Skywalk, engineers cantilevered it to the cliff using 94 steel rods that bore 46 ft into the limestone. It is estimated to withstand 71 million lb of weight, roughly equal to 71 fully loaded Boeing 747s. However, operators have limited the maximum occupancy to 120 people.

Engineers for the steel structure and heavy plate shop needed to speed up productivity in their existing submerged arc setup to meet the project's tight timetable. A potential fabricator for the project, AISC-member Mark Steel Corporation, Salt Lake City, had been using a DC submerged arc set-up for jobs of this scope with typical results. But upon discovering the Power Wave AC/DC 1000 from The Lincoln Electric Company, the company learned that a tandem arc setup, one in AC and another in DC, could boost its welding productivity by more than one million pounds of steel for the Skywalk.

With just a few days notice, Mark Steel engineers flew to Lincoln's world headquarters in Cleveland to purchase and train on the new equipment. Training wrapped up in about a day, and the company was then equipped to win the job to fabricate the skywalk's frame and anchor system by demonstrating productivity advantages afforded them by their new technology.

Securing the Structure

The Skywalk's steel anchors were flux-core welded with 5/64 Outershield 70 and 1/16 Outershield 71M with 100% CO_2 shielding gas. The steel sections were 2 in. thick, 8 ft long, 2.5 ft wide, and 4.5 ft deep. Joined to form 46-ft anchors, they are now weighted in cement to secure the structure.

The horseshoe itself was formed from two box girders of A572 grade 50-carbon steel welded with Lincoln's Lincolnweld L-61 wire and 865 flux. The fabrication was performed in accordance with AWS D1.1. The girder sections are 2 in. thick, 6 ft long, and 2.5 ft wide. They were shipped in 40-ft sections and assembled on-site.

While welding the box girders, productivity gains were captured mostly by the tandem submerged arcs. One AC arc and the other DC, operators used digital push-button controls on the Power Feed 10A to set waveform frequency, balance, and amplitude to obtain the optimal balance between penetration and deposition. Welding waveforms could be adjusted to any frequency between 10 and 100 Hertz with the turn of a knob. This allowed operators to pinpoint maximum productivity and quality for varying materials and jobs.

Embedded software allows opposing arcs to run in tandem without interfering with one another. This translated to a travel speed of 26 to 28 in. per minute. Deposition rates increased from about 28 lb per hour with the lone DC set up to about 55 lb per hour, using 3/16 wire on two arcs. This proved particularly helpful for some of the longer welds, which ran 38 to 40 consecutive ft. (Ultrasonic testing revealed that the project's weld reject rate was less than 2%.)

The shops' fabricators had typically beveled material of this size 30° on each edge to form a combined 60° bevel at the joint. Now with greater penetration abilities, the bevels have been reduced to 22.5° at each edge to form a 45° total wedge.

This narrower gap allowed reduced prep time and grinding with less weld metal required per inch of weld. Overall, Mark Steel saw a productivity gain of 25% to 30% and a corresponding reduction in consumable cost. The company also realized a 10% to 15% reduction in electrical costs using the inverter-based equipment.

The Skywalk is equipped with three 3,200-lb oscillating steel plates inside hollow bridge beams that act as shock absorbers. They move up and down to neutralize vibrations from foot traffic and wind gusts. Set atop the box girders, the walkway itself is constructed of 3-in.-thick heat-strengthened glass.

To meet the tight project deadline, Mark Steel welded around the clock. As such, equipment reliability and technical support were key considerations in the decision to go with brand new and unfamiliar equipment in the eleventh hour. Thanks to the success of the project, Mark Steel plans to incorporate Power Wave equipment more and more in their other projects.

A New Record

In May of 2006, final tests were conducted on the Grand Canyon Skywalk, and the structure passed engineering requirements by 400%. The Skywalk is now the highest man-made structure in the world, built with more than one million pounds of steel. It was designed to withstand an 8.0-magnitude earthquake 50 miles away.

—Tony Noah, Technical Sales Representative, The Lincoln Electric Co. Cleveland

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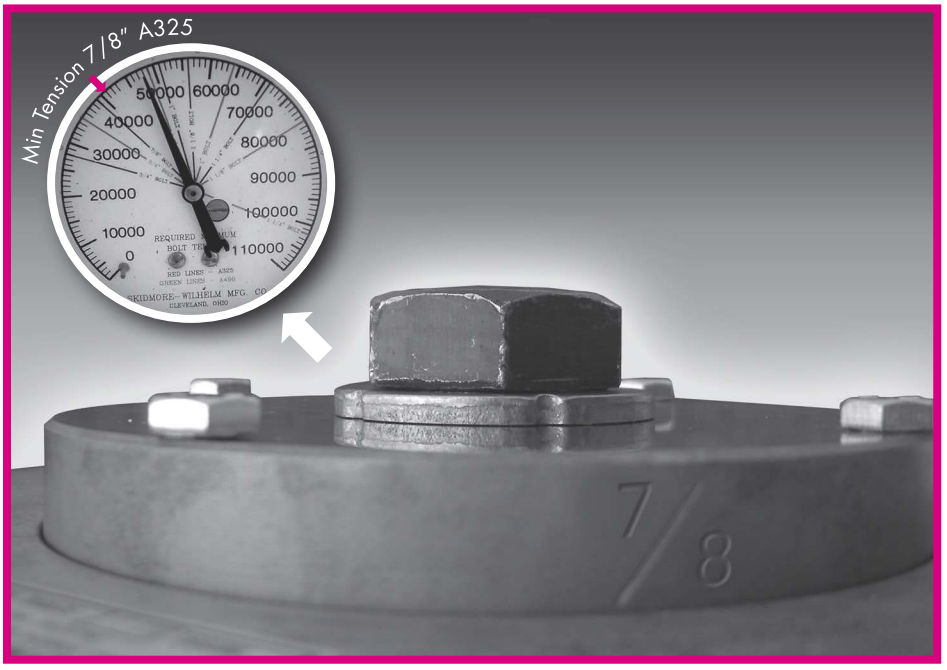

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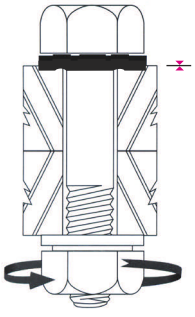

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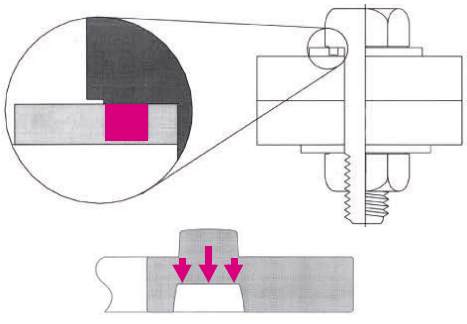

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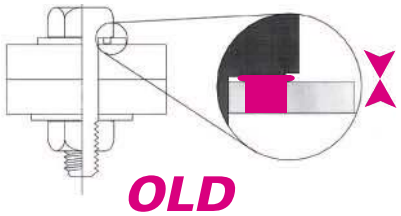

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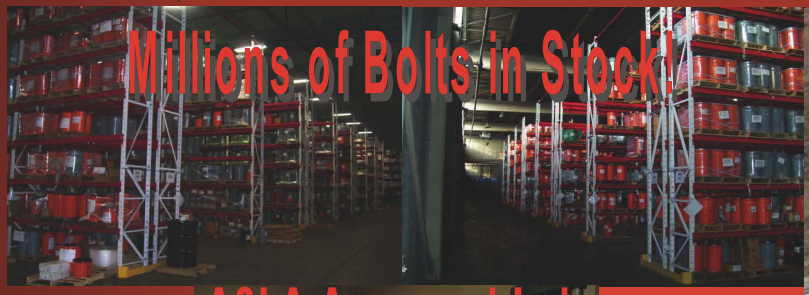

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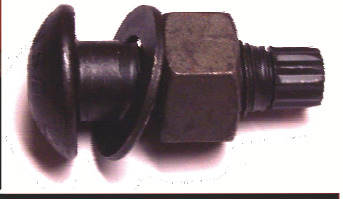

PRODUCTS

Heavy Hex Bolts (A325, A490)
TC Bolt Assemblies (F1852 & F2280)
Low Carbon Bolts (A307)
Anchor Bolts (F1554 gr.36,55,105 as well as A449, B7, Stainless Steel)
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BBC Fasteners www.bbcfasteners.com 708.597.9100	**Structural Bolts**	Domesitically manufactured and tested in-house. Larger quantities can be cold-headed and smaller quantities, especially of larger parts, can be hot-forged.
	Low-temperature Applications	May require special grades and heat treating of alloys and non-ferrous materials. Charpy testing at reduced temperatures will ensure ductility.
	Special Anchors	Can be made as large as 4 in. in diameter in A36 or high-strength grades. Tie rods for marine consturction are also available.
	Weathering Grades A325-3 and A490-3	A specialty of ours, along with A588 material for bridge and highway projects.
Bernard www.bernardwelds.com 800.946.2281	**S-Gun**	A fully customizable MIG welding gun featuring a steel "monocoil" cable designed to withstand the most demanding construction environments, while maximizing operator comfort and control.
	Centerfire	Consumables feature non-threaded, rotatable contact tips, an industry-leading gas-flow system, and high-quality materials and machining.
Biach Industries, Inc. www.biach.com 908.276.3110	**Bolt and Stud Tensioning Equipment**	Custom-designed bolt tensioners to suit field applications indicating tight spacing, high load requirements, and difficult work environments. Tensioners include spring-powered piston return for faster operation and drive-gear style of nut rotation for ease of operation and accurate nut seating.
Bug-o Systems/ **Cypress Welding Equipment** www.bugo.com 800.245.3186	**Uni-Bug III**	Makes continuous or intermittent stitch welds and is designed to run directly on specific steel profiles such as flat bar, angle, channel, I-beams, and bulb flats.
	Mini-Vert	A compact, battery-powered welding travel carriage that will travel and carry a welding gun in flat and vertical positions producing continuous and uniform welds.
CERBACO Ltd. www.cerbaco.com 908.996.1333	**Non-metallic Weld Backings**	Achieve full-penetration, x-ray-quality welds from one side without grinding or back gouging
ESAB Welding & Cutting Products www.esabna.com 800.ESAB.123	**CORESHIELD**	Time after time, weld after weld, Coreshield self-shielded flux core wires combine exceptional strength, high deposition rates, outstanding arc characteristics, and higher welder appeal than any wire in its class.
Grating Fasteners, Inc. www.gclips.com 800.227.9013	**G-clips**	Grating fasteners for attaching grating to structural members, that can be applied with simple hand tools. Saddle-type grating clips: "M-style" clips for attaching bar grating to various structures. GFI provides both stainless steel and galvanized carbon steel saddle clips.
Haydon Bolts, Inc. www.haydonbolts.com 215.537.8700	**Fabricated Steel Anchors and Rods**	Anchor bolts and tie rods up to 4 in. in diameter using materials such as ASTM F1554 grades 55 and 105, A588, A325, A449, A490, A354, and A193. All made of domestic steel with full material certifications available.
	Structural Bolts	Products include a full line of heavy hex structural bolts ASTM A325-1 and A325-3, and ASTM A490-1 and A490-3; and a full line of tension control bolts ASTM A325/F1852 and ASTM A490/F2280.
Hilti www.us.hilti.com 800.879.8000	**Kwik Bolt 3 Expansion Anchor**	Satisfies a range of fastening applications in various environments, with improved wedge design, higher strength base material, and various sizes.
Hobart Brothers Company www.hobartbrothers.com 800.424.1543	**Formula XL-550**	An all-position gas-shielded flux-cored wire that features low hydrogen levels, high impact toughness, and x-ray quality welds, even through mill scale and rust.
	Fabshield XLR-8	Meets D-designator standards under AWS A5.20:2005. It is well-suited for vertical-up welds at high currents and offers excellent slag removal, high deposition rates, and a large voltage window.
Hodell-Natco Industries, Inc. www.hodell-natco.com 800.321.4862	**Structural Fasteners**	We carry a large, diverse inventory including A325 and A490 heavy hex bolts, A325 and A490 tension control bolts, A307 hex bolts, A563 heavy hex nuts, and F436 and load-indicating washers.
	Anchoring Systems	We offer both mechanical and adhesive anchoring systems. We carry bent anchor bolts, double-ended studs, and all thread rod for low-carbon as well as high-strength applications.
	Miscellaneous	Weld studs; chain; wedge anchors; Grade 5 and 8 hex cap screws; self-drilling screws; drywall screws; flat washers; lock washers; hex nuts; and lock nuts.
Infasco www.infasco.com 450.658.8741		Tension-control bolts/nuts/washers assemblies, round-head Type 1 ASTM F1852/F2280; heavy hex structural bolts ASTM A325/A490 and nuts ASTM A563 and washers ASTM F436, assembled.
Kee Industrial Products, Inc. www.keeklamp.com 800.851.5181	**BeamClamp**	Connects steel together without on-site welding or drilling. Utilizing standard hardware, steel members are secured together easily and quickly with a guaranteed safe working load and factor of safety.
	BoxBolt	Easy-to-install high-strength blind bolt used to fasten anywhere that access is limited or restricted to the rear of a connection.
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	Stud Welding Products and Equipment	Headed weld studs, deformed bar anchors, threaded studs, electric arc and capacitor discharge stud welding equipment, rental equipment, parts, and accessories.
	Anchoring Products	Redhead and Powers anchoring systems in stock. Mechanical anchors include wedge and sleeve anchors, HD screw anchors, and bent anchor bolts. Chemical anchors include acrylic and epoxy adhesives, capsules, dispensing tools, and accessories. Threaded rod cut to length.
The Lincoln Electric Company www.lincolnelectric.com 216.481.8100	**ULTRACORE Wire**	This line of gas-shielded, flux-cored wires for mild steel welding delivers smooth and stable arc performance. Each is designed for a particular shielding gas mix, group of welding positions, or industrial applications.

Company	Products Offered	Product Description
Lincoln Structural Solutions www.lincolnstructural.com 800.571.6884	**Commercial-grade Structural Fasteners**	Structural bolts, nuts, washers, load-indicating washers, tension control bolts, expansion anchors, all-thread rod. Available plain, Type 3, mechanically and hot dip galvanized and zinc plated.
	Nuclear Certified Structural Steel and Fasteners	Steel pipe, bar, tubing, sheet, plate, rod, shapes, and fasteners compliant to NQA-1, ASME Section 3 NCA-3800, ANSI N45.2, 10 CFR Appendix B and 10 CRF 21.
Lindapter North America, Inc. www.lindapterna.com 888.724.2323	**Girder Clamp**	Pre-engineered clamp to connect secondary steel to structural members. No welding, no drilling, reduced installation time, no hot work permit, no damage to steel coatings, and no special tools.
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	LindiBolt	A blind, self-heading bolt to connect square, rectangular, or circular structural tube on conventional steel where access is available from one side only and a small hole size is needed.
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PLANT SUPERINTENDENT WANTED

INDIANA STEEL LOCATED IN SOUTHERN INDIANA IS SEEKING A HANDS-ON BRIDGE AND STRUCTURAL STEEL SHOP SUPERINTENDANT. MUST HAVE A MINIMUM OF 3-5 YEARS SUPERVISORY EXPERIENCE IN AN AISC CERTIFIED STRUCTURAL AND BRIDGE SHOP. HOLDING A CURRENT CWI CERTIFICATE WOULD BE A PLUS OR HAVING THE QUALIFICATIONS AND THE ABILITY TO OBTAIN ONE. COMPETITIVE SALARY AND EXCELLENT BENEFITS INCLUDING HEALTH INSURANCE AND A 401K PLAN AVAILABLE.

PLEASE SEND RESUME, REFERENCES AND SALARY HISTORY TO:

INDIANA STEEL & ENGINEERING CORP.
P.O. BOX 668
BEDFORD, IN 47421-0668
OR E-MAIL: **joew.elliott@iseco-bcs.com**

Regional Manager

Drake-Williams Steel, Inc., a 20K+ tons/yr. structural steel fabricator based in Omaha, NE, is looking for a Regional Manager for their Denver, CO office. Responsibilities include the development and maintenance of current and potential customers in both the construction and industrial market areas as well as the management of the Denver office. The successful candidate will also provide project management services that include preparing and monitoring schedules, estimating and submitting change order requests, and preparing billings as required.

Drake-Williams Steel, Inc. offers a competitive salary and benefit package to the successful candidate. For more information, go to **www.dwsteel.com**. EOE.

Send resumes to:

Drake-Williams Steel, Inc.
1602 N. 11th St.
Omaha, NE 68110
scarlisle@dwsteel.com

PROJECT MANAGERS, ESTIMATORS, DETAILERS, CNC PROGRAMMERS

STROCAL, INC. is looking for dedicated and experienced candidates for all aspects of its business including management positions, contracts managers, and shop fabrication. STROCAL, INC. is a Large Structural Steel Fabrication and Erection Company headquartered in Stockton, CA with an additional facility in Eloy, AZ. We offer excellent wages and great benefits.

For immediate consideration, please e-mail resume to jobs@strocal.com or contact:

STROCAL, INC.
2324 Navy Drive
Stockton, CA 95206
Fax: (209) 948-4585
www.strocal.com

Multi-Division Structural Steel Fabricator

Due to company-wide growth, Steel Supply and Engineering, a division of The Armada Group with headquarters in Grand Rapids, Michigan and facilities in Kalamazoo, Michigan and Indianapolis, Indiana has the following openings.

Structural Steel Project Manager: Grand Rapids, Michigan
Structural Steel Project Manager: Indianapolis, Indiana
Miscellaneous Metals Project Manager: Grand Rapids, Michigan
SDS2 Structural Steel Detailers: Kalamazoo, Michigan
SDS2 Structural Steel Detailers: Indianapolis, Indiana
Miscellaneous Metals Detailer: Grand Rapids, Michigan
Detail Manager: Indianapolis, Indiana
Structural Steel Estimator: Grand Rapids, Michigan
Quality Inspector (Structural Steel): Grand Rapids, Michigan
Quality Inspector (Structural Steel): Indianapolis, Indiana
Plant Accountant: Grand Rapids, Michigan

ASSOCIATE MEMBER

Successful candidates will have:
- At least three-five years experience in the Structural Steel industry.
- Experience managing multiple projects.
- The personality and ability to be an analytical self-starter capable of working in a team environment.
- A customer focused and people orientated personality.
- A proven track record of accomplishments.

Steel Supply and Engineering offers competitive pay with an excellent benefit package. We are looking for people with the personality and skills to join a company geared for growth. For more information go to www.the-armada-group.com.

Send resume to: **chris@mfgsearch.com** or mail or fax to:

mfg/Search
431 E. Colfax Avenue, Ste. 120
South Bend, IN 46617
Attn: C. Villaire
Fax: 574.232.0982

Structural / Miscellaneous Steel Detailer

Southern California

Plas-Tal Steel Construction, one of the leading steel fabricators in Los Angeles for over 50 years, is seeking an experienced structural and miscellaneous steel detailer. The ideal candidate will satisfy the following requirements:

- A minimum of 5 years detailing experience using AutoCAD.
- A comprehensive knowledge of AISC and ADA codes and standards.
- Miscellaneous steel detailing experience.
- Structural steel detailing experience.
- Stair and rail systems experience.
- Good communication skills.

ASSOCIATE MEMBER

The position offers a competitive salary commensurate with experience, full medical and vacation benefits, 401(k) plan, profit sharing and performance bonuses.

Qualified candidates should submit resumes via fax or email to:

Plas-Tal Steel Construction
Attn: Colin Honeyman,
Drafting Manager
Fax: (562)696-7620
Email: colin@plas-tal.com

Project Manager/Detailers/Checkers

SteelStar Corporation is an aggressively growing detailer/fabricator/erector (16-20 Million/Annually) in the Denver Metro area along the beautiful Front Range of Colorado.

Project Manager ($65-95K Annually)
We are currently seeking an aggressive and skilled project manager with experience in low to mid rise commercial/industrial, miscellaneous and architectural/ornamental metals projects from 500-2000 Tons.

The successful candidate must have a minimum of five years experience in construction project management. Requirements to include, but are not limited to; excellent computer/technical skills, organizational skills, scheduling skills and documentation skills as well as great communication and customer service skills. Most important of all, the successful candidate must have a great attitude! An Associates or Bachelors degree is required; this may be waived in lieu of experience. Relocation to Colorado Required. Must have excellent references and project track record.

Detailers/Checkers ($15-$35 Per/Hour)
We are currently seeking (3) skilled Tekla (Xsteel) and (4) AutoCAD/AutoSD detailers & checkers with experience in low to mid rise commercial/industrial, miscellaneous and architectural/ornamental metals projects up to 2000 Tons.

The successful candidate must have a minimum of (3) year's structural and/or miscellaneous steel detailing experience. Requirements include, but are not limited to; excellent computer/technical skills and Tekla or AutoCAD experience. Most important of all, the successful candidate must have a great attitude! Relocation to Colorado Required. Candidate must be able to provide excellent references and drawing examples. All candidates must be currently eligible to work in the United States.

We offer the security of a financially stable company, profit sharing, competitive wages, relocation reimbursement, medical benefits, 401K, paid holidays and paid leave time, and most of all, a fun place to work with opportunity for advancement. Please send resume to: SteelStar Corporation, P.O. Box 218 - Dacono, CO 80514 Attn: Employment - Fax 303.828.4092 or email employment@steelstar.com. Visit us @ www.steelstar.com.

The Steel Deck Institute – Technical Director

The Steel Deck Institute (SDI), the trade association responsible for setting standards for the steel deck industry, is currently seeking qualified candidates for the position of Technical Director. The Technical Director is responsible for coordinating the Institute's technical committees and research programs, the presentation of technical seminars, representing SDI and participating in activities of other organizations such as AISI, AISC and ICC, providing engineering assistance to design professionals and managing special projects such as updating ANSI/SDI standards.

Qualified candidates should possess a BS in Civil or Structural Engineering. Professional Engineer's License or the ability to be registered is required. Experience in cold-formed steel design or metal building industry is also a plus. Strong communication, organizational, presentation and computer skills a must as well as the ability to work with limited supervision. Relocation to the Chicago, IL suburban area is preferred.

We offer a competitive compensation package including medical insurance and paid vacation.

Applicants should mail, fax or email resumes (in confidence) to:

Steel Deck Institute
Attention: Steven A. Roehrig, Managing Director
P.O. Box 25
Fox River Grove, IL 60021-0025
847-458-4647 (fax) 847-458-4648
email: steve@sdi.org

JOURNEYMAN WORKING FOREMAN

Ready for a change? Seeking more opportunity and responsibility? Small but established Northwest fabricator seeks person to lead a crew producing structural products requiring Cbr certification and FC endorsement.

Minimum requirements:
- 10 years of varied production experience in structural steel.
- Expert in reading blueprints and an English-unit tape measure.
- Ambitious.
- Relevant leadership experience.
- Responsible and reliable person outside of work.
- Legal US resident.

ACTIVE MEMBER

Pay is $1,000 per week. Subsidized health insurance, paid vacation, profit sharing.

ADDISON Corporation
Bend, OR 97708
FAX resume to (541)389-9668

THE FUTURE IS NOW

RISA-3D VERSION 7

The new features in RISA-3D Version 7, from the implementation of the latest design codes to a faster, more robust sparse solver, enable engineers to work more productively and stay ahead of the competition.

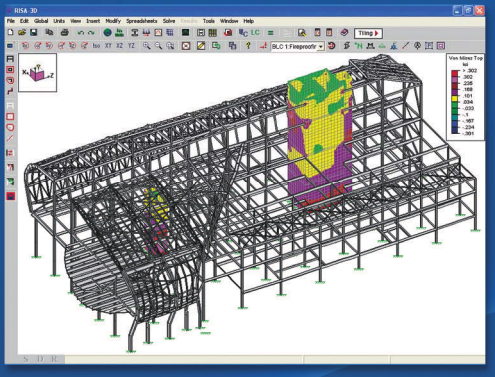
RISA-3D

AISC 13TH EDITION STEEL CODE

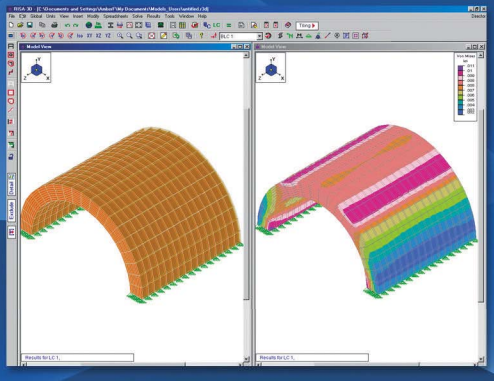
RISA-3D Version 7 incorporates the new Direct Analysis Method of the AISC 13th Edition. This version allows users to design for either the ASD or LRFD requirements of this new steel code.

ACCELERATED SPARSE SOLVER

RISA-3D Version 6 used a Skyline solver, which is the current industry standard. The new accelerated sparse solver offered in RISA-3D Version 7 can solve models up to 100 times faster, making RISA-3D the future of structural analysis.



The Concourse J of the Miami International Airport took nearly 11 minutes to solve and required more than 600 MB of storage space using the current industry standard solver technology. The accelerated sparse solver in RISA-3D Version 7 solved the same model in 6 seconds and required only 2MB of storage space. That's more than 100 times faster!



SOLID ELEMENTS

RISA-3D Version 7 now offers 8-node solid elements which opens a whole new range of modeling and analysis possibilities. This new element combined with RISA-3D's automatic meshing features opens up a whole new world of modeling and analysis possibilities!

Integration with RISAFoundation and Revit Structure 2008 as well as the implementation of the 2005 NDS wood code make RISA-3D Version 7 the right choice for today and for the future.

Try RISA-3D today and see how good structural engineering software can be!

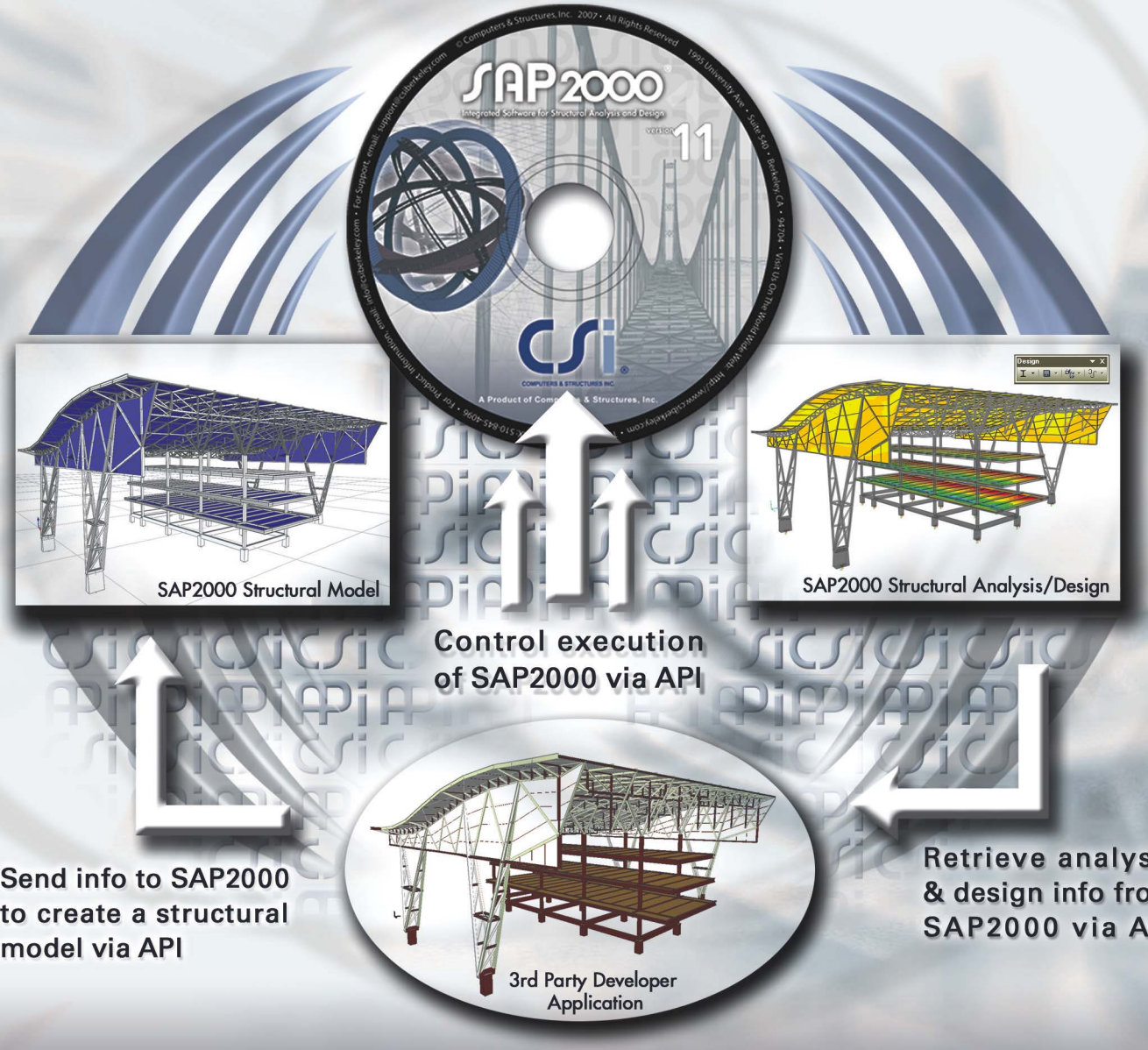
RISA TECHNOLOGIES

WWW.RISATECH.COM **800.332.RISA**

DEFINING THE STANDARD OF STRUCTURAL INTEROPERABILITY

COMPUTERS & STRUCTURES, INC.

INTRODUCING THE SAP2000® APPLICATION PROGRAMMING INTERFACE (API)



TURBOCHARGE YOUR APPLICATION WITH THE POWER OF SAP2000!

In response to requests from many of our users, Computers and Structures, Inc. is pleased to announce the release of an Application Programming Interface (API) for SAP2000. The API provides users and developers of products for CADD and 3D modeling seamless and efficient access to all of the sophisticated analysis and design technology of SAP2000. Third-party developers can now create rich and tight two-way links with SAP2000, allowing for accurate transfer of models into SAP2000, complete control of SAP2000 execution, and extraction of analysis and design information from SAP2000, all from within their application. Similar capability will soon be available for ETABS®.

For more information go to http://csiberkeley.com/SAP2000API.html

CSi
COMPUTERS & STRUCTURES INC.

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